ASTRONOMY

AND

ASTRO-PHYSICS.

THE SIDEREAL MESSENGER
NAME OF THE FIRST TEN VOLUMES.

VOL. XI.

1892.

EDITORS:

W. W. PAYNE,
GENERAL ASTRONOMY.

GEORGE E. HALE,
ASTRO-PHYSICS.

NORTHFIELD, MINN.:
GOODSELL OBSERVATORY
1892.

CONTENTS BY NUMBERS.

JANUARY.

FEBRUARY.

MARCH.

APRIL.

MAY.

JUNE.

AUGUST.

OCTOBER.

NOVEMBER.

DECEMBER.

ILLUSTRATIONS.

GENERAL ASTRONOMY.

NEW SERIES, No. 1. JANUARY, 1892. WHOLE No. 101.

THE EFFECT OF PRESSURE UPON THE TRANSMISSION OF RADIANT ENERGY THROUGH GASEOUS MEDIA.

SEVERINUS J. CORRIGAN.

FOR GENERAL ASTRONOMY.

While pursuing, recently, an investigation having for its object the determination of the absolute quantity of energy radiated, in unit time, from the filament of an incandescent electric lamp of a given candle power, I found that certain facts anent the *modus operandi* of "radiation" and the laws governing it, were disclosed thereby. So far as I know, they have not been noticed heretofore, and as they have a bearing upon important astronomical questions, I have thought that a publication of the results of this investigation would fall within the scope of ASTRONOMY AND ASTRO-PHYSICS, and prove of interest to some of its readers.

The following is a statement of the problem that presented itself for solution:

By what amount will the absolute quantity of energy radiated in unit time from a body of given surface, heated to a given degree of temperature while enclosed in a vessel containing atmospheric air or other gases at a given pressure, be changed by variation of the pressure or the density of the enclosed gas?

In attacking this problem my first step was to frame a hypothesis as to the nature and cause of the pressure of a gas against the walls of a containing vessel. I assumed, and this assumption is sanctioned by most eminent authority in "Molecular Physics," that this pressure is due to the impact of the minute particles of which the gas is composed, upon the enclosing walls, this impact being caused by the incessant and almost inconceivably rapid vibration of these particles. It is also assumed, and I purpose to prove the validity of this assumption by the agreement between theory and observation or the results of experiment, that the total pressure against the envelope, which pressure will be designated by P, is proportional to the product of the mass, M, of the enclosed gas into the number of vibrations made in unit time, which number will be designated by n. It is obvious that the pressure, or in other words, the result of impact will be greater or less as the number of particles of equal mass, m, and also the number of vibrations in unit time are greater or less; thus one particle vibrating twice in unit time will produce the same effect as two particles vibrating only once in the same time. This fact is expressed by the equation $P = Mn$ (1). It must be borne in mind that in this equation and also in those which are to follow, only relative values are considered.

From the well known definition of density, it is plain that the mass, M, of the gas contained within the walls of the vessel, is inversely proportional to the cube of the distance by which the particles are separated. Calling this distance d, this fact is expressed by the equation, $M = \frac{1}{d^3}$ (2); hence equation (1) can be written $P = \frac{n}{d^3}$ (3).

It is now necessary to make some hypothesis as to the nature of the vibration the frequency of which is denoted by n.

I assume that the molecules of any gas are each composed of at least two atoms of equal mass m, and that these atoms are in continuous and, almost inconceivably, rapid revolution around a common center of attraction lying between them, just as are the components of a binary system of stars, and that the law governing the action of this attractive force is the same as that of gravity, *i. e.*, that the force varies inversely as the square of the distance of the atoms from the common center around which they revolve.

The revolution of the stars of a binary system around their common centre of gravity, and also the revolutions of the planets around the sun, are vibrations of this nature, and the number of such vibrations in a unit of time is given by the well-known equation, "Analytical Mechanics," $n = \frac{\sqrt{k}}{a^{\frac{3}{2}}}$ (4), which is one expression for that one of Kepler's laws of planetary motion which asserts that "the squares of the times of revolution of any two planets, around the sun, are proportional to the cubes of the mean distances of said planets from the common center of gravity around which they revolve. In equation (4) which is, as I may say, the *corner stone* of the theory which I have constructed, n represents the mean motion or the angular velocity; *i. e.*, the number of revolutions or complete vibrations in a unit of time; k is the unit of attractive force and is a constant, therefore the only variable is a, which represents the mean distance of the revolving body from the center of gravity of the system, and, in the case of a circular orbit, is the radius; consequently, considering only relative values, $n = \frac{1}{a^{\frac{3}{2}}}$ (5).

Since I have assumed that the vibrations of the atoms are subject to the same law that governs the revolutions of the planetary masses, it follows that equation (5) will give the value of n used in equation (1), if we replace in equation (5), $a^{\frac{3}{2}}$ by $d^{\frac{3}{2}}$, which can be done because the distance d, between the revolving atoms of each system is equal to $2a$; replacing $a^{\frac{3}{2}}$ by $d^{\frac{3}{2}}$ equation (5) will become $n = \frac{1}{d^{\frac{3}{2}}}$ or $n = \frac{1}{d^{1.5}}$ (6). Substituting this value of n in equation (3) the following results: $P = \frac{1}{d^3} \cdot \frac{1}{d^{1.5}}$ or $P = \frac{1}{d^{4.5}}$ (7); whence $d = \frac{1}{P^{\frac{1}{4.5}}}$ (8).

The last equation expresses the fact that the distance apart of the revolving atoms is inversely proportional to the 4.5th root of the pressure of the gas. The quantity of energy transmitted by the gas, from a given "source of heat," is now to be determined. It is known, from the principles of "Analytical Mechanics," that the quantity of energy, Q, generated by a mass, m, moving with a linear velocity, v, is proportional to the product of one-half the mass into the square of the linear velocity. This fact is expressed by the equation, $Q = \frac{1}{2} mv^2$ (9). If, as before, we denote the mean distance of the revolving mass by a, we find that, since the linear velocity, v, is equal to the angular velocity, n, multiplied by the mean distance a, $v = na$, or as since shown by equation (6), $n = \frac{1}{d^{1.5}}$, $v = \frac{a}{d^{1.5}}$ (10); but as a is proportional to the distance d, being equal to $\frac{1}{2}d$, equation (10) can be written $v = \frac{d}{d^{1.5}} = \frac{1}{d^{\frac{1}{2}}}$ (11); therefore $v^2 = \frac{1}{d}$ (12);

hence $Q = \frac{1}{2} \frac{m}{d}$ (13); but since m is constant we will have

$Q = \frac{1}{d}$ (14); and since equation (8) shows that $d = \frac{1}{P^{\frac{1}{4.5}}}$ we can write $Q = P^{\frac{1}{4.5}}$ (15); equation (14) expresses the fact that the quantity of energy transmitted, from a given "source of heat," by and through a gas in any given time, is inversely proportional to the distance apart of the revolving atoms, while equation (15) shows that it is directly proportional to the 4.5th root of the pressure of the gas.

Equation (15) thus furnishes the theoretical solution of the problem under consideration, but since it is founded upon an assumption as to the nature of the pressure of a gas, which assumption is expressed by equation (1), it is necessary to learn whether the results derived from experiment agree with the deductions from theory. I have found that they do. Experiments have been made by a skillful physicist, upon the radiation of heat from the surface of a mass of copper placed in an enclosing vessel; the difference of temperature between the copper and the walls of the enclosure was 90 degrees Fahrenheit, and the quantity of heat in absolute measure, (*i. e.* in pound-degrees Fahrenheit per second) radiated from each square inch of the surface of the mass of copper was determined, both when the enclosed air was at the ordinary atmospheric pressure of 30 inches of mercury and when the pressure was only 0.4 of an inch, or only $\frac{1}{75}$ of the normal pressure. Taking the normal pressure of 30 inches as the unit, the pressure at 0.4 inches will be represented by the equation $P = \frac{1}{75}$; substituting this value of P in equation (15), the following expression for the relative quantity of heat radiated will be $Q = \sqrt[4.5]{\frac{1}{75}} = .3831+$. The quantity radiated at pressure of 30 inches was .0002271 of a thermal unit; hence, by my theory the quantity radiated at the pressure of 0.4 inches should be .0000870 of a thermal unit; the quantity found by experiment was .0000875 of a thermal unit; certainly a very close agreement between theory and observation.

Another experimental result, even more conclusive, is that furnished by a determination of the quantity of heat radiated from the filament of an incandescent electric lamp. Taking the pressure of the air remaining within the glass-bulb of the lamp at only one-millionth of the ordinary atmospheric pressure, in other words making $P = \frac{1}{1000000}$, I found that the the theoretical result derived by means of equation (15), and expressed in units of electrical energy, was practically identical with those derived from many actual tests upon a 16 candle-power light, these tests having been made by several different lighting companies. This agreement between theory and observation, in cases where the relative pressures, viz.: $\frac{1}{75}$ and $\frac{1}{1000000}$, differed so widely seems to me to establish the truth of the hypothesis upon which the theoretical results above given are based, and the validity of the law expressed by equation (15).

By another, but indirect, method the legitimacy of the assumption expressed by equation (1) and of the results flowing therefrom, in regard to the *orbital* motion of the atoms under the influence of a centripetal force which varies inversely as the square of the distance, can also be established. Boyle's law asserts that the pressure of a gas when the temperature of the latter remains constant, is proportional to the density of the gaseous mass; this law is expressed by the equation $P = D = \frac{M}{V}$ (16), in which P represents the pressure, D the density, M the mass, and V the volume of the gas. If the density be varied either by an addition to, or an abstraction from the mass, the volume remaining constant, we will have $P = M$ (17). If the variation of density be effected by changing the volume, the mass remaining constant, the pressure will be given by the equation $P = \frac{1}{V}$ (18); therefore both mass and volume being variable, the pressure will be directly proportional to the mass, and inversely proportional to the volume; hence the ratio between any two pressures, P_1 and P_2, should, if Boyle's law be perfectly true, be expressed by the equation $\frac{P_1}{P_2} = \frac{V_2}{V_1} = \frac{M_1}{M_2}$ (19); but, as a matter of fact, the ratio of the pressures does not follow, exactly the law expressed by the equations (19), but is represented by the following:

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{1.41} = \left(\frac{M_1}{M_2}\right)^{1.41} (20),$$

in which the exponent 1.41 represents the ratio between specific heat at constant pressure and specific heat at constant volume. This ratio has never been determined, so far as I know, otherwise than by experimental research. I will now endeavor to demonstrate that it can be derived analytically, and also to show its signification, *i. e.*, that it is due to the *orbital* motion of the revolving atoms, and is a function of the factor, n, in equation (1).

Comparing equation (17), or $P = M$, with equation (1) or $P = Mn$ we see that they differ by only the factor n, which represents the angular velocity or the number of vibrations of the atoms, around their common center of attraction in unit time; therefore I claim that the exponent 1.41 in equation (20), or the ratio between specific heat at constant pressure and that at constant volume, depends upon n, or the angular velocity of the revolving atoms. According to equation (7), $P = \frac{1}{d^{4.5}}$; but, since the volume V is proportional to the cube of the distance between the atoms, $d^3 = V$, and therefore $d^{4.5} = V^{1.5}$; hence equation (7) can be written: $P = \frac{1}{V^{1.5}}$ (21). Furthermore, since the mass M

is inversely proportional to the cube of the distance, $M = \frac{1}{d^3}$ and $\frac{1}{d^{4.5}} = M^{1.5}$, but from equation (7) $\frac{1}{d^{4.5}} = P$, therefore

$P = M^{1.5}$ (22). If we now consider the ratio between any two pressures, P_1 and P_2, we find that $\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{1.5} = \left(\frac{M_1}{M_2}\right)^{1.5}$ (23).

Comparing these expressions with equations (20) we cannot fail to note a resemblance so strong as to force us to the conclusion that they are identical, and we may, I think, regard the exponent 1.5 which, as we have seen, results from the assumption of an orbital motion of the atoms whose angular velocity is denoted by the factor *n*, in equation (1), as representing the ratio between specific heat at constant pressure and specific heat at constant volume. It is true that it differs slightly from 1.41, the value generally accepted, but this value has been determined from experiments on the velocity of sound in air, which experiments are, of course, subject to more or less error, and since the effect of moisture in the atmosphere is not well known, the slight discrepancy may be regarded as of no importance, and the value of the ratio between the specific heats, in the case of perfect gases, can, I think, be taken as 1.5.

The nature of this quantity can be better understood if illustrated by an example. If we reduce the volume of a gas by any amount, one-half for instance, the pressure would be, by Boyle's law expressed by equation (20), inversely proportional to the amount of the reduction; *i. e.*, in this case it would be doubled, but, as a matter of fact, when no heat is allowed to enter or to escape from the gas, the pressure is found to be more than double being in this case, according to equation (23), equal to $2^{1.5}$ or to 2.83, the difference between 2 and 2.83 representing the increase of the orbital velocity, due to the decrease of the distance, *d*, between the atoms of each molecule of the gas, which decrease is caused by the compression of the latter, and this increase of vibrational velocity represents the quantity of heat generated in the gas by the compression. If a gas confined in a vessel be heated from an external "source of heat," it tends to expand, but since the volume remains constant the gas cannot expand and its tendency to do so causes an increase of pressure, consequently by reason of this increase it is still further heated, and a less quantity of applied or external heat is required to raise the temperature of the gas through one degree, than would be required if the gaseous mass were free to expand so that the distance *d*, between the atoms could become greater and therefore the orbital motion, or the *internal heat* be decreased.

The ratio between the quantities of external heat necessary to be applied in order to raise the temperature of the gas through one degree in the respective cases where the gas is kept at constant pressure and at constant volume, is the quantity whose commonly accepted value is 1.41 but which is, as I have shown, properly 1.5.

[TO BE CONTINUED.]

BRORSEN'S SHORT PERIOD COMET.*

GEORGE A. HILL.

FOR GENERAL ASTRONOMY.

The return of Brorsen's comet, which, according to the advance calculations of Professor E. Lamp, had confidently been expected to occur in the beginning of the past year, has not taken place. It will, therefore, be not uninteresting, to look back, in this article, at the condition of brightness and visibility under which this comet has been observed up to the present time; for in this manner we are best enabled to perceive in how far we were justified to expect with certainty its reappearance during the opposition of last year.

The circumstance that the period of the comet is nearly 5.5 years—the great perturbations of Jupiter in September 1866, decreased it from 5.54 to 5.48 years—causes the returns to perihelion to divide themselves into spring and autnmn appearances. The former are extraordinarily favorable for observation, since, at that time the comet, in consequence of its great inclination, reaches a high northerly declination; in the latter, the comet remains always near the equator, and is visible, if at all, only in the morning hours shortly before sunrise.

We will first consider the spring oppositions which have been observed, up to the present time, 1846 III, 1857 II, 1868 I and 1879 I. In the opposition of 1857, the comet was discovered independent of the ephemeris; its identity with 1846 III was established only through the calculation of its orbit. Van Galen had furnished an advance calculation for this return, but which in consequence of erroneous computation fixed the date of perihelion passage a fourth of a year too late, and would, therefore, not have led to the discovery of the comet.

---

* Translated from the Vierteljahrsschrift der Astronomischen Gesellschaft, 26 Jahrgang Erstes Hept.

In the last two named appearances, the comet was found according to ephemerides computed by Plummer and Schulze.

The following ephemerides will furnish a review of the apparitions in question. "H" expresses the factor of brightness $\frac{1}{r^2\Delta^2}$; the first place of the ephemeris is the date of discovery, the last is the date of the last observation.

1846 III.
Perihelion Feb. 25.

1846		α	δ	H
		h	°	
Feb.	26	1	+ 14	5.4
March	10	1	34	6.4
	21	0	52	5.5
April	1	23	67	4.4
	22	17	+ 71	2.1

1857 II.
Perihelion March 29.

1857		α	δ	H
		h	°	
March	18	2	+ 8	1.7
April	6	3	30	2.8
	18	4	45	2.9
May	2	6	60	2.3
	12	9	63	1.7
Jan.	1	12	48	0.8
	22	13	+ 30	0.3

1868 I.
Perihelion April 17.

1868		α	δ	H
		h	°	
March	22	2	0	0.6
April	11	3	+ 17	1.5
	18	4	24	1.9
	27	4	33	2.1
May	12	6	46	1.9
June	1	10	49	1.2
	23	12	+ 34	0.5

1879 I.
Perihelion March 30.

1879		α	δ	H
		h	°	
Jan.	14	23	− 29	0.1
Feb.	19	1	14	0.5
Mar.	1	1	− 7	0.7
	20	2	+ 9	1.9
April	10	3	23	3.3
May	1	6	60	2.9
	12	8	65	2.2
	23	11	+ 58	1.3

In connection with the foregoing review the following details should receive attention:

1846 III. The last observations were made in Bonn, April 21, and in Berlin, April 22. The Washington observations of the latter part of May (referred to by Bruhns, A. N. 1686, Carl Repertorium, Annuaire du bureau des longitudes) are based upon a confounding of this comet with another, 1846 VII, also discovered by Brorsen.

1857 II. In general, the observations cease with the end of May. From June 18 to 22 the comet, greatly reduced in brightness, was observed only at Berlin.

1868 I. The first re-discovery by Tempel, on March 22, seems doubtful; the comet was not seen with certainty until April 11. In June, the comet was seen only by Schmidt at Athens.

1879 I. The regular ephemeris begins in the middle of March; prior to that time, the comet was seen only Jan. 14 in Arcetri, Feb. 17, in Rome, and Feb. 26, at Windsor.

Noteworthy is the small light intensity of the comet when discovered by Tempel on Jan. 13, in a very southerly declination.

With regard to the brightness of the comet, we may accept it as an established fact that, notwithstanding the smaller theoretical light intensity, the comet was considerably brighter in 1857 than in 1846. Schmidt at Olmütz even believes that he saw the comet with the naked eye on April 8-12, 1857—a brightness which it has never before or since reached. In the year 1868, the comet was fainter than in 1857, but this may be explained by the less favorable conditions of light. In the opposition of 1879, the comet occupied the same position in the heavens as in 1857, but, as may be concluded from the early discontinuance of the observations—it does not appear to have reached the same degree of brightness as formerly.

The general appearance of the comet in the three apparitions 1857, 1868 and 1879, remained always the same; it was that of a large, pale nebula of 4′ diameter, with a condensation in the centre that was very distinct at the time of perihelion, but, which, according to the concurrent testimony of all observer s did not condense itself into a star-like neucleus.

In the year 1846, this strong exhibit of light in the centre of the comet did not take place, a circumstance which will most readily explain the relative faintness of light connected with that apparition.

A characteristic phenomenon connected with Brorsen's comet, and one observed at all returns, is the rapid decrease of light which takes place several weeks after its perihelion passage, and which appears to be connected with a considerable increase of its diameter, amounting to 8′ to 10′.

In the year 1846, when this phenomenon was observed for the first time, the comet, as described by D'Arrest in A. N. 1079, appeared to dissolve in such a manner in its departure from the sun, "that for this reason its reappearance was considered very doubtful at the Berlin Observatory." The fact that in all returns, so soon as the brightness had fallen below unity, observations were possible only in exceptional cases, is directly connected with this phenomenon.

Before the perihelion passage the faintness of light does not appear to be so pronounced as afterwards; at least we could not otherwise explain the fact that in the year 1879, Tempel was able to find the comet on Jan. 14, and Tebbutt could observe it on Feb. 26 with a 4½-inch refractor.

Of the unfavorable autumn returns, the only one observed thus far, is the apparition 1873 VI, perihelion Oct. 10. In this apparition, the comet was discovered Aug. 31, according to ephemerides by Plummer and Schulze, and observed until Oct. 26. It was always faint, of a diffused appearance and without noticeable condensation. The maximum theoretical brightness, 20, was attained in the beginning of October, a brightness which caused the comet, in 1868, to appear as an object of the eighth or ninth magnitude; but in the latter case, the increased faintness of light is fully explained by the comet's unfavorable position in the morning sky.

In the years 1851, perihelion Sept. 22, and 1884, perihelion Sept. 14, the comet was nearer the sun than in 1873, so that under those conditions, its non-discovery is fully accounted for. In view of the comet's non-appearance during the past year, it would, at all events, be of great interest to learn whether and to what extent, especially in the year 1884, search was made for it. Up to the present time, only two short notices have appeared on this subject, one by Trépied (A. N. 2614), and the other by Pechüle (A. N. 2710). In the year 1862, the perihelion passage occured about Oct. 12; it would, therefore, have been possible to have discovered the comet, as is shown by the apparition of 1873—if an ephemeris had been available.

According to the advance computation of Professor E. Lamp, the perihelion passage in the year 1890 occurred on Feb. 24; the return should, therefore, have been exactly analogous to the very favorable first return, 1846 III.

As, notwithstanding this fact the comet was not found either before or after its perihelion passage, we are necessarily compelled, from what has been said above, to conclude that its lack of brilliancy was such as to be out of all proportion with that of former returns.

Whether the comet has actually been lost to us will have to be decided by subsequent observations.

A complete discussion of the hitherto observed returns of Brorsen's comet is yet to come. Professor Lamp is at present engaged in adjusting the last three appearances 1868 I, 1873 VI and 1879 I. Although his investigations are not yet concluded, he feels himself already justified in saying that a combination of the three returns is not possible without an empirical change in the mean daily motion. *Written by* H. KREUTZ.

The above article which I have translated from the magazine published by the German Astronomical Society will be found to contain many interesting facts connected with the history of one of the short period comets that seems to have gone astray.

In connection with what Mr. Kreutz has said, I desire to add that I searched for this comet on 22 nights between Dec. 16, 1889, and March 11, 1890.

I first started with an ephemeris I had computed by the aid of the elements determined in 1879 by Professor Schulze.

It will be remembered that his elements placed the comet in the evening sky, to the east of the sun. Mr. Wittstine had determined a set of elements from observations made in 1879, and there is quite a difference between the value of the mean daily motion of the Schulze and the Wittstine elements, so much so that the latter elements gave an ephemeris that placed the comet on the west side of the sun, nearly 40° from the place indicated by the Schulze elements. This led me to take the observations made of the comet in 1879 and compare them with Professor Schulze's orbit which had been computed from the observations of 1868 and 1873 and the perturbations allowed for in the interval.

For a short time before perihelion, in 1879, the ephemeris agrees fairly well with observations, but after perihelion, say, from April 10th to the last observation made, May 23, the difference between computed and observed places is very large indeed.

I do not feel competent to criticise Professor Schulze's work upon the orbit of this comet, but I am positive that some errors have inserted themselves into his calculation.

The orbit I have determined from the observations extending from March 10 to May 23, 1879, differs quite a good deal from his, not only in the mean daily motion, which I find to be smaller, but in the longitude of the perihelion and the node.

I hope to be prepared to publish before the next return of the comet, my discussion of the several returns and the elements corrected for the perturbations between 1879 and the next apparition.

NAVAL OBSERVATOY, Washington, D. C.

THE SPECTRA OF STARS WITH LARGE PROPER MOTION.

J. E. GORE, F. R. A. S.

FOR GENERAL ASTRONOMY.

In his note on Star Distribution in the November number of THE MESSENGER, Mr. Monck suggests that "solar stars of any magnitude will, on the average, have a greater proper motion than the Sirian." To test the accuracy of this prediction I have gone through the Draper Catalogue of Stellar Spectra, a valuable volume recently issued from the Harvard Observatory, and the results are given in the following table. The magnitudes and proper motions of the stars are taken from Miss Clerke's valuable work, "The System of the Stars." Some of the fast moving stars are either too faint or too far south to be included in the Draper Catalogue. It will be seen that of 29 stars of which the spectrum has been determined, 26 stars are of the second or solar type, a striking confirmation of the truth of Mr. Monck's theory.

Star.	R. A. 1900.		Dec. 1900.		Mag.	Annual Proper Motion.	Spectrum.
	h	m	°	′		″	
Groombridge 1830,	11	46.9	+ 38	31	6.5	7.0	I (A ?)
61 Cygni, Double	21	2.1	+ 38	13	5.1	5.2	II (H)
40 Eridani, Triple	4	10.7	− 7	47	4.4	4.1	II (H?)
μ Cassiopeiæ	0	1.2	+ 54	27	5.2	3.7	II (H)
P II 123	2	30.5	+ 6	24	6.3	2.4	II (H)
α Bootis	14	11.1	+ 19	44	0.2	2.3	II (K)
Bradley 3077	23	8.3	+ 56	36	5.9	2.1	II (H)
τ Ceti	1	39.5	− 16	28	3.6	1.9	II (G ?)
σ Draconis	19	32.5	+ 69	31	4.7	1.9	II (I?)
61 Virginis	13	13.2	− 17	45	4.8	1.5	II (H)
B.A.C. 160 (?)	0	32.1	− 25	19	5.6	1.4	II (F)
20 Mayer	0	43.1	+ 4	46	5.7	1.4	II (H?)
Groombridge 1618	10	4.0	+ 50	0	6.5	1.4	II (H)
ι Persei	3	1.8	+ 49	14	4.1	1.3	II (F)
Weisse IV, 1189	4	57.1	− 5	39	6.5	1.3	I (A)
Sirius, Double; binary	6	40.7	− 16	34	−1.4	1.3	I (A ?)
Procyon	7	34.1	+ 5	30	0.5	1.3	II (F)
Lalande 27744	15	8.9	− 0	58	7.0	1.3	II (H)
γ Serpentis	15	51.8	+ 16	0	4.0	1.3	II (F)
85 Pegasi, Double; binary	23	56.8	+ 26	34	5.8	1.3	II (E)
η Cassiopeiæ, Double; binary	0	43.0	+ 57	17	3.6	1.2	II (F)
δ Trianguli	2	10.8	+ 33	46	5.0	1.2	II (F)
43 Comæ	13	7.3	+ 28	22	4.4	1.2	II (F)
36 Ophiuchi, Double	17	9.2	− 26	27	4.7	1.2	II (I)
θ Ursæ Majoris	9	26.3	+ 52	8	3.2	1.1	II (F)
70 Ophiuchi, Double; binary	18	0.4	+ 2	32	4.1	1.1	II (K)
Lalande 16304	8	13.7	− 12	18	6.0	1.0	II (E)
w (72) Herculis	17	16.9	+ 32	37	5.4	1.0	II (E)
b (31) Aquilæ	19	20.2	+ 11	43	5.3	1.0	II (H)

To the above may be added *α* Centauri which has a proper motion of 3″.7 per annum, and I believe a spectrum of the solar type.

CAPTURE OF COMETS BY PLANETS.

H. A. NEWTON.

In a paper published in 1878 I obtained a simple expression for the change of energy of a small body, a comet for example, that passes near enough to a large planet to have its orbit so seriously changed that all the minor terms in the perturbation may be disregarded. The great interest recently shown in this particular problem of perturbation has led me to take up again the formula, and deduce some results that logically follow from it. The details of the algebraic work are given in a paper in the *American Journal of Science* [3] vol. XLII, Sept. and Dec., 1891. Some of the principal results are given below. Most of the computations made refer to the case of comets moving originally in parabolic orbits about the sun, and passing very near to the planet *Jupiter*, though small changes will make the reasonings apply equally to other comets and planets.

1. The different ways in which such comets can approach *Jupiter* may, by disregarding the plane of *Jupiter's* orbit about the sun, be treated as depending on three independent variables. Let d be the shortest distance between the orbit of the planet and the unperturbed orbit of a comet, ω the angle between the two tangents to those orbits at the extremities of d, and h the distance *Jupiter* has yet to travel to reach one end of d at the moment when the comet would if unperturbed be at the other end of d. The elements of a given cometic orbit, along with the elements of *Jupiter's* orbit, furnish easily the corresponding values of d, ω and h.

2. The loss of energy during the whole transit of the comet past the planet is capable of expression in terms of d, h and ω. Hence the semi-axis major of the elliptic orbit after large perturbation may be expressed in terms of the same three quantities. In other words, the elements of the orbits of the comet and the planet before perturbation furnish the means of computing directly and simply the periodic time of the comet after a large perturbation.

3. If m is the mass of the planet, r its distance from the sun, and if s, A and ϑ are functions of ω defined by the equations

$$s^2 = 3 - 2\sqrt{2}\cos\omega,\quad A = \frac{mr}{s^2} \text{ and } 2s\cos\vartheta = 1 - s^2,$$

then the equation

$$a = \frac{s}{4m}\cdot\frac{A^2 + d^2 + h^2\sin^2\vartheta}{A\cos\vartheta + h\sin^2\vartheta}$$

gives a the semi-axis major of the elliptic orbit of the comet about the sun after perturbation; if a is negative it is the half of the transverse axis of the resulting hyperbolic orbit.

4. For a given value ω and a given positive value of a the two quantities d and h can be treated as the abscissa and ordinate of an ellipse. For values of d and h corresponding to points

within the ellipse a is smaller than for values of d and h corresponding to points upon or outside of the ellipse. As a varies the ellipses constitute a *faisceau* of similar and similarly situated ellipses having the straight line $A \cos\vartheta + h \sin^2\vartheta = 0$ for their common radical axis. For points above the radical axis the final orbit is an ellipse, for points below it is an hyperbola.

5. The greatest effect of pertubation of a planet moving in a circular orbit in shortening the periodic time of a comet moving originally in a parabola is obtained if the comet's original orbit actually intersects the planet's orbit at an angle of 45°, and if the comet is due first at the point of intersection at the instant when the planet's distance therefrom is equal to the planet's distance from the sun multiplied by the ratio of the mass of the planet to the mass of the sun. The relative velocity of the comet on leaving the planet's sphere of action, would be equal to and directly opposite to the planet's velocity, and the comet would be left entirely at rest to fall to the sun.

6. In order to facilitate the consideration of the effect of a planet upon comets as a group two arbitrary assumptions have been made relative to the distribution of the comets themselves, and the distribution of the directions of their motions.

(*a*) If about the sun as a center a spherical surface S be described with an arbitrary radius, it is assumed that near S space is filled equably with comets.

(*b*) It is further assumed that the directions of the comets in each cubic unit of space near S are at random: that is, that the quits and goals of the comets' motions relative to the sun are distributed equably over the surfac of the celestial sphere.

So far as these assumptions are not true in nature, so far modifications of conclusions resting upon them will need to be made.

7. It follows from the assumptions of (6) that if comets be grouped according to their perihelion distances the number of comets whose perihelion distances are less than q is proportional to q.

8. If the two assumptions are true for a spherical surface S, they will be true for every smaller concentric surface.

9. It also follows that if r is the planet's distance from the sun, and r' is small relative to r, the number of comets, which, in a given period of time come nearer to the sun than r is to the number that (unperturbed) come nearer to the planet than r' as $6r^2$ is to $7r'^2$. The factor $\frac{7}{6}$ expresses the increase of numbers caused by the planet's motion in its circular orbit.

10. The number of comets which in a given period of time pass their perihelia nearer to the sun than a given planet, is to the number of comets whose periodic times are reduced by the perturbing action of the planet so as to be less severally than one-half, once, three-halves, and twice, the periodic time of the planet, as unity is to the square of the mass of the planet multiplied severally by 0.139, 0.925, 1.876 and 2.943.

11. With the same assumptions, and regarding the planet as without dimension so as to intercept any comets, if in a given period of time a thousand million comets come in parabolic orbits nearer to the sun than *Jupiter*, 126 of them will have their orbits changed into ellipses with periodic times less than one-half that of *Jupiter;* 839 of them will have their orbits changed into ellipses with periodic times less than that of *Jupiter;* 1701 of them will have their orbits changed into ellipses with periodic times less than once and a half-times that of *Jupiter;* and 2670 of them will have their orbits changed into ellipses with periodic times less than twice that of *Jupiter.*

12. Of the 839 comets whose periodic times after perturbation are less than *Jupiter's* period, 203 will after perturbation have retrograde motions, and 636 will have direct motions. Also 267 of them will have quits less than 45° from *Jupiter's* quit, while 38 of them will have quits less than 45° from *Jupiter's* goal. Also 257 of them will move in orbits whose planes are inclined less than 30° to *Jupiter's* orbit, while 51 will move in orbits inclined more than 150° to *Jupiter's* orbit.

13. Each comet has been thus far considered as approaching *Jupiter* while moving in a parabolic orbit about the sun. If the comet, however, is moving in any other orbit, and it passes near to the planet, the result of the planet's perturbing action will in general be quite similar to the result when the orbit is parabolic, the other circumstances of the approach being assumed to be alike in the two cases.

The above conclusions refer moreover to perturbations during one transit of the comet past the planet. But the comet, unless the orbit is still further changed by another planet, must return at each revolution to the place where it encountered *Jupiter.* At some time *Jupiter* will be nigh that place nearly at the same time as the comet, and the comet will suffer a new, and perhaps a large perturbation. Its period will again be changed, being shortened or lengthened according as the comet passes before or behind the planet. The process will be repeated again and again, since after any number of encounters the new orbit of the comet will still pass near to the orbit of the planet.

This repeated action makes it possible, and even usual, to have an orbit shortened in period by several passages near to *Jupitei* instead of its being done at one passage. A much larger proportion of comets than 839 out of 1,000,000,000 must therefore have their periodic times reduced below the period of *Jupiter*.

If the comet's orbit is largely inclined to the ecliptic, and hence its motion makes a large angle with that of *Jupiter*, there is nearly an even chance that the velocity will be increased or diminished. A considerable fractional part of the whole number of such comets will at each passage be thrown out of the solar system altogether, or thrown into such long orbits that they will return only at very great intervals of time. This class of comets cannot be therefore regarded as permanent members of the family of short period comets, except such of them as happen to come so near to other planets as to have their orbits changed in such wise that they do not have thereafter the near approach to *Jupiter's* orbit. But when an orbit is greatly inclined to the plane of the solar system the comet passes through the plane in general at a considerable angle, and the chance of coming close to another planet is relatively small.

On the other hand, all the comets which after perturbation are moving in orbits somewhat, but not greatly inclined to the ecliptic, are liable to meet, (in fact, are sooner or later almost certain to meet) other planets in such a way as to suffer perturbations that will prevent future close encounters with *Jupiter*. After such changes those comets must be regarded as tolerably permanent members of the solar system.

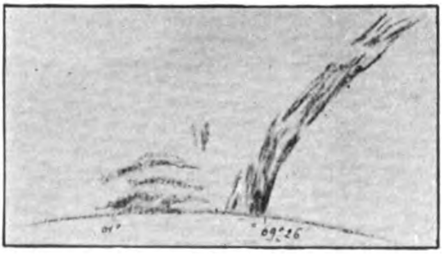
Comets that have motions not greatly inclined to *Jupiter's* motion are more likely in subsequent passages near to *Jupiter* to have their periodic times shortened than lengthened. On the contrary, those passing in nearly opposite direction to *Jupiter's* motion will be quite sure to have their periods lengthened rather than shortened.

All these causes combine and work together to the one end that those comets which are changed by the perturbing action of *Jupiter*, or other planets, from parabolic orbits of every possible inclination to the ecliptic into short period ellipses, and become permanent members of the solar system, will as a rule (but with exceptions) move in orbits of moderate inclination to the ecliptic, and with direct motions.

We know as a fact, that most short period comets do move in orbits having small inclinations and direct motions, while long period and parabolic comets move at all possible inclinations to the ecliptic. If the short period comets have been changed by *Jupiter* and other planets from parabolic orbits, the preceding investigation shows why their orbits have now small inclinations to the ecliptic, and the comets themselves have direct motions.

PLATE III.

Eruption photographed July 9, 1891, at Chicago, 11h. 55m. A.M. Chicago M.T.
(7h. 1m. P.M. Kalocsa M.T.)

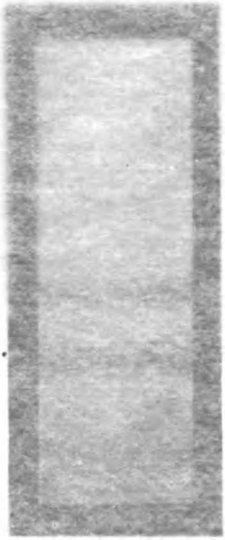


Eruption drawn July 9, 1891, at Kalocsa, Hungary,
at 7h. 0m. P.M. Kalocsa M.T.

PLATE IV.

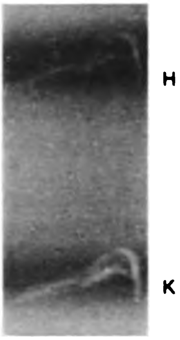
Promin *, at 2 h. 30 m. P. M.*

Distortion of Calcium lines photogra *m. A. M.*
Showing velocity of 64 miles f *.*



A. M. Chicago M.T.

PLATE IV.



Prominence photographed Oct. 20, 1891, at 2 h. 30 m. P. M.

Distortion of Calcium lines photographed Oct. 20, at 10 h. 58 m. A. M.
Showing velocity of 64 miles per second toward the earth.

ASTRO-PHYSICS.

THE ASTRO-PHYSICAL JOURNAL.

It was early in June of the present year that the publication of a journal devoted to spectroscopy and astro-physics was suggested to the writer by Professor C. A. Young, but a projected European trip allowed no definite action to be taken at that time. While abroad, however, an opportunity was afforded of discussing the matter with many astronomers and spectroscopists, and the interest so generally manifested led to the belief that strong support and a wide field of usefulness might be expected for such a publication. It is very evident to anyone acquainted with the present condition of astronomy and physics that in these sciences no one instrument plays a more prominent part than the spectroscope. Long recognised as a powerful means for the chemical analysis of near and distant luminous bodies, it has but recently been promoted to the distinction of an instrument of precise astronomy, in consequence of its closely concordant measures of stellar and nebular motion in the line of sight. This upward step, long since foreseen by our still active pioneer, Dr. Huggins, has disarmed whatever of prejudice against the spectroscope that may have existed among members of the older school of astronomy, and few observatories are considered fully equipped without this efficient aid to research. With its recent rapid developments spectroscopy may well be regarded as having entered upon a new and promising era of progress; already we are in reach of a simple and direct method of determining the distance of the sun by its means, and the relations now known to exist between the spectra of some of the elements suggest equally important advances to the physicist.

On account of its manifest importance, and its appeal to astronomers, physicists, and, to some extent, chemists, it is much to be regretted that the literature of spectroscopy is so widely scattered. Few investigators are so fortunate as to have easy access to the files of all the journals, the innumerable publications of learned societies, and the annals of all observatories. Again, however perfect may be the familiarity of the English-speaking scientist with languages other than his own, there can be no doubt that he allows to pass unread many papers which would at least be rapidly scanned for points of importance, were they printed in English.

For these and other reasons the publication of an astro-physical journal seemed eminently desirable. The question has been thoroughly discussed in conversation with Professor Young, Dr. Huggins, Professor Vogel, Dr. Scheiner, Mr. Ranyard, Herr Schumann, Professors Liveing and Dewar, M. Deslandres, M. Trouvelot, Professor Pickering, Professor Hastings, Professor Keeler and many others. All expressed interest in the idea, and promised to assist the journal by the contribution of papers. But there were many objections to adding another to the already long list of astronomical publications, and Professor Payne's recent suggestion of a union with THE SIDEREAL MESSENGER was considered so desirable that it was at once accepted. Though printed with THE MESSENGER, which will be seen to have undergone many modifications and improvements, THE ASTRO-PHYSICAL JOURNAL will have an individuality of its own, and fully as much space will be devoted to it as would be the case in a separate publication.

It shall be our endeavor to bring our papers both to the astronomer and to the physicist, for in many cases the spectroscopist can ill afford to lose either portion of his audience. Translations and reprints of important papers will be freely used, the idea being to place within reach of all a large portion of the current literature of astro-physics.

We append below a number of letters which have been received with permission to publish. Supplementing as they do the promises of support already mentioned, there seems to be sufficient reason to confidently hope for success. It should be added that most of the letters were written before a union with THE SIDEREAL MESSENGER had been suggested. All who have since heard of this plan heartily approve of it.

UPPER TULSE HILL, London, S. W., 28 Oct., 1891.

Professor George E. Hale,

DEAR SIR:—I am very pleased indeed to hear that you intend to carry out the project you mentioned to me when you were in England, of publishing an Astro-Physical Journal.

I think that you have a very large and unworked field before you, and I wish you most heartily the highest success possible. It will be a pleasure to us to send you any papers we may have, at as early a date as possible, for insertion in your new journal. . . . .

Yours sincerely,
WILLIAM HUGGINS.

THE OBSERVATORY, PRINCETON, N. J., Oct. 17, 1891.

My Dear Mr. Hale:—

. . . .

As to the Journal, I am delighted to hear that you have finally decided to undertake its publication. I think it will be extremely useful and valuable, and I most cheerfully promise to do whatever I can to aid you in the enterprise.

. . . .

Yours sincerely,
C. A. YOUNG.

Observatoire d'Astronomie Physique de Paris,
Meudon, le 21 Nov., 1891.

Cher Monsieur:

J'ai beaucoup regretté de ne pas m'être trouvé à Meudon quand vous y avez passé. J'aurais aimé à causer avez vous de l'intéressant observatoire consacré principalement à la spectroscopie, que vous fondez vous-même, et où vous avez déja obtenu de remarquables résultats.

Vous m'écrivez que vous voulez fonder un journal spécialement consacré à la spectroscopie et vous me demandez mon avis.

Je pense que tous les astronomes physiciens ne pourront que vous encourager et vous aider. Un recueil, même non regulièrement périodique, qui nous donnerait les travaux et les découvertes en spectroscopie, résumés autant que possible par les auteurs eux-mêmes, aurait un bien grand intèrêt et plus tard serait bien précieux pour l'histoire de cette spectroscopie céleste dont l'avenir est immense.

En vous souhaitant plein succès je vous prie de croire à mes sentiments les plus distingués et dêvoués. J. Janssen.

Cambridge, England, 1 Nov., 1891.

To Professor George E. Hale,

Dear Sir:—It is with pleasure that we have learnt your intention to publish an Astro-Physical Journal. The great advances in our knowledge of the physics of the heavenly bodies consequent on the use of the spectroscope, and the increasing number of workers in that line of research, seem to us good reasons for thinking that your proposal will meet a want of the time. Moreover it seems to us very fitting that the Journal should be published in America, where there are not only many excellent observers possessing first-class instruments, but also a climate far better suited for astronomical observations than we on this side the Atlantic enjoy. We shall be glad to coöperate in the undertaking so far as it lies within our power. We are, dear sir, very truly yours,

G. D. Liveing,
James Dewar.

Harvard College Observatory, Cambridge, Oct. 19, 1891.

Professor G. E. Hale, Kenwood Physical Observatory, Chicago,

Dear Sir:—The plan which you have formed for the publication of The Astro-Physical Journal appears to me very judicious, and I think that the work will be of much value and interest. Your intention of making it include translations of articles from foreign journals fully commends itself to me. It will give me pleasure to communicate to The Astro-Physical Journal any observations made here which relate to the problems to be discussed in it, and such remarks upon those problems as I can find time to prepare.

Very truly yours,
Edward C. Pickering.

---

915 Cathedral Street, Baltimore, Dec. 4, 1891.

Dear Sir:—The science of spectroscopy has certainly advanced far enough to furnish material for a new journal, and I have no doubt that the publication of your Astro-Physical Journal would do much to still further advance the subject. I shall do all I can to make it a success, and hope that others will do likewise.

Yours sincerely,
Henry A. Rowland.

Paris, le 5 Nov., 1891.

Monsieur:—

Au retour d'un assez long voyage je trouve votre lettre et m'empresse de vous remercier de vos aimables propositions.

Je serai très heureux et très honoré de recevoir l'hospitalité dans The Astro-Physical Journal; je regrette seulement de n'avoir pas présentement à vous adresser un memoire digne de figurer à côté de ceux des savants illustres qui sont déjà vos collaborateurs.

Je serai particulièrement disposé à vous envoyer quelques résultats relatif à la spectroscopie pour les faire connaitre au public Américain; je me souviens trop bien tout ce que je dois à vos savants compatriotes L. Rutherford et le Professeur Rowland, dont les admirables réseaux m'ont été si utiles dans mes recherches.

Veuillez agréer, je vous prie, Monsieur, l'expression de mes sentiments bien dévoués. A. CORNU.

SMITHSONIAN INSTITUTION, Washington, D. C., Oct. 21, 1891.

DEAR SIR:—I have the honor to acknowledge the receipt of your letter of the 15th instant, advising me that you contemplate publishing an ASTRO-PHYSICAL JOURNAL about the first of December. I can heartily assure you of my interest and good wishes for the undertaking, and I shall hope to have an opportunity of communicating results of observations made in the Smithsonian Astro-Physical Observatory in due time.

. . . .

Yours very truly,
S. P. LANGLEY, Secretary.

WILLESLIE HOUSE, 1, Wetherby Place, London, S. W., 22 Nov., 1891,

DEAR SIR:—Owing to an absence I was unable to reply to your letter before. I shall be glad to send you advance sheets of my papers to the Royal Society. I am sure that a journal, such as you propose bringing out, will be most useful to astronomers and physicists, and should command support on both sides of the water. The bill of fare which you promise in your first number will be sufficient evidence of the useful scope of the JOURNAL.

Wishing you all success in your enterprise, Believe me, yours faithfully,
W. DE W. ABNEY.

ALLEGHENY OBSERVATORY, Allegheny, Penna., Oct. 15, 1891.

Professor George E. Hale, Chicago, Ills.,

MY DEAR SIR:—I am glad to learn from your letter of Oct. 12, that you intend to start a journal devoted to astro-physics and spectroscopy. There seems to be a good field for such a journal in this country, and I have no doubt that the enterprise will have the success it merits.

It will give me pleasure to send you occasional contributions from this observatory. Yours very truly,
JAMES E. KEELER.

ROYAL OBSERVATORY, Greenwich, London, S. E., Oct. 27, 1891.

DEAR SIR:—I am very glad to learn of your intended enterprise, and most heartily wish you all success in it. I feel sure it will do much good by increasing the interest felt in Physical Astronomy, and possibly by bringing forward new workers. If I am able in any way or at any time, to help, I shall be very pleased to do so, though I fear that any assistance I may be able to render will be of the slightest. Yours very truly,
E. W. MAUNDER.

LEIPZIG, den 4 Nov., 1891, No. 25 Mittelstrasse.

HOCHGEEHRTER HERR!—Ihre Absicht, demnächst ein spectroskopisches JOURNAL herauszugeben, begrüsse ich mit Freuden, denn eine Zeitschrift, die speciell der Spectroskopie gewidmet ist, existirt zur Zeit nirgends. Was die Spectralwissenschaft zu Tage fordert, gelangt meist in Journalen verschiedenen Inhalts zur Publication; hierdurch wird die Orientirung auf spectralen Gebiete ungemein erschwert. Der Spectroskopiker setzt sich demzufolge mehr wie jeder andere Forscher der Gefahr aus, wiederzuentdecken, was schon andere vor ihm ausfindig gemacht haben. Das wird besser werden, sobald die Spectroskopie über eigene Organe verfügt. Ihr Unternehmen, die Gründung einer solchen Zeitschrift, dürfte sonach einen längst gehegten Wunsche aller Spectralkundigen entsprechen. Ich wünsche Ihnen besten Erfolg dazu.

Meine spectralen Ergebnisse, die Ihnen zum Theil aus eigener Anschauung bekannt sind, werde ich Ihnen nach und nach zur Aufnahme in Ihr spectroskopisches JOURNAL zukommen lassen. Die Spectrogramme kleinster Wellenlänge

($<\lambda 1800$), die dem Spectrum des Wasserstoffs angehören, werde ich Ihnen ebenfalls zur Verfugung stellen, sobald meine photographischen Aufnahmen im evacuirten Raume zum Abschluss gelangt sind.

Mit vorzüglicher Hochachtung,
V. SCHUMANN.

LICK OBSERVATORY, Mt. Hamilton, Nov. 10, 1891.

My Dear Mr. Hale:—

I sincerely congratulate you on having found a satisfactory means of publishing THE ASTRO-PHYSICAL JOURNAL, and I wish you every success in your plan. I have no doubt whatever that you will command success, and it will be our pleasure to give you all the support which we can from Mt. Hamilton.

With kind regards, sincerely yours,
EDWARD S. HOLDEN.

STONYHURST OBSERVATORY, Lancashire, Nov. 2, 1891.

George E. Hale, Esq.

DEAR SIR:—I received duly your very kind letter of the 14th ult., and I beg to thank you for the honor you have done me in asking me to contribute to your ASTRO-PHYSICAL JOURNAL. I shall be only too glad to do so whenever I have the means. But the nature of my work in the College leaves me without much leisure for writing.

I shall value THE JOURNAL very much, as most of my work at the observatory is with the spectroscope. And if you will kindly inform me, I shall be glad to be a subscriber.

. . . .

Yours very truly,
WALTER SIDGREAVES.

MEUDON, France, Oct. 31, 1891.

DEAR SIR:—I am much pleased to learn that you have decided to publish the journal on spectroscopy you mentioned in your last visit to Meudon. I think that such a work, conducted by so able and enthusiastic a worker as yourself, will certainly prove of great assistance to spectroscopists, as well as it will materially assist in developing this branch of science.

I will take great pleasure in occasionally contributing papers on my line of research.

Very truly yours,
E. L. TROUVELOT.

WORCESTER, Mass., Nov. 27, 1891.

My Dear Mr. Hale:—

I am very glad to learn of the enterprise you have in hand, and shall be very happy to contribute anything of my own work which may pertain to the subject.

You are quite welcome to reprint anything of mine which has been published, but the results which I communicated to you in New York have not yet appeared in print, and—while I have not the slightest objections to your making any use you please of the rather rambling statements I then made—I should hardly like to publish anything *yet*, over my own name; though I may be in a position to do so in a few months.

With kind regards, and most cordial wishes for the success of the new enterprise,

I am, Sincerely yours,
ALBERT A. MICHELSON.

JOHNS HOPKINS UNIVERSITY, Baltimore, Oct. 17, 1891.

Professor Geo. E. Hale, Kenwood Physical Observatory, Chicago, Ill.

MY DEAR SIR:—Your letter of the 12th inst. was duly received.

I think your idea of publishing a journal specially devoted to spectroscopic work is a capital one. Not only will it be of great benefit to the investigators themselves; but it will also serve to interest others in this, one of the most fruitful and attractive fields of Physics. I shall do all in my power to further your interests.

. . . .

Most sincerely yours,
JOSEPH S. AMES.

1416 K St., Washington, D. C., Oct. 26, 1891.

DEAR SIR:—I am pleased to learn that we are to have in the United States a journal devoted to Astro-Physics, and I assure you that I shall be very glad to contribute any papers that may arise from my work, unconnected with official duties, which may be connected with this subject.

. . . .

Yours truly,
FRANK H. BIGELOW.

RUSTHALL HOUSE, Tunbridge, Welis, October 31, 1891.

Professor George E. Hale,

DEAR SIR:—I fully appreciate your object in bringing out "THE ASTRO-PHYSICAL JOURNAL," and if able to forward that object at any time, I will gladly do so. With kind regards, I remain

Yours very truly,
FRANK McCLEAN.

7, KENSINGTON PARK GARDENS, London, W., Nov. 2nd, 1891.

To Professor G. E. Hale, Kenwood Physical Observatory, Chicago, U. S. A.

MY DEAR SIR: I am glad you are going to bring out the "ASTRO-PHYSICAL JOURNAL," and I shall await the first number with great interest. I think it will fill a gap in our scientific literature. . . . .

With kind regards, believe me,
Very truly yours,
WILLIAM CROOKES.

DISTRIBUTION OF ENERGY IN STELLAR SPECTRA.*

PROFESSOR E. C. PICKERING.

FOR ASTRO-PHYSICS.

The relative brightness of stars or other luminous objects of different colors cannot be correctly indicated by any single number or ratio. It is necessary to employ a curve or series of numbers which shall give a measure of the energy of rays of each different wave-length. Stellar magnitudes only have a value so long as we can neglect the differences in distribution of the light according to the wave-length. Therefore when we compare the results of different processes, as photography and visual observations, entirely different results will be obtained for objects of different colors. If, however, we deal with rays of a single wave-length, all methods should give the same relative intensities. The intensities of rays of different wave-lengths may be determined by comparing the densities of different portions of a photographic spectrum. But large corrections must be applied for various sources of error for rays of each wave-length. Among these may be mentioned the absorption of the earth's atmosphere, the absorbtion of the prisms and lenses, the unequal sensitiveness of the silver salts, and the dispersion of the prisms by which the violet

---

* Communicated by the author.

rays are spread over a larger surface than the red rays. The direct determination of all these quantities would be a matter of no little difficulty. Fortunately this problem is greatly simplified by making the measures differential and comparing them with the elaborate determination of the distribution of the energy in the solar spectrum made by Professor Langley with the bolometer. He was aided in this research by Professor F. H. Very, and has kindly furnished approximate values of their results, from which the quantities given in the accompanying table are derived. The values of the wave-lengths are given in the first column, and the logarithm of the corresponding amount of energy in the second. The unit of energy is here assumed to be that of the hydrogen line G, this point being selected since it is near the center of the photographic spectrum. Instead of the usual logarithmic expressions corresponding to numbers less than unity, the equivalent negative expressions have been used. Thus —.26 is substituted for 9.74, etc. to make the table conform to the usual method of representing negative quantities. They can thus be readily converted into intervals on the scale of stellar magnitudes if desired by dividing by 0.4. Thus the logarithmic interval —.26 would correspond to .65 of a unit of stellar magnitudes.

From the collection of photographs of stellar spectra forming part of the Henry Draper Memorial nine were selected, all taken under similar conditions. They represent α Virginis, γ Cassiopeiæ, α Canis Majoris, α Canis Minoris, α Aurigæ, Saturn, α Tauri, α Orionis, and the sun. The spectrum of α Virginis is of the first type, but the Orion lines are well marked; γ Casslopeiæ contains bright lines; α Canis Majoris is a typical first type star; α Canis Minoris is intermediate between the first and second types; α Aurigæ is of the second type; Saturn's spectrum closely resembles that of our sun, so also does that of α Bootis; α Orionis is of the third type, or intermediate between the second and third. The spectrum of the sun was obtained by reflecting its rays through a narrow slit and then rendering them parallel by means of a concave mirror having an aperture of 15 inches and a focal length of 150 inches.

Measures were then made by Mrs. Fleming of twenty points in each of the spectra, by comparison with a standard photographic wedge (Harvard Observatory Annals XXVI, p. 6). These measures were converted into logarithmic intervals, and the measure corresponding to the wave-length 434, which is that of the hydrogen line G, was subtracted from each. The values of the logarithm of the energy of the solar light taken from the second column of the table was next subtracted. The remainder will show the excess or deficit of energy of the star as compared with that of the sun, eliminating the various sources of error enumerated above. Finally the observed points were plotted and smooth curves were drawn through them. From these curves the values were found for each of the wave-lengths given in the table. The results for the various stars observed are given in the successive columns of the table. Thus in the case of α Orionis the energy for the wave-length 390, or near the line α, is —.57 as compared with that of sunlight. The numerical ratio is 0.27, whose logarithm is 9.43. The absolute energy is found by adding the tabular number to that given for sunlight in the second column. Thus —.26 —.57 = —.83, corresponding to the ratio 0.15. In the case of α Orionis, therefore, the energy of the light of wave-length 390 is only about one-seventh of that of wave-length 434. The numerical values of the energy of sunlight are given in the last column of the table. It therefore equals the anti-logarithm of the second column.

λ	log. E.	α Virg.	γ Cass.	α Can. Maj.	α Can. Min.	α Aur.	Saturn	α Tauri.	α Ori.	E.
390	—.26	+.32	+.25	+.37	+.07	+.32	—.36	—.35	—.57	.55
400	—.19	+.14	+.10	+.10	—.04	+.08	—.20	—.14	—.38	.65
410	—.12	+.04	+.03	+.01	—.03	+.03	—.11	—.04	—.23	.76
420	—.07	.00	+.01	.00	—.01	+.01	—.06	—.02	—.11	.85
430	—.02	.00	.00	.00	.00	.00	—.02	.00	—.02	.95
440	+.02	+.01	.00	—.01	+.01	.00	.00	+.01	+.05	1.05
450	+.06	+.01	.00	—.02	+.01	—.01	+.01	+.02	+.10	1.15
460	+.09	—.04	.00	—.03	—.03	—.03	+.03	+.02	+.10	1.23
470	+.12	—.17	—.04	—.10	—.10	—.09	+.04	—.01	+.08	1.32
480	+.14	—.37	—.14	—.21	—.23	—.22	+.03	—.12	+.03	1.38
490	+.16	—.59	—.26	—.35	—.40	—.36	+.02	—.26	—.04	1.45
500	+.18	—.83	—.39	—.51	—.61	—.51	+.01	—.43	—.12	1.51
510	+.20	—1.10	—.54	—.71	—.84	—.67	.00	—.63	—.21	1.58

In the case of sunlight, a small correction should be applied for the selective reflection of the silvered glass mirror. This effect does not appear to be large, since the spectrum of Saturn gives nearly the same results as that derived from direct sunlight, except for rays of short wave-lengths. The negative values derived from these rays in the case of Saturn may be due to the selective reflection above mentioned. The corresponding residuals of the other spectra might be corrected by the amount thus indicated. Perhaps, however, Saturn is really bluer than the sun, in which case the values already given are correct. The curve for α Aurigæ is nearly the same as that of α Canis Majoris which shows that although its lines are the same as those of the sun, the distribution of its light resembles that of a first type star.

The red color of α Tauri and α Orionis as compared with α Virginis and α Canis Majoris is clearly shown by the change in sign of the residuals.

Observatory of Harvard College,
Cambridge, Mass., U. S. A., October 31, 1891.

SPECTRUM OF β LYRÆ.*

PROFESSOR EDWARD C. PICKERING.

The spectrum of the variable star, β Lyræ, is unlike that of any other star hitherto examined. With the aid of Mrs. M. Fleming and Miss A. C. Maury a careful study has been made of twenty-nine photographs of this object. These photographs form part of the Henry Draper Memorial. The images on four other plates were too indistinct to be used and were not included in the following discussion. The spectrum is traversed by broad dark bands due to hydrogen and also by other lines characteristic of many stars in the constellation of Orion and forming that division of the first type which is designated as B in the Draper Catalogue. But besides these several bright lines are visible which change their positions. The most conspicuous of them have the approximate wave-lengths 486, 443, 434, 410, 403, and 389. The first, third, fourth and sixth of these apparently coincide with the hydrogen lines *F*, *G*, *h* and α. The others are two of the most marked of the Orion lines. The bright lines sometimes have a slightly greater wave-length than the corresponding dark lines, so that the latter sometimes appear to have bright edges on the less refrangible side while at other times the reverse is the case.

It is obviously desirable to trace any connection which may exist between these changes and the variations in the brightness of the star, the principal minima of which occur at regular intervals of about 12^d 22^h. There are two maxima occuring at 3^d 5^h and 9^d 16^h after the principal minimum and an intermediate minimum following it 6^d 11^h. Of the eleven plates in which the bright lines had a diminished wave-length it was found that all had been taken during the second half of the period of variation, that is after the second minimum and more than 6^d 11^h after the principal minimum. The fourteen plates taken during the first half of the period all showed an increase in wave-length of the bright lines, that is, the dark lines appear bright on the side

---

* *Astr. Nach.* 3051.

towards the red. There are, however, three exceptions, plates at $6^d\ 13^h$, $7^d\ 12^h$ and at $11^d\ 11^h$ show an increased instead of a diminished wave-length. A re-examination of these three plates showed that the deviation of the lines was not very marked, and two other plates taken near the two minima showed a tendency of the lines to occupy an intermediate position and sometimes apparently to fall on the dark lines so as to nearly disappear.

Since the observations extend over more than four years or 130 periods of variation of the star, this latter period must coincide, or at least agree very closely with the period of change in the lines. It seems probable that they are due to the same cause. It should be noticed, however, that bright lines are not visible in the spectra of other variable stars of short period. The spectrum of S Monocerotis is of the Orion type, with dark lines resembling those in the spectrum of β Lyræ; ζ Geminorum, X Sagittarii, V Sagittarii, η Aquilæ and δ Cephei have spectra of the second type and the spectrum of T Vulpeculæ is intermediate between the first and second types.

The actual changes in the spectra when studied in detail are much more complicated than has been stated above and show a variety of intermediate phases, and changes in the dark as well as in the bright lines. In some of the photographs several of the bright lines appear to be double. Micrometric measures are now in progress, additional photographs are being taken, and a complete study of the whole will be made.

The most natural explanation of the motion of the bright lines is that the object emitting them is revolving in a circular orbit having a period of $12^d\ 22^h$. The maximum velocity is approximately 300 English miles (500km). The corresponding minimum value of the radius of the circle would be about 50,000,000 miles. Perhaps this object is a close binary resembling β Aurigae but with components having unlike spectra. The phenomena may also be due to a meteor stream, or to an object like our sun revolving in $12^d\ 22^h$ and having a large protuberance extending over more than 180° in longitude. The occasional doubling of the lines would then be due to both ends of the protuberance being visible at the same time, one receding, the other approaching. The variation in light may be caused by the visibility of a larger or smaller portion of this protuberance.

Harvard College Observatory,
Cambridge, Mass., June 29, 1891.

STARS HAVING PECULIAR SPECTRA. NEW VARIABLE STAR IN LACERTA, DM + 39°.4851.*

M. FLEMING.

A photograph taken at this Observatory on July 6, 1891, shows that the hydrogen lines *G* and *h* are bright in the spectrum of a third type star DM. + 39°.4851 Magn. 8.8, whose approximate position for 1900 is in RA. $22^h\ 24^m.7$, Decl. + 39° 48′. As this has been assumed to be a distinctive feature in the spectrum of variables of long period, charts of the region containing this star were examined and measured. The charts were taken on Nov. 6, 1889, August 6, 1890, July 9, and July 13, 1891, and the approximate magnitude of the star on these respective dates was < 12.9, 12.7, 9.5, and 9.9. The estimated magnitude on the spectrum plate from which the star was discovered is 9.7. The variability of this star is thus confirmed. — The variable star in Hydra, announced in the Astr. Nachr., Bd. 126, p. 117, was in declination —27° 52′ and is W Hydræ, which had been previously announced by Mr. E. F. Sawyer in the Astronomical Journal, Vol. IX, p. 94. — In the Astr. Nachr., Bd. 127, p. 5, the new variable star in Aquarius is given as in RA. $20^h\ 41^m.3$ and should be RA. $20^h\ 43^m.1$ for 1900. — Several photographs have been obtained of the spectrum of DM. —10°.5057, Magn. 7.0, whose approximate position for 1900 is in RA. $19^h\ 17^m.7$, Decl. —10° 54′. The star was supposed to be of the fourth type and was announced in the Astr. Nachr., Bd. 126, p. 163, but in later photographs more marked peculiarities are seen. The lines in the spectrum are not those due to hydrogen. In some photographs they are broad bands, while in others the lines appear to be double. No other star has yet been found here whose spectrum resembles that of this object. As the stellar magnitude is 7.0 a large dispersion cannot be used. A visual examination with the 15-inch equatorial telescope failed to show the peculiarities mentioned above. — The nebula, G. C. 844, whose approximate position for 1900 is in RA. $4^h\ 17^m.8$, Decl. —55° 11′, is well shown on a photograph taken at Mt. Harvard, Peru, on Sept. 8, 1890. Two well marked spiral rays surround the stellar nucleus, the preceding one turning through about 240°, the following one through about 130°.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., July 23, 1891.

---

* Communicated by Edward C. Pickering, Director of Harvard College Observatory, to *Astr. Nach.* 3054.

THE MODERN SPECTROSCOPE.

Within the past few years some very important advances have been made in the construction of spectroscopes. In few cases, however, have the details of instruments been minutely described, and the merits and demerits of the various types are not very generally known. For this reason it has been considered desirable to publish a series of papers on "The Modern Spectroscope," in which the most important instruments now in use will be examined in detail. The concave grating is described by Dr. Ames in the first paper of the series. Professor Keeler is preparing an article on the Lick Spectroscope for our February number, and others of equal interest will follow.

The Concave Grating in Theory and Practice.[*]

BY JOSEPH SWEETMAN AMES, PH. D., ASSOCIATE IN PHYSICS IN THE JOHNS HOPKINS UNIVERSITY, BALTIMORE.

The following paper is in the main a reprint of an article with the same title in the Johns Hopkins University Circulars, No. 73, May, 1889, which afterwards appeared in the Philosophical Magazine, May, 1889. It gives the general theory of the instrument and its adjustments, and a full description of the apparatus in use in Professor Rowland's laboratory at the Johns Hopkins University.

GENERAL THEORY.

The theory of a concave spherical grating gives (See Rowland, *Phil. Mag.*, vol. XVI, p. 197, and *Amer. Jour. Sci.*, vol. XXVI, p. 91) as the radius vector of the focal curve, referred to the center of the grating as origin (see Fig. 1).

$$r = \frac{R\rho \cos^2 \mu}{R(\cos \mu + \cos \nu) - \rho \cos^2 \nu}$$

μ is the angle r makes with ρ the radius of curvature of the grating; and R and ν are the coördinates of the source of light. For any given value of R and ν there is a curve defined by r and μ, on which the various spectra are brought to a focus; and there is a second curve passing through R, ν, such that, if the source of light be placed at any point of it, the spectra will be brought to focus along the curve r, μ. These two curves are, then, conjugate, and their properties have been discussed by Mr. Baily in the *Phil. Mag.* for 1883.

---

[*] Communicated by the author.

If we make $R = \rho \cos \nu$, *i. e.*, place the slit on the circle whose diameter is the radius of curvature of the grating, $r = \rho \cos \mu$. Hence the two focal curves coincide. This case is shown in Fig. II.

As is well known this arrangement is mechanically secured by placing the slit at the intersection of two beams set at right angles, on which are ways to carry the grating and eye-piece, these two being kept at a constant distance ρ apart by an iron girder. Or, the grating and camera box may be kept fixed, and the slit moved along a circular track. The former method is in use generally. Thus: in Fig. III the slit is at A, the grating at B, and the eye-piece or camera at C.

The reasons for putting the eye-piece at C, where $\mu = 0$, are easily found. Imagine the micrometer screw carrying the eye-piece, to be placed at D, Fig. IV, tangent to the focal-circle. Let the eye-piece be displaced along the tangent by an amount $\overline{DD'}$ or "a."

$$a = \frac{\rho}{2} \sin 2(\mu - \theta)$$

$$da = \text{one turn of micrometer}$$

$$= \rho \cos 2(\mu - \theta)\ d\mu = \Delta$$

But by theory of diffraction (see Rayleigh, *Encyc. Brit.*, Wave Theory of Light, vol. XXIV, p. 437)

$$\lambda = \frac{\omega}{N} (\sin \nu + \sin \mu)$$

where ω is grating space and N the order of spectrum

$$\therefore d\lambda = \frac{\omega}{N} \cos \mu\ d\mu = \frac{\Delta\omega \cos \mu}{N\rho \cos 2(\mu - \theta)}$$

Or, if a photographic plate, bent to radius $\rho|_2$, were placed at D, one scale division Δ along plate

$$= \rho\ d\mu$$

$$d\lambda = \frac{\omega}{N} \cos \mu\ d\mu$$

$$= \frac{\Delta\omega}{N\rho} \cos \mu$$

Now, if $\theta = 0$, *i. e.*, if the micrometer eye-piece or the camera-box be placed perpendicular to the arm $\overline{BC}$, we have

$$d\lambda = \frac{\Delta\omega}{\rho N}$$

since μ is so small that we can put $\cos \mu = 1$. Hence the spectrum is "normal" at C. Further, in this case,

$$\lambda = \frac{\omega}{N} \sin \nu$$

$$\therefore \text{since } AC = \rho \sin \nu$$

$$\lambda = \frac{\omega}{\rho N} \overline{AC}$$

Thus, if one absolute wave-length is known, and if the instrument is in perfect adjustment, we can mark on the beam $\overline{AC}$ a scale of wave lengths for each spectrum, and the absolute wave length of any line is known at once. It is important to notice that this scale on the beam is identical with the scale on the photographic plate, and that all the spectra are in focus at C at the same time, and *stay in focus* however C moves along $\overline{AC}$, it being rigidly fastened to B. These facts alone would render a concave grating preferable to a plane one; but it has many other points of superiority. It is the only spectroscope suitable for use in both the ultra-violet and the infra-red. Much longer photographic plates can be used than with any other instrument, since they can easily be bent so as to be entirely in focus. Between the slit and the camera-box, no lens is interposed. Besides saving in light and cost, there are no corrections necessary for spherical aberration, imperfections of lenses, right and left handed quartz, etc. Further, the concave-grating is *astigmatic*, *i. e.*, a point of light as the source is brought to focus not in a point, but in a line. The advantages of this fact are:

1st. A narrow spark at the slit is broadened into a wide spectrum.

2d. Greater accuracy in comparing metallic and solar lines is secured, as will appear later when the use of the instrument is described.

3d. There are no "dust-lines," for they are brought to a different focus.

4th. A spectrum is obtained which is broad enough to stand enlarging.

THEORY OF ERRORS IN ADJUSTMENT.

The mounting of the slit, grating and camera-box on the circumference of a circle of radius $\frac{\rho}{2}$ passing through the center of the grating, is the ideal one. In practice it is impossible to attain it; and so it becomes necessary to study the effect of any small displacement from the perfect adjustment.

I. Let ρ be slightly less than the fixed arm $\overline{BC}$. Fig. V.

$$BC = a$$
$$BD = \rho$$

We wish to find r in the neighborhood of $\mu = 0$

$$\therefore r = \frac{\rho R}{R + R\cos\nu - \rho\cos^2\nu}$$

But we keep $R = a \cos \nu$

$$\therefore r = \frac{\rho a}{a + a \cos \nu - \rho \cos \nu}$$

$$\text{Let } a = \rho(1 + \theta) \qquad i.\,e., \theta = \frac{CD}{DB}$$

$$r = \rho \frac{1 + \theta}{1 + \theta(1 + \cos \nu)}$$

If θ is small

$$r = \rho(1 - \theta \cos \nu)$$

Let the camera-box be placed in focus when $\nu = 0$; its distance from the grating is then $\rho(1 - \theta)$ $\therefore$ the distance it is out of focus for any position ν is $y = \rho(1 - \theta \cos \nu) - \rho(1 - \theta) = \rho\vartheta(1 - \cos \nu)$ $= a\vartheta(1 - \cos \nu)$

Put $\overline{AC} = x = a \sin \nu$

$$\therefore y = a\vartheta - \vartheta\sqrt{a^2 - x^2}$$

This is the equation of an ellipse having center at $(0, a\vartheta)$ and having as semi-axes a and $a\vartheta$. Fig. VI.

II. Let the slit be slightly displaced from A along $\overline{AB}$. Fig. VII.

$$BD = R$$
$$AD = b$$

As before

$$r = \frac{\rho R}{R + R \cos \nu - \rho \cos^2 \nu}$$

But $\rho \cos \nu = R + b$

$$\therefore r = \frac{\rho^2 R}{\rho R - Rb - b^2}$$

$$\text{Let } \frac{b}{\rho} = \alpha, \text{ a small quantity}$$

$$\therefore r = \rho(1 + \alpha)$$

for all values of R removed from 0, as it always is in practice.

Hence, if the camera-box is once put in focus, it stays so, wherever it is moved along $\overline{AC}$.

III. Let the two beams $\overline{AB}$ and $\overline{AC}$ make an angle $\pi|_2 - \vartheta$ with each other. Fig. VIII.

As before

$$r = \frac{\rho R}{R + R \cos \nu - \rho \cos^2 \nu}$$

$$\text{And} \qquad \rho \cos(\nu - \vartheta) = R \cos \vartheta$$

$$\therefore \rho \cos \nu = R - \rho \sin \nu \tan \vartheta$$

$$\therefore r = \rho \frac{\rho R}{\rho R + R\rho \sin \nu \tan \vartheta} \qquad \text{if } \vartheta \text{ is small}$$

$$= \rho(1 - \sin \nu \tan \vartheta)$$

If camera-box is put in focus when $\nu = 0$, it will be out of focus at any point an amount, $y = \rho(1 - \sin\nu \tan\vartheta) - \rho = -\rho \sin\nu \tan\vartheta$.

$$\text{But } x = \overline{AC} = \rho \frac{\sin\nu}{\cos\vartheta}$$

$$\therefore y = -x \sin\vartheta = -a \tan\vartheta$$

the equation of a right line making an angle ϑ with axis of x. Fig. IX.

IV. Let the grating be turned on its axis so that its radius of curvature makes a constant angle α with the arm BC. Fig. X.

$$BD = \rho$$

$$BC = a$$

Since μ is kept equal to α

$$r = \frac{R\rho\cos^2\alpha}{R(\cos\alpha + \cos\nu) - \rho\cos^2\nu}$$

But $a\cos(\alpha + \nu) = R$

$$\therefore r = \rho \frac{a\cos(\alpha+\nu)\cos^2\alpha}{a\cos(\alpha+\nu)(\cos\alpha + \cos\nu) - \rho\cos^2\nu}$$

Put $a = \rho(1 + \delta)$, and suppose both α and δ to be small. Then

$$r = \rho(1 + \alpha\sin\nu - \delta\cos\nu)$$

Let the camera-box be placed in focus when $\nu = 0$; the distance it is out of focus at any point is then

$$y = \rho(1 + \alpha\sin\nu - \delta\cos\nu) - \rho(1 - \delta)$$

$$= \rho(\alpha\sin\nu + \delta - \delta\cos\nu)$$

$$x = a\sin(\alpha + \nu)$$

$$\therefore y = \alpha x + a\delta - \delta\sqrt{a^2 - x^2}$$

Since α and δ are both small, this curve is the sum of those found in Cases I and III.

Case V. Let the slit be displaced along $\overline{AC}$. See Fig. XI.

We have

$$AD = b$$

$$DC = x$$

As before

$$r = \frac{\rho R}{R + R\cos\nu - \rho\cos^2\nu}$$

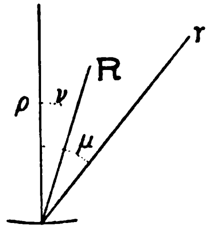
But $R^2 = \rho^2 - x^2 - 2bx$

$$\text{and } \cos\nu = \frac{\sqrt{\rho^2 - x^2}}{\rho}, \text{ since } \frac{b}{\rho} \text{ is small}$$

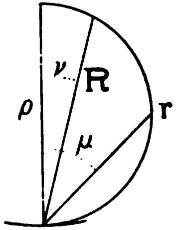
$$\therefore r = \rho\left\{1 + \frac{bx}{\rho\sqrt{\rho^2 - x^2}}\right\}$$

$$y = r - r_{\nu=0} = \frac{bx}{\sqrt{\rho^2 - x^2}}$$

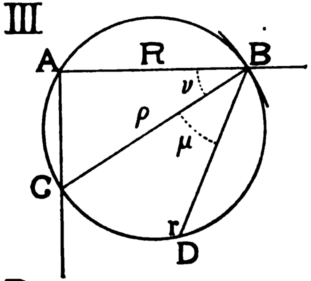
I



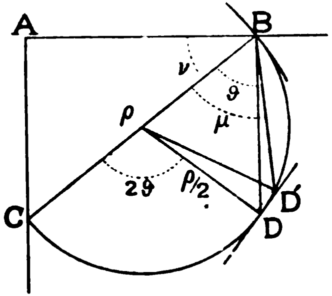
II



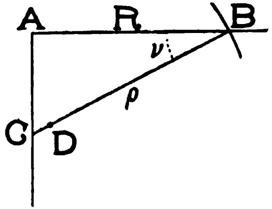
III



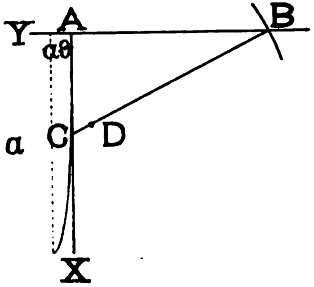
IV



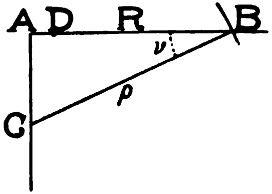
V



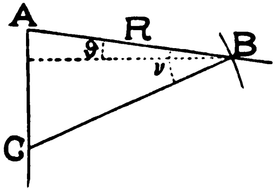
VI



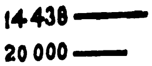
VII



VIII

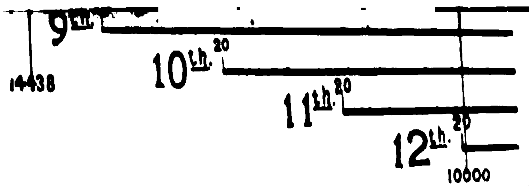


IX.



X.

XI



lly
be
the
ab-
ver
run-
rver
the
For
is a
t the
part-
se, be

peres
mum.
induc-
ark of
ens dy-
and ⅛

inch are
t, while
a 20,000
l surface.
tographic
his thick-
as without
on by Pro-
Warnerke's
for enlarge-
l for gaseous
glass is neces-

dividing engine
5 inches, and the
made according to
in his article on the

light are necessary at
one should extend half
st room has some light in

wooden buttons against pieces of hard rubber so that it is bent to the proper radius. There is in *B* a frame which can be moved vertically by a rack and pinion; and to this *A* is fastened by dowel pins on the bottom and hooks at the top. On the back of the camera-box, *B*, is hinged a board "*C*," which can be held firmly in place by hooks. This board carries a brass plate (see Fig. XV) having a longitudinal opening of a width equal to the thickness of the plate itself and capable of revolution around a horizontal central axis. By means of stops this revolution is confined to 90°. This plate is used for the comparison of spectra, as described below.

The grating-holder is made of brass. It consists (see Fig. XVI) of a heavy platform carrying an upright frame, *B*, which can move in slots on *A*. To *B* is fastened by screws at the sides, *P*, a square piece of brass *D*. *D* is moveable around the axes, *P*, by means of a screw, *S*. To *D* by means of an axis, *P′*, at the bottom is fastened the frame *C*. By means of a screw at *S′* whose nut is rigidly connected with *D*, *C* can be moved around the axis, *P′*. Springs take up the slack of the screws when unscrewed.

The grating itself stands on two projections at the bottom of *C*, and is held there, *free from all constraint*, by a soft wax. By means of the side and back screws the grating can, then, be turned around its centre in its own plane, or tipped back and forward.

The slit, placed at *A*, is of somewhat complicated mechanism. See Fig. XVII. It has the following adjustments:

1st. Width of slit can be regulated by a micrometer screw. It is generally not open more than 0.001 in.

2d. The slit can be rotated about a central axis so as to make it parallel to the lines of the grating. This adjustment is one of the last to be made in mounting the grating, and is done by turning the slit until the definition is the best possible. This is most important, as the excellence of the photographs depends largely upon it. The definition is spoilt, if the slit is 0°.5 out.

3d. Stops can be inserted at top and bottom, thus causing the grating to be illuminated by the center of the solar image only. Otherwise the definition may be spoilt by the rotation of the sun. It is important, therefore, that the image of the sun on the slit be quite large. With the larger apparatus in use in the Johns Hopkins University it is 1.2 cm. in diameter, and this is reduced one-half by the stops.

For solar work, a heliostat, having a south-exposure, throws the light on the slit by means of a condensing lens and a totally reflecting prism. The lens is held in a brass frame, and can be adjusted from within the building. Between the prism and the lens is a revolving stage with circular openings, across which absorbing solutions can be placed. Both this stage and the lever arm carrying the reflecting prism are controlled by strings running along $\overline{AC}$; so that, without leaving his seat, the observer can place different solutions before the slit, or put aside the prism, when a metallic spectrum is to be photographed. For this *last* purpose, along the line of the slit and grating, is a wooden tube with condensing lens, which focuses on the slit the image of the arc-light or spark, placed in a separate compartment. See Fig. XII. All lenses and prisms must, of course, be made of quartz.

For the arc-light a Weston dynamo of 150 volts, 30 amperes power is used, or an alternating Siemens of 700 volts maximum. For spark spectra, Professor Rowland has constructed an induction coil, which (with from 3 to 12 gallon jars) gives a spark of intense brilliancy, when driven by the alternating Siemens dynamo. Using this coil, iron wire of 1/16 in. diameter melts, and ⅛ in. wire is heated red hot.

Gratings with 10,000, 14,438, and 20,000 lines to the inch are used. For ordinary purposes a 10,000 one is sufficient, while for photographing in the ultra violet it is best to have a 20,000 grating, with a ruled space of 5½ in. on a 6 in. polished surface. The radius of curvature is generally 21.5 ft. The photographic plates are 19 in. long, 2 in. wide, and 1/16 in. thick. This thickness allows the plates to be bent to the required radius without breaking. They are flowed with an ammonia emulsion by Professor Rowland himself, and register from 15–20 on Warnerke's sensitometer. Quick plates give too coarse an effect for enlargement. For short focus gratings, such as are used for gaseous spectra and direct stellar spectra, microscope-slide glass is necessary.

The micrometer eye-piece used is more like a dividing engine than an ordinary micrometer. It has a run of 5 inches, and the screw is to all purposes perfect, having been made according to the directions given by Professor Rowland in his article on the Screw in the *Encyc. Brit.*, Vol. XXI, p. 552.

Hoods of black cloth to keep out stray light are necessary at the slit, and at the camera-box where one should extend half way to the grating, as even the darkest room has some light in it.

ADJUSTMENTS.

The adjustment of these various parts of the apparatus is comparatively simple. The two beams carrying the grating and camera-box are made as level as possible and placed at right angles by the "3, 4, 5" rule. The two axes at the ends of the girder must be made parallel, *while the girder is under stress.* To do this the girder is supported at its ends on two "horses;" and the axes are adjusted by the control-screws until the two are vertical. This is the most difficult adjustment.

The camera-box, grating-holder, and slit are put in place at the proper height. Most gratings give a brighter spectrum on one side than on the other; and so, before placing the grating on its holder, it must be examined to see which side should be used. The grating is then placed in position, free from constraint; and a candle is held at the center of the camera-box, directly over the axis of the carriage. The grating is turned and the girder lengthened until the flame and its image coincide. By this, the grating is placed perpendicular to the girder, and the girder itself is given the correct length. The camera box is then made vertical by a plumb-line. To adjust it perpendicular to the girder, a piece of plate glass is fastened to its face, and a candle is held on the girder near the grating. The camera-box is then revolved until the flame and image come in line. The reflecting prism is now put in place so as to illuminate the *entire* grating, and the slit opened. The spectrum formed at the camera-box is observed by the eye, or thrown on a piece of paper; and the back-screw of the grating-holder is turned until it falls at the right height. The camera-box is moved to the right or left, and in general the spectrum rises or falls. This is corrected by the side-screw of the grating holder. These two adjustments are repeated many times until the spectrum stays in place however the camera-box is moved. Then the slit is narrowed, and revolved until the best definition is secured. The instrument now should be in perfect adjustment, and, to test this, an exposed photographic plate, off which the emulsion has has been partially scraped, giving it a lattice-work appearance, is put in the camera-box, emulsion side toward the grating. The spectrum formed on the plate and the emulsion itself ought now to be in focus at the same time in all orders of spectra; that is, if the plate is observed with an eye-piece, there should be no par allax between the two. In general further adjustment is found necessary. It was to this end that the theory of errors, as above, was deduced. Let the camera-box be placed in focus when it is near the slit: and then, as it is moved away from it, suppose the parallax increases proportionally to the distance along the way. This would lead one to think that the two beams were not exactly at right angles. Similarly for the other displacements. It is found in practice that it does most good to turn the grating-holder slightly around its vertical axis.

If, in setting up the instrument, a micrometer eye-piece is used instead of a camera, practically the same adjustments are found necessary.

USE OF INSTRUMENT.

Gratings in Practice.

Special gratings should be selected for special purposes. Every grating has spectra of different brightness on the two sides; and one should be used which is bright in the particular spectra desired. But more than this, even if the red of any one spectrum is bright, the violet may not be. This fact must be especially noted in working beyond the visible spectrum. Further, the various parts of the grating, especially if it is concave, may give spectra of varying brightness. For instance, the second spectrum may be uniformly bright for all parts of the grating, while one end of the grating may give a bright third spectrum and the other end a faint one. This fact may be brought out by viewing the grating directly with the eye. It is only when extreme accuracy is wished and the overlapping spectra of different orders are to be used that this imperfection must be guarded against. Since a 10,000 grating has on the whole better definition than a 20,000 one, and as it is much cheaper, it is better to use one in all cases when possible. For use with the micrometer eye-piece, when, of course, ultra-violet spectra do not interfere, one can always be used.

It is only when work is to be done with the camera in the ultra-violet part of the spectrum that it becomes necessary to use a 20,000 grating. This is due to the fact that for the same dispersion with a 20,000 grating as for a 10,000, there are fewer overlapping spectra. The range of concave gratings mounted as above are as follows:

Lines per inch	1st Spectrum	2d Spectrum	3d Spectrum	4th Spectrum	5th Spectrum
10,000	Entire	Entire	Entire	To 6,000	To 4,800
14,438	Entire	Entire	To 5,760	To 4,330	To 3,460
20,000	Entire	To 6,000	To 4,000	To 3,000	To 2,400

These limits are taken at the *center* of the photographic plate. At the end of the plate the limit is somewhat greater, being 6,260 in the second spectrum for a 20,000 grating.

With a grating of 21.5 feet radius the width of the spectrum varies from ¼ in. to 4 in. In the green of the 1st spectrum of a 20,000 grating it is ¾ in., and in the green of the 2d it is 2⅝ in. This gives an idea of the width of the photographic plate which is required.

The scale of the negatives in the various spectra, with gratings of 21.5 feet radius, is as follows;

	Scale of Spectra as compared with Angström's map.			
Lines per inch.	1st.	2d.	3d.	4th.
10,000	.26	.51	.77	1.03
14,438	.37	.75	1.12	1.50
20,000	.52	1.03	1.55	2.07

i. e., using a 20,000 grating in the third spectrum, the scale is 1.55. This means that 1.55^{mm} on the photographic plate includes 1 Angström unit. For gratings of 10 ft. radius, the scale is diminished in the ratio of 100 : 215, or 20 : 43.

Since with a concave grating all the spectra are in focus at the same time, it is important to know what wave-lengths of the different spectra are on the photographic plate or in the field of the eye-piece for any position they may be in. For this purpose I have given a diagram of the overlapping spectra on the plate. This explains itself: Wave-length 6,000 in the 2d spectrum coincides with wave-length 4,000 in the 3d spectrum, with wave-length 3,000 in the 4th spectrum, and so on. The vertical lines give the range of the different gratings as explained above.

If it is desirable to cut off any interfering spectrum, glass plates or absorbing solutions may be used. A list of the principal absorbents, and the parts of the spectrum which they *let through*, is given below.

Greenish plate glass	3,300–8,000
Salicylic acid in alcohol, saturated, in quartz cell	3,500–8,000
Aesculin, 1 gr. in 1 oz. water, with one drop of Ammonia—fresh,	4,100–8,000
Potassium ferrocyanide	4,400–8,000
Primrose or Anilide Yellow	5,000–8,000
Fluorescine or Chlorine of Gold	5,200–8,000
Chrome Alum, Malachite Green, Bitter-almond Green, Brilliant Green,	3,200–3,700 and 4,600–5,200
Cobalt Chloride	3,400–4,500
Gentian Violet, strong	3,600–4,600 and 6,000–8,000
Potassium permanganate	3,900–4,600 and 5,800–8,000

For example, using a 10,000 grating and photographing in the 4th spectrum, the following absorbing solutions are used at the places specified:

At 3,800	Cobalt Chloride in water.
4,000	Cobalt Chloride or Gentian violet in water in glass cell.
4,200	Potassium permanganate or Gentian violet in water.

4,400	Aesculin and Potassium permanganate.
4,600	Aesculin.
4,800	Aesculin and Malachite Green in water.
5,000	Aesculin and Potassium ferrocyanide.
5,200	Aesculin and Potassium ferrocyanide.
5,400	Aesculin and Primrose.

Before using a solution an observer should always see, by a preliminary experiment, what its effect is.

Methods of Work.

A spectroscope is used for two purposes, to measure the lines in solar or metallic spectra, or to establish coincidences simply. For both of these the concave grating is far superior to any other on account of the overlapping spectra.

The micrometer eye-piece, of course, can be used only in the visible spectrum, while the methods of photography give us this and the invisible too. Rowland's micrometer eye-piece, as noted above, has a run of five inches, and so it can include a great number of lines. When a metallic spectrum is to be measured, the solar spectrum is turned on; a series of measurements is taken; then the solar spectrum is replaced by the metallic; another series is taken; and finally the series of solar lines is observed again. All this is done without the observer leaving the eye-piece. The solar lines are found on Rowland's map, and then the wave-lengths of the metallic ones are deduced by interpolation. This same method of interpolation will also give the relative wave lengths of the solar lines using the over-lapping spectra. The probable error of a wave length determined this way is ±0.01 Angström unit.

Now that we have Rowland's map and his list of solar lines, the photographic process for the measurement of metallic spectra is generally used as far as the erythrosin plates extend or to the *D* line, although those expert in the use of cyanine plates may photograph below *C* or even *A*, as Mr. Burbank has shown in the *Phil. Mag.* for Oct., 1888.

Owing to the astigmatism of the grating, it is not possible to adopt the usual method of illuminating part of the slit with the solar image, and part with the spark or arc; and so a different and far better plan is adopted. A compound photograph of the two spectra is taken in the following manner: The brass plate on the back of the camera-box (see Fig. XIV) is placed vertical, the solar spectrum is photographed along the middle of the sensitive plate, the sun-light is turned off, the brass plate is revolved through 90°, and the metallic spectrum is allowed to fall along the upper and lower parts of the photographic plate.

Then finally the sun-light is turned on again along the middle of the plate. If there has been any gradual displacement of the camera during the operation, the error is eliminated by this process, if the two times of exposure to the solar spectrum are the same.

It is important to notice that record must in all cases be kept of thermometer and barometer readings; for the corrections due to variations in temperature and pressure may be considerable.

Since no absorbing solution is known which lets through the ultra-violet rays alone, the following method has to be used to determine what lines on any negative are ultra-violet ones. A compound negative, as just described, is taken, having all the overlapping spectra at the point in question along the middle of the plate and the visible lines alone, obtained by inserting absorbents, along the top and bottom. Those lines present in the first and not in the second are then ultra-violet ones.

For arc or solar light, five minutes exposure is the average time required for the most sensitive part, in the third spectrum on plates registering 18 on Warnerke's sensitometer. Ten minutes are required above the *D* lines in the second spectrum using erythrosin plates. One hour is needed for cyanine plates, photographing down to the *C* line. As a practical example, the entire iron and solar spectra were photographed in the second and third spectra from the *D* lines down to the extreme ultra-violet in nine hours. This includes time spent in developing. Thirty plates, each 19 inches long, were exposed, giving, of course, many duplicates. Only 10 plates are necessary in the 2d spectrum of a 20,000 grating for the whole spectrum from the *D* line to the extreme ultra-violet, wave length 2,000. In one case Liveing and Dewar used 170 plates for the ultra-violet spectrum alone.

With the powerful induction coil, worked by a Siemens alternating dynamo, with six gallon Leyden jars, 10 minutes is enough in the most sensitive part and 30 in the extreme ultra-violet, wave length 2,200.

A compound negative taken in the above manner is placed on a dividing engine; the pitch of the screw being one w. l. on the negatives and measurements are made on the lines of the two spectra, using a low power microscope with a single stretched cross-hair. Since the solar spectrum continues down to 3,200, the same orders of the two spectra can be compared thus far. Beyond this it is necessary to use different orders. For instance, wave length 2,800 in the 3d spectrum can be compared with solar lines about wave length 4,200 in the 2d. This same method is used to determine the relative wave lengths of the solar spectrum.

To enlarge photographs with a scale of wave-lengths, like Rowland's map of the spectrum, one must proceed as follows:

To make the scale, a thick plate of glass, slightly longer than the negative, is albuminized and treated with collodio-chloride. It is then put in any developer until it turns black. A longitudinal strip of the width of the negative is scraped off; and on the edge of this strip the scale is ruled with a dividing engine. The negative is clamped in place to this scale, and together they are put in the enlarging camera. The accuracy with which the scale can be made, and the negative fitted to it is most satisfactory. On Professor Rowland's new map the greatest error is .03 of an Angström unit; and the probable error is less than .02 of a unit. If the scale is, say, .0001 too large or too small, the photographs can be made to fit the scale by altering the distance between the grating and camera-box by .0001 of its amount, and then focusing by moving the slit in or out.

When this scale is once made, it can be used to give direct readings for the wave-lengths of the lines on any negative, simply by placing the negative on the scale.

A word should be said as to the difficulties of ruling gratings which may explain why so many orders for gratings remain unfilled. It takes months to make a perfect screw for the ruling engine, but a year may easily be spent in search of a suitable diamond point. The patience and skill required can be imagined. Most points make more than one "furrow" at a time, thus giving a great deal of diffused light. Moreover, few diamond points rule with equal ease and accuracy up hill and down. This defect of unequal ruling is especially noticeable in small gratings, which should not be used for accurate work. Again, a grating never gives symmetrical spectra; and often one or two particular spectra take all the light. This is of course desirable, if these bright spectra are the ones which are to be used. Generally it is not so. It is not easy to tell when a good ruling point is found; for a "scratchy" grating is often a good one; and a bright ruling point always gives a "scratchy" grating. When all goes well, it takes five days and nights to rule a 6 in. grating having 20,000 lines to the inch. Comparatively no difficulty is found in ruling 14,000 lines to the inch. It is much harder to rule a glass grating than a metallic one; for to all of the above difficulties is added the one of the diamond point continually breaking down. For this reason, Professor Rowland has ruled only three glass gratings. One of them has been lost, and the other two are kept in his own laboratory. These two were used by Dr. Bell in his determination of the absolute wave-length of the *D* lines.

ON THE PHOTOGRAPHIC METHOD OF DETERMINING STELLAR PLACES BY TRANSITS FREED FROM THE ERROR OF PERSONAL EQUATION.*

PROFESSOR FRANK H. BIGELOW.

Some accounts of the preliminary experiments looking to the elimination of the error of personal equation from star transits by employing a photographic registration of the passage of the star over the reticle of the transit instrument, have already been published by those who have been engaged upon the work. Professor Pickering in the Memoirs of the American Academy, Vol. XL., p. 218, describes his breaking up a smooth star trail by alternating motions imposed upon a bit of photograph plate, and shows that by means of an auxiliary micrometer the instants of time can be determined in general to about 0.03 of a second. Mr. Willard P. Gerrish has described a commutator in THE SIDEREAL MESSENGER of October, 1889, by which the standard clock of an Observatory is enabled to give the required alternating motion to this plate, the duration of exposure in any position being regulated automatically. The Rev. Fr. Fargis, assistant in the Georgetown Observatory, has published in a paper on the subject, entitled "The Photochronograph and its Application to Star Transits," a description of the form of instrument devised and adopted by him in determining the places in right ascension of a zone of the bright stars. My own contribution to this subject consisted in a series of experiments at the Harvard College Observatory in the summer of 1889, by which the star was successfully referred to the collimation axis of the telescope, using photography alone, the first complete transit being thus obtained. Since that time I have been interested in reducing the method to a practical form, and upon introducing the subject to Mr. G. Saegmuller of Washington, and Rev. Fr. Hagen, Director of the Georgetown College Observatory, was encouraged by substantial coöperation on their part in the construction and use of the pre-

---

* Read before the Washington Philosophical Society.

liminary forms of apparatus. Without going further into any detailed description of the apparatus than can be found in the papers above mentioned, it is my purpose to give a summary of the present status of the process as an art, and to discuss briefly the main points that seem to have been brought out conspicuously in the course of experiments.

There are two different modes of making the record of the star transit as referred to the instants of time indicated by the clock, and one method of inscribing the transit upon the reticule of the telescope. In order to clear the ground for the discussion involved in a comparison of the two ways of operating the plate, it may be said that the reference of the recorded instants of time to the collimation axis of the telescope is accomplished by illuminating the field of the telescope for two or three seconds, by means of a bright light held in front of the object glass. The action of this light is to fog down the whole exposed area of the plate very uniformly, with the exception of the spaces lying behind the reticle threads, which appear upon development to have definite edges, suitable for the setting of a micrometer thread. These boundary lines, being shadows cast by rectilinear rays of light, are much sharper than the trails produced by the moving image of the star. For simplicity and accuracy nothing can be desired in this regard, and my plates produced in Cambridge by this process are excellent. At first it was supposed that rather thick threads would be needed to cast this shadow, but I soon found by trial, as was done in exposing some plates on the large meridian circle of the Observatory and also on the small Russian Transit, that the ordinary glass ruled reticles were suitable, thus disposing of the necessity of making special reticles and also of the danger of breaking the threads, as is likely to happen during operations in the dark. The photographic plate is, of course, to be placed as near the plane of the reticle as is convenient, but experiment showed that a considerable range is permissible without introducing any blurring of the edges, which would be caused by the light coming from the sides of the object-glass if the plate was located at any great distance from the apex of the cone of rays.

The two methods already introduced for connecting the transit with the clock are as follows: 1, the alternating motion of the plate, perpendicularly to the trail of the star, through a small distance approximately that of the width of the trail itself, the effect being to cause a double row of dots to be seen upon the developed plate; and 2, the alternate exposure and occultation of the star trail by means of a bar moved in obedience to the clock, the result being a series of dots along a single star trail. The former method was devised by Professor E. C. Pickering, and the latter was adapted by Fr. Fargis, having been used for similar purposes during many years in Kew Magnetographs, and in other instruments for physical measurements.

The occulting bar method is fully described and illustrated in the Monograph of the Georgetown Observatory already referred to, but in order to bring into comparison with it the action of the alternating plate, I take the liberty of introducing an illustration with a short description of the way in which it was made. Each of these methods has such obvious advantages that it seems good to present them together in order that other workers in this field may have the benefit of our experience.

The illustration is an enlargement from a plate on which the diameter of the field of view is about 50*m.m.* The original plate was exposed in the small equatorial telescope, with uncorrected or visual lens, of aperture 6¼ inches and focal length 83¾ inches.

As the work was experimental all the arrangements were of the simplest kind, and this accounts for the crudities seen on the plate. The reticle was of silk thread drawn through holes in a small ring, which was secured to the end of the tail-piece by a bed of wax. The plate rested in a small paper holder, of utility chiefly in passing from the dome to the laboratory, and this was moved on a frame between two sets of abutting screws, through the narrow range exhibited in the photograph. The motion was communicated to the plate by the observer making and breaking the circuit in the current passing through the magnet which controlled the armature and frame, counting the beats of a chronometer, the armature being rigidly joined to the frame. There are endless mechanical combinations for this purpose, the only requisite in them all being that the plate move parallel to itself through the distance occupied by the breadth of the trail, and that it have no motion sidewise, a combination easy to secure by fine pivots or by a thin flexible spring. It should be stated here with emphasis that the only prime necessity is that this operation be *constant in its action*, inasmuch as the corresponding interval of time goes into the determination of the clock error and then comes out again upon applying the correction. In short, the main advantage of this system is to reduce the transit to certain constant mechanical errors, instead of to the fluctuating errors involved in the personal equation.

The star shown is α Aquilæ, Altair, 1.2 mag., selected for its advantage in reproduction for THE JOURNAL. There are several trails set at different altitudes: 1, an unbroken trail; 2, a trail alternating every second for an interval of two minutes; 3, a broken trail showing ten second intervals unbroken, or broken into seconds; and 4, a broken trail showing ten and twenty second intervals.

I will state at this place that from my knowledge of the ability of this work to record a star transit relatively to any chosen thread in the telescope, that the *error need not exceed one hundredth of a second of time*, so far as the transit is concerned, and that it is *wholly free from personal equation*. Of course the final resulting place of the star as reduced to any epoch, will contain the errors arising from the performance of the clock and from the determination of the level, azimuth and collimation of the instrument. We are not now concerned with the variations arising from these sources, but we are aiming to show that the position of the star relatively to the reticle can be accurately determined. A mere inspection of the situation suggests that the position of the star in declination admits of an equal degree of precision in discussion. When the fluctuating motion of the star is considered, caused by the movements of the atmosphere, whereby it is literally tossed about, also the fact that in any transit observed in the usual manner the setting is made upon some momentary position, the advantage of such a permanent record across the whole field must add greatly to our resources in dealing with the subject.

In the original plate the motion was controlled by the observer's hand, but a commutator can be constructed with several combinations of second intervals that will operate automatically from the standard clock. Mr. Gerrish has such an one at the Harvard College Observatory which works excellently. In principle it consists of a finger resting on the surface of a copper disc or set of discs, which jump forward one notch by the clock each second, the disc having insulated spaces of greater or less length, so that the finger makes or breaks the circuit for the interval that it rests upon a copper or a rubber space respectively. The action is steady and follows the clock with precision. It will be seen that the use of such an arrangement is necessary, because otherwise the work will be confined to an equatorial belt, if the intervals are limited to the second breaks of the standard clock.

The advantages possessed by the use of the alternating plate can be summarized as follows: 1. It secures the full value of the star trail as an actinic effect, its brightness not being obscured during the transit. Inasmuch as the photographic process is ineffectual below the stars of 4° magnitude near the equator, in small telescopes, this is important. If stars are taken nearer the poles by means of the commutator, the fainter stars may be called into use, as their slower motion will give the requisite trail, the time observation being compensated in the ratio of the secant of the declination. 2. The action of the clock marks sharply the instant it breaks, one interval being ended and the other begun. The photographic spreading of the light is in opposite directions, but unobstructed, so that the instant is not transferred along the line by any changes in the battery or the auxilary apparatus. Thus the breaks follow the clock absolutely. If the breaks were made upon a single line, one of two results must happen, as in the case of the occulting bar; either the interval of exposure must be very short with reference to the occulted interval, on account of the spreading of the photographic image in the film, as for example, one-tenth to nine-tenths of a second; or else the trail ends will blurr into each other so as to become useless. If an exposure is a small fraction of a second, the number of stars whose brightness is available will be considerably diminished near the equator, and also it will be impossible to extend the method towards the poles, because the angular motion of the star shortens up so much that tenth-second exposures unite with one another. This is a serious disadvantage inasmuch as the bright stars of this region are omitted from the determination of instrumental errors, and also from the final and resulting catalogue.

The advantages of the occulting bar have been carefully enumerated in the Georgetown paper. They are: 1, the extreme simplicity and the lightness of the apparatus, these qualities obviously being at a maximum; 2, the fixed position of the photographic plate during the making of it.

There are certain disadvantages inhering in each system, some of which are common to both and others which are peculiar to one or the other method: 1, the objection arising from the so-called photographic parallax, or blurring of the edge of the reticle lines by the action of the light in passing from the reticle to the plate, has been stated as belonging to the alternating plate, but it is common to both, if it exists at all, because this distance is so small that the angular aperture of the telescope transferred from the photographic focus to the plate represents an infinitesimal linear distance upon it, and also being symmetrically distributed does not shift the center of the image of the thread; 2, the partial obliteration of the trail, said to be produced in the illumination of the object-glass unless covered by the occulting bar, was never seen to exist in the work at Cambridge, but it was always supposed that the general face of the plate and the star trail itself both advanced a little in density during the operation, so that the original contrast in color, would persist. In short I never found that a long illumination, up to nearly the point of blacking the plate, as compared with a very brief one, tended to obscure the star trail. Certainly in practice there is no danger of losing a trail by this fact. On the other hand it would seem to be advantageous to retain the impression of the horizontal threads, and it will be necessary to do so if the work is to include, as it ought, the determination of the star place in declination as well as in right ascension.

The objection arising from changes in the action of the battery, the springs and the moving parts of the apparatus, or the variable component of the force of gravity, would at first sight seem to be against the alternating plate on account of its weight, and in favor of the occulting bar on account of its lightness. But it is quite otherwise. The weight of the moving part consists of a bit of thin glass one inch square, and of a light metallic frame to hold it, which rocks on pivots or a piece of spring, since by using a ruby light in the observing room the plate box can be abandoned. My first plate holder consisted of a folded piece of black paper; we afterwards tried metalic holders in Washington, but I should advise the use of none. With a much heavier plate-holder at Cambridge, and using two Daniell's cells, I never found any trouble arising from this cause.

By recalling the action of the break on a chronograph the point I have to make will be evident. The *beginning* of the break is always sharp and constant, responding to the clock precisely; the *length* of the break varies, depending upon the battery, the spring and friction. The alternating plate uses the beginning of the motion only for its point of reference; the occulting bar uses the dot produced by the total break, and since the micrometer thread is set into the middle of this dot, its position relatively to the beginning of the clock beat is clearly a function of the motion involved. My opinion is that very little practical value adheres in this objection as against either form of apparatus, but the theoretical objection is not against the alternating plate.

The question will finally be settled by a comparison of the validity of two main difficulties that have already been mentioned.

The first point raised by one who looks into the apparatus used in the alternating method is that *the plate moves.* There is one reply that covers the ground. The plate moves, but it moves in a *constant fashion*, and whatever that motion may have been, the reticle is thrown down upon it accurately, so that the micrometer measures take up all the movement that may exist. It will have to be shown that the mechanical operation of the plate, through the space of three-tenths of a millimeter, is a *variable* action before the objection becomes valid. I have seen no reason to suspect it in the apparatus that I employed.

It is this objection that will have to be offset against the tenth of a second exposures used in the occulting bar process. Increasing the exposures to nine-tenths of a second, as can be done, will blur the series of dots into one line so that the setting of a micrometer thread cannot be made upon the clock intervals. To vary the exposure from one-tenth to two, three or four-tenths of a second, will shift the time of a transit along by half the variation of the interval, and this cannot be measured accurately. To change in any other manner involves the use of a commutator as above described. Not to make these variations is to limit the work to the equatorial belt of stars, at the sacrifice of the polar regions for all purposes. At present I see no way of escape from using the alternating plate and commutator, or limiting the work so far as to fail in its complete development.

We have only space to enumerate, but not to discuss, some definite advantages of the photographic transits, by whatever methods they are taken :

1. The general accuracy of the transit itself is well known to all who have operated with the method, the average error being about one-hundredth of a second.
2. The freedom from a variable personal eqation is unquestioned.
3. The permanence of the record of the transit, as compared with fleeting vision of the star that has passed over the field, not only enables a complete discussion of the event, but a comparison of the transits of the samestar at widely different epochs.
4. The superior accuracy of each transit involves a much more rapid approximation to the true result, than by the method of taking the mean of many inferior observations. As the precision increases the necessary cost of observation and computation will diminish.
5. It is obvious that the application of this method to the determination of Longitudes has decided advantages. The clock at one station will beat the breaks of the chronograph at each station and also the star transit, all at the same time. By alter-

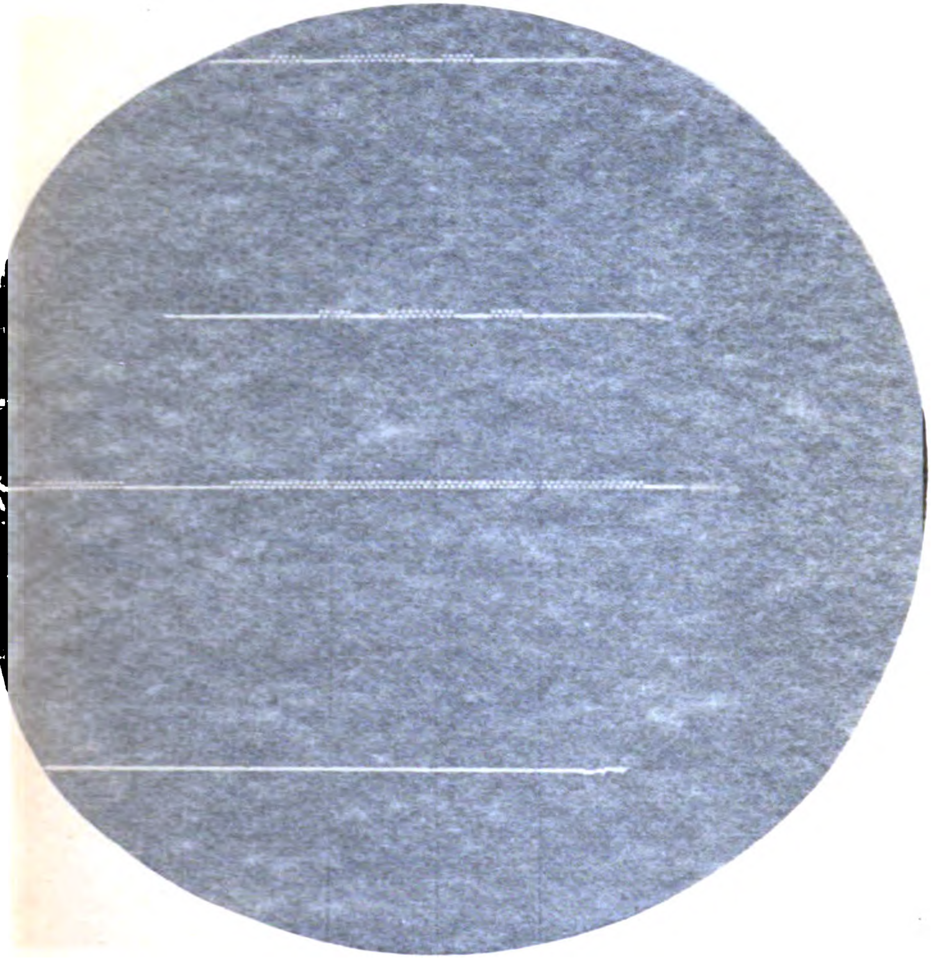


Plate Accompanying Professor Bigelow's Paper on the Photographic Method of Determining Stellar Places by Transits Freed from the Error of Personal Equation.

[illegible] The plate moves, but it moves in a [illegible] whatever that motion may have been, the [illegible] on it accurately, so that the micrometer [illegible] the movement that may exist. It will [illegible] the mechanical operation of the plate, [illegible] tenths of a millimeter, is a *variable* ac- [illegible] becomes valid. I have seen no reason to [illegible] that I employed.

[illegible] it will have to be offset against the tenth [illegible] used in the occulting bar process. Increas- [illegible] nine-tenths of a second, as can be done, will [illegible] into one [illegible] that the setting of a micro- [illegible] clock intervals. To vary [illegible] one-tenth to two, three or four-tenths of a sec- ond [illegible] transit along by half the variation of th [illegible] this cannot be measured accurately. To change in any other manner involves the use of a commutator as above described. Not to make these variations is to limit the work to the equatorial belt of stars at the sacrifice of the polar regions for all purposes. At [illegible] I see no way of escape from using the alternating plate [illegible] commutator, or limiting the work so far as to fail in [illegible] development.

We have only [illegible] enumerate, but not to discuss, some [illegible] photographic transits, by whatever [illegible]

[illegible] accuracy of the transit itself is well known to [illegible] with the method, the average error being [illegible] of a second.

[illegible] from a variable personal eqation is unques- [illegible]

[illegible] of the record of the transit, as compared [illegible] of the star that has passed over the field, [illegible] a complete discussion of the event, but a com- [illegible] transits of the same star at widely different epochs. [illegible] accuracy of each transit involves a much more [illegible] to the true result, than by the method [illegible] of many inferior observations. As the precision [illegible] necessary cost of observation and computation will [illegible]

[illegible] obvious that the application of this method to [illegible] of Longitudes has decided advantages. The [illegible] at [illegible] the breaks of the chronograph at each [illegible] transit, all at the same time. By alt [illegible]

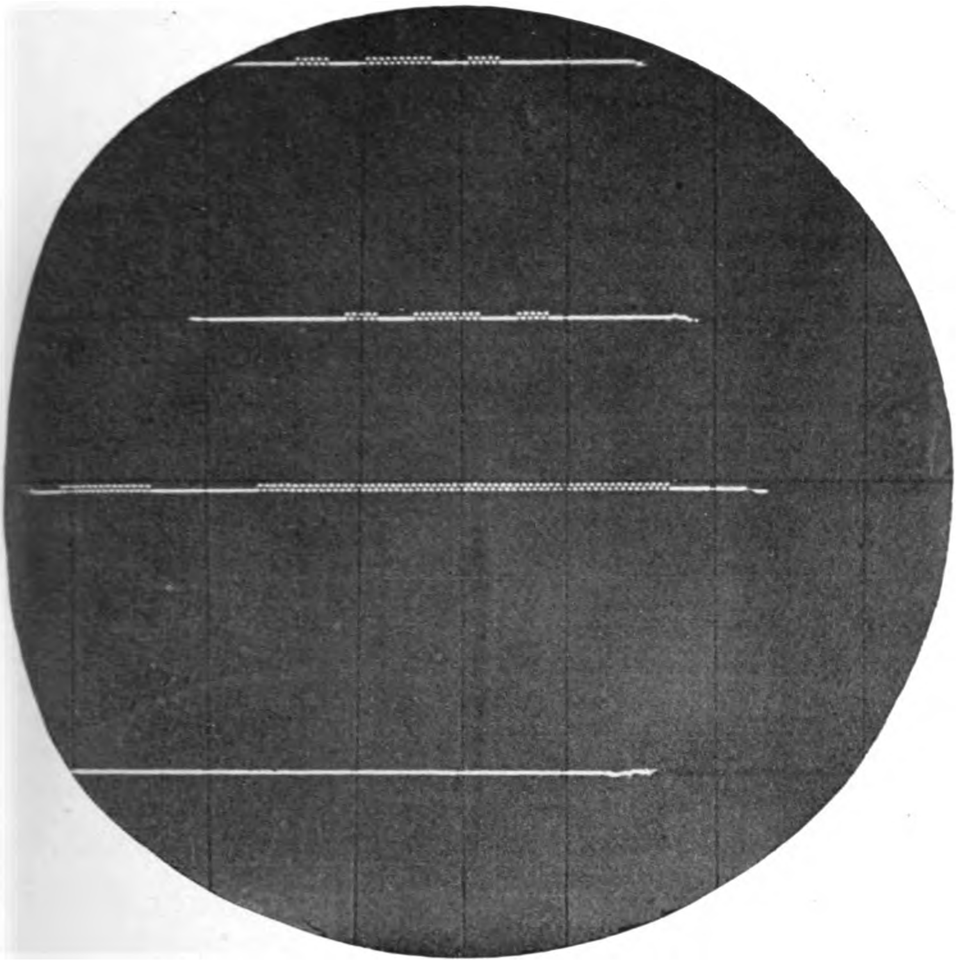


PLATE ACCOMPANYING PROFESSOR BIGELOW'S PAPER ON THE PHOTOGRAPHIC METHOD OF DETERMINING STELLAR PLACES BY TRANSITS FREED FROM THE ERROR OF PERSONAL EQUATION.

nating the clocks of two stations in this way a most interesting result should be obtained.

6. In determining the variablity of latitudes it will be only necessary to take the star trail of a zenith star, the time being marked by the clock beats, referring the same to a series of horizontal reticle threads. A comparison of a set of such plates taken throughout a year should give a strong hold upon the problem. The principal advantage is that the variations of the atmosphere, and the tossing about of the light of the star, is recorded accurately, the whole case being completely taken down at each exposure.

7. Finally a catalogue of bright stars in both right ascension and declination, for use in connection with the photographic charts of the heavens will be very important. The comparability of the ways in which they are both produced, will make their fitness for each other recognized at once.

8. There are many meridian circles of the older patterns which might readily be turned to such work as that suggested above, since their object glasses will give satisfactory results, as has already been demonstrated. The prime requisite is practical skill in producing the results, the first cost in money being insignificant.

This subject is, therefore, cordially commended to the attention of such as have time to bestow upon these most promising astronomical investigations.

WASHINGTON, NOV. 20, 1891.

ON THE ABSORPTION OF HEAT IN THE SOLAR ATMOSPHERE.*

W. B. WILSON, M. R. I. A., F. R. A. S.

The author endeavors to determine with accuracy the ratio of the heat received from the limb and the center of the solar disc, and thus by taking yearly observations through a sun-spot cycle, to find out if the solar atmosphere varies in depth.

The apparatus consists of a heliostat which throws a small pencil of sunlight into a dark room. It is received on a 4-inch concave silver-on-glass mirror of about 10 feet focus. A small convex mirror is placed inside the focus of the concave mirror, and thus forms an image of the sun of 80 centimètres in diameter. This image is allowed to fall on a radio-micrometer of Pro-

---

* Communicated by the Author.

fessor C. E. Boys. The tube of the instrument is stopped down to nearly 1 mm. in diameter, so that only about $\frac{1}{500000}$ part of the solar image is at any moment giving its heat to the instrument.

A slice of lime-light is allowed to fall on the mirror of the radio-micrometer, and is reflected from it on to a horizontal slit in the side of a box which contains a photo-plate. This plate during an observation is allowed to fall with a uniform rate by a piece of clock-work. Any motion of the mirror of the radio-micrometer thus records itself on the plate in a curved line.

The clock of the heliostat is stopped and the image of the sun is allowed to transit across the mouth of the radio-micrometer, and the curve giving the values of the heat received from the solar disc is recorded on the photo plate.

A seconds pendulum swings across the track of the limelight, so that the photo curve is notched into seconds of time, and a means is thus given of localizing the position of the instrument on the solar disc.

THE ULTRA-VIOLET SPECTRUM OF THE SOLAR PROMINENCES.*

GEORGE E. HALE.

In various papers published during the past year I have called attention to some of the advances in our knowledge of the Solar Prominences which might be expected to follow the application of photographic methods to a study of their forms and spectra. The August number of the *American Journal of Science* contains reproductions of some photographs obtained in the course of my investigations on this subject at the Kenwood Astro-Physical Observatory. I am indebted to Professor Lockyer for the use of a measuring machine during a recent visit to London, and I am now able to give my determinations of wave-length for the new prominence lines, and some conclusions to be drawn from them. But perhaps it will first be well to consider for a moment the apparatus and methods at present employed in the work.

To the eye-end of the 12.2-inch equatorial refractor of the Kenwood Observatory a large solar spectroscope is rigidly attached by three steel tubes, and as the spectroscope extends about five feet beyond the focus of the telescope, the declination axis is

---

* Read at the Cardiff meeting of the British Association for the Advancement of Science, August, 1891.

placed at the center of the combined lengths of the two instruments, in order to reduce the amount of counter-balance required at the object-glass end. The result is very satisfactory, and there can certainly be little fear of flexure in the combination. The whole spectroscope may be rotated by a rack and pinion, so as to make the slit tangential or radial at any point on the Sun's limb. The object-glasses of the collimator and observing telescope have 3¼ inches clear aperture, and 42½ inches focal length. The 4-inch Rowland grating is ruled with 14,438 lines to the inch, and as the telescopes make with each other a constant angle of 25°, different orders of spectra are brought into the field of view by rotating the grating. A diagonal eye-piece at the end of the observing telescope allows the spectrum to be observed after the photographic plate is in position.

In photographing the spectrum of a prominence the following is the ordinary process. Let us suppose that it is desired to use a radial slit, in the H and K region of the spectrum. The C line in the second order is brought into the field, and while observing this line the spectroscope is rotated until the slit is radial at some point on the limb where a prominence is seen. The driving-clock is then started, and the telescope clamped, so that the sun's image is kept as nearly as possible stationary on the slit plate. A small strip of metal, pushed in just behind the slit, excludes the direct solar light, except from a small region near the limb. The whole collimator is next moved by a screw until the slit is brought to the proper focus of the equatorial for K, and the collimator and observing telescope are set at the focus for the same line, the positions being taken from a table of foci, determined by experiment, for the principal lines in the spectrum. After placing the sensitive plate in position, the grating is rotated until the K line in the fourth order is in the middle of the field, the slit is covered, the slide drawn, and the proper exposure given. The exposure of course depends upon the aperture and focal length of the equatorial, the width of the slit, the brilliancy of the grating, the sensitiveness of the plate, etc., but with the ordinary dry plate of sensitometer No. 23 furnished by the Seed Company, and a slit about 0.001 inches wide, I usually find that an exposure of from 20 to 30 seconds gives the best result.

For the first time without an eclipse the prominence spectrum was thus photographed early in April of the present year. The only bright lines then obtained were found to fall nearly at the centers of the dark bands H and K of the solar spectrum, but these were remarkably strong, seeming to fully equal C in intensity, and were present in every prominence photographed. Work was continued on the violet and ultra-violet for some weeks, but with the exception of some lines which had all the appearance of ghosts of the brilliant H and K reversals, no new lines were discovered until June 23, when an exceptionally bright prominence was found. This gave four lines in the ultra-violet, and the least refrangible of these was found to be double. A line slightly less refrangible than H, nearly but not quite at the position where the first ghost would be expected to fall, was much stronger than any of the other ghosts, and it seemed very possible that it was an independent line. This prominence remained visible for several days, and a number of photographs of its spectrum were made with both radial and tangential slit.

In reducing the wave-lengths of these lines it might be considered easy to obtain values for a given line agreeing closely in the hundredths place of tenth-meters, but two causes have combined to lessen the accuracy of determinations. The H and K reversals almost invariably show some indications of motion of the prominences in the line of sight, and the consequent distortion renders somewhat difficult the proper setting of the spider line of the measuring machine. Again, the plate-holder used was made for another purpose, which required that the plane of the plate should be at right angles to the axis of the observing telescope. As the object-glass of the telescope is corrected for the visual region, it is evident that near K there must be a slight change in focus from one side of the plate to the other, and a small error is thus introduced. It will be seen, however, that the measures are sufficiently accurate to allow very little doubt as to the identity of most of the lines. The fact that the solar spectrum, due to the diffuse light of the atmosphere, is photographed simultaneously with the prominence spectrum, is of great advantage in determining the position of the prominence lines, though it has a corresponding disadvantage in concealing very faint lines, which would otherwise be brought out. The wave-lengths of certain standard lines in the solar spectrum have been taken from the list published by Professor Rowland,* and it has thus been easy to find the wave-lengths of the prominence lines by simple interpolation. The value of the micrometer screw has been determined for several regions on every plate by measuring the positions of properly distributed standard lines, the number of separate settings of the spider line in each case ranging from five to fifteen, depending upon the character of the line measured. In the following table

---

* "Amer. Jour. Sci.," 1887, p. 182.

the first column contains the wave-lengths of the ultra-violet prominence lines; the second the positions assigned by Ames to lines in the hydrogen stellar series; and the third, the wave-lengths of the calcium lines at H and K, which Professor Rowland has been kind enough to furnish in advance of publication. I am informed that they are provisional only, but may be relied on to within 1 or 2 in the last place of decimals. In the case of hydrogen, Ames considers that the error in any wave-length cannot amount to more than 0.05 of a unit,* and my own values for the prominence lines must possess about an equal degree of accuracy. In the fourth and fifth columns I have added Cornu's measures of the hydrogen lines,† and Dr. Huggins' wave-lengths of lines in the hydrogen stellar series,‡ both reduced to the scale of Rowland's map.

Prominences. Hale	Hydrogen. Ames.	Calcium. Rowland.	Hydrogen. Cornu.	First Type Stars. Huggins.
3968.56	...	3968.61 (H)	...	...
3933.86	...	3933.80 (K)	...	...
3888.73	...	...	...	...
3970.11(?)	3970.25	...	3969.6	3969.6
3889.14	3889.15	...	3888.5	3888.2
3835.54	3835.6	...	3835.1	3834.6
3798.1	3798.0	...	3797.5	3795.6
3770.8	3770.7	...	3770.0	3768.1
...	3750.15	...	3749.9	3746.1
...	3734.15	...	3734.2	3730.6
...	3721.8	...	3721.1	3717.9
...	3711.9	...	3711.1	3707.9
...	...	...	...	3699.4

Let us first consider the prominence lines which lie near the centres of the broad dark shades at H and K. In his observations of the chromosphere and prominence spectrum at Mount Sherman, in 1872, Professor Young succeeded in seeing these reversals in a number of cases, but the character of the bright lines could not be made out, and it was considered probable that the broad dark bands were included in the reversal, only the brighter central portions, however, being strong enough to affect the eye. We now find, on the contrary, that the substance producing the bright prominence lines may possibly be entirely distinct from that causing the broad bands in the solar spectrum, for though the lines certainly do lie near the centres of the bands, they are narrow and sharp, and it is easily conceivable that their position may be simply the result of chance, though perhaps probability would point the other way. We are hardly in a

---

* "Phil. Mag.," July, 1890, p. 49.

† "Journal de Physique," [10] V. (1886)

‡ "Phil. Trans." Part II., 1880, p. 669.

position to discuss the cause of the unique appearance of the dark H and K bands, but it may be that we may learn something in this connection from Dr. Huggins' important investigations of stellar spectra. It will be remembered by everyone that in his memoir "On the Photographic Spectra of Stars" communicated to the Royal Society in 1880, Dr. Huggins arranged the stars observed in a series, in which the principal criterion of position was the character of the K line. In Arcturus, for instance, this line is broader and more diffuse than in the sun itself, while in Sirius it has narrowed down to a fine, sharp line. Other stars give intermediate breadths, and in some instances it has entirely disappeared. In the case of H the question is complicated by the fact that hydrogen and calcium possess lines which form a close double at this point, so it is best to consider only K. From the variations of this line it will be seen, apart from the interesting subject of stellar evolution so evidently suggested, that the narrow dark line at the centre is very possibly produced by the same substance which, vibrating under different conditions, causes by its absorption the broad dark band.

As the central dark line is known with a high degree of certainty to be due to calcium, it becomes likely that the band is due to the same substance, and as the central dark line of H is also a calcium line, it might perhaps be safe to attribute the H band to the same metal, though in neither case is it well to be too positive in the assertion, for it is somewhat peculiar that the bands and lines appear together in the solar spectrum. If the same substance produces both, and each requires different conditions, possibly of temperature or pressure, for its production, these conditions must presumably exist at different elevations above the photosphere.

The question now arises whether the bright lines in the prominence spectrum agree in position with the dark lines at the centres of the H and K bands. Only one or two of my prominence spectra happened to be given the proper exposure to bring out both the bright and dark lines, but in these the coincidence is fairly satisfactory. I have not as yet, however, been able to obtain the wave-lengths of the dark lines in hundredths of a tenth-metre, but Professor Rowland's determinations of wave-lengths for the corresponding calcium lines will answer nearly as well. These have been given in the third column of the table of wave-lengths. It will be seen that in the case of H the prominence line is 0.05 tenth-metres more refrangible, while at K the prominence line is 0.06 tenth-metres less refrangible. Professor Rowland considers his values correct within 1 or 2 hundredths tenth-metres, while the probable errors in the position of the prominence lines, deduced on the assumption of equal weights for the wave-lengths given by each of six plates, are 0.021 and 0.036 tenth-metres for H and K respectively. On the whole, then, there can be little doubt that these prominence lines are due to calcium, and are therefore probably true reversals of the central dark lines of the H and K bands.

It will be of interest next to consider briefly the character of these two prominence lines. In all cases they are quite narrow and sharp, except when motion in the line of sight has produced broadening or distortion. In seven photographs made with a radial slit both lines gradually become narrower as the distance from the limb increases, and have a pointed appearance. This might be due to an actual decrease in the width of the lines, but, as there is usually a certain increase of intensity toward the limb, the effect may be purely photographic. In several plates, however, there is so little change of intensity that the widening can hardly be due to this cause. The arrow-head appearance, so frequently seen with the C and F lines, is often shown when the slit is radial. A rather curious appearance has been found on three plates made with radial slit, and in the two which best show the effect there is a very sudden decrease of intensity in the upper part of the lines. Instead of becoming narrower toward the top, the lines seem to expand symmetrically on either side, and the edges become hazy and indistinct. As in the case of the pointed lines, there is also an expansion toward the limb, but here the edges are clearly defined. The arrow-head appearance is shown in two of these plates. With a tangential slit two plates show the lines expanded at the ends, and in one plate they are pointed. Though in most cases the forms of H and K are very similar, there is a single instance where K is shown sharply double in the fainter portions at each end of the line, and at one end the components seem to diverge slightly. That this is not the result of poor focusing is attested by the sharpness of the lines in the background of solar spectrum; at the same time the appearance is hardly that of an ordinary reversal. One further peculiarity will show that it is safest, for the present at least, not to draw any conclusions from such appearances as have been noted. In a certain position of the mirror of the measuring machine the illumination was such that the edges of the radial black lines appeared bright, while the Fraunhofer lines of the solar spectrum were also bright, as with ordinary illumination.

One of the negatives, in which H and K were broader and fainter at the top, brought out the effect particularly well. The central dark line extended two-thirds of the distance to the top of the prominence, and in the upper part it was excessively narrow and delicate. Lower down it gradually widened, until at a point very near the limb the widening became much more rapid, and at the limb itself the line was nearly as wide as when seen under ordinary conditions.

A paragraph from Dr. Schuster's report on the results obtained with the spectroscopic cameras at the total eclipse of August 29, 1886, seems to refer to a somewhat similar appearance. Speaking of the photographs of the coronal spectrum, Dr. Schuster remarks*: "A bright line shows black on the negative, and is bounded on both sides by an apparently lighter background. This is a well-known contrast effect. The H and K lines, for instance, seem to be surrounded by a lighter band, which follows the contour not only of the lines, but also of the wing by the side of the prominence. If, now, a Fraunhofer line happens to be by the side of a bright line, the contrast is strengthened, and both the bright and the dark lines appear more distinctly than they otherwise would. This is the only simple way in which I can explain some of the appearances of the photographs." The first part of the quotation is all that concerns us at present, for in the negative which I have mentioned as showing this peculiarity particularly well, the Fraunhofer lines are hardly visible above the limb, and none appear within the dark bands at H and K. As Dr. Schuster does not speak of the illumination, I assume that the appearance was generally seen, and this constitutes another point of difference. A penumbra formed by light reflected from the back of the plate would probably extend but little higher than the central line, but in the future plates backed with a dyed collodion film will be employed to obviate any effects of this kind. No entirely satisfactory explanation of the peculiar appearance of these lines has as yet suggested itself.

But on another point there is little room for doubt. The bright H and K lines certainly extend to a very considerable elevation above the sun's limb, and it is extremely probable that calcium is carried to the very top of the highest prominences. With the improved apparatus to be used in a continuation of this research, I hope to be able to ascertain the relative heights of various lines in the prominence spectrum. For in-

---

* "Phil. Trans." Vol. 180 (1889), (A.) p. 329.

stance, while a photograph is being made of H and K, the height of C in the same prominence can be measured with a micrometer. The comparative observations and photographs made up to the present time suggest the belief that calcium attains the highest elevations reached by hydrogen, and the remarkable brilliancy of H and K at the eclipse of 1882 attest the importance of calcium in the prominences. Dr. Schuster is of the opinion that the coronal spectrum contains calcium injected by the prominences, and this may only very gradually descend again to the level of the photosphere*. This supposition seems a very plausible one, and if it be at the same time considered probable that the H and K bands and their central lines are produced by the same substance, the possibility is suggested that the broad dark shades may be caused by the absorption of the cooler vapor at a considerable elevation, while the absorption near the photosphere gives rise to the narrow central lines. This view need not necessarily conflict with a belief in a shallow reversing layer, where absorption ordinarily takes place, for the H and K bands are unique in the solar spectrum. It rests, however, on somewhat insecure foundations, and cannot be credited with much weight.

On account of the dark shades at H and K it has proved quite easy to photograph prominence forms with an open slit. With other prominence lines the brilliancy of the background is much increased when the slit is opened, but this is not the case with H and K, and it is often possible to use a slit nearly a quarter of an inch wide. The fourth order spectrum has been employed for this work, and the best results are obtained with an exposure of about one second. It is considered that great advantage will result from a material reduction of this exposure, as the disturbances in our atmosphere have as yet made it impossible to secure the finest details of structure.

It is of interest to note, however, that the first photograph ever taken of the rapid development of a prominence was made in this way by my assistants on July 8, 1891, at 23^h 55^m Chicago M. T. As at first observed through C, the prominence was low, but very bright, and changing rapidly. A great tongue moved rapidly out to an elevation of about 80,000 miles, and at this time the extension was photographed through H and K. In fifteen minutes the prominence had returned to its original form. A reproduction of the photograph is given in the August number of the "American Journal of Science," and though much has been lost in the printing process, some idea of the actual appearance of the prom-

---

* "Phil. Trans." Vol. 180 (1889), (A.) p. 328.

inence may be gained.* A new apparatus for photographing the prominences is now being constructed as the outcome of my investigations on this subject, and this is expected to do away with many of the difficulties previously encountered. It will consist of two slits, moved in opposite directions across the ends of the stationary collimator and observing telescope by means of a peculiar form of clepsydra. The sun's image and photographic plate will be stationary, and the apparatus is thus to be constructed on the principle of the second method devised by myself in 1889, but so altered as to avoid the defects of the original scheme.†

Decision must be reserved for the present as to the line at λ 3970.11. The wave-length has been determined from four plates, but as the line is not far from where a ghost of H should fall, I cannot be certain that it belongs to the prominence spectrum. At the same time it is very much brighter than any other of the seven ghosts of H and K, and its position with respect to H is not symmetrical with that of the first ghost on the opposite side of this line, while in the case of K the ghosts are very regularly spaced. My assistants report that they were able to *see* H very plainly double in a brilliant metallic prominence observed July 27, and on several occasions Professor Young has made out the same thing. The agreement in wave-length with Ames' hydrogen line at 3970.25 is by no means satisfactory, and more observations and measures are required before a conclusion can be reached.

No one can doubt that the next four prominence lines are members of the well-known hydrogen series, for their agreement in wave-length with the values given by Ames is certainly very striking. Cornu's measures show considerable differences, as do also those of Dr. Huggins, but the small dispersion employed by the latter in this investigation must be borne in mind. There can be little question that Ames' wave-lengths are very near the truth, for they almost exactly correspond with those calculated by Balmer's formula. The measures of the prominence lines also serve to confirm them.

The remaining prominence line at λ 3888.73 has not been accounted for. It forms a close double with the hydrogen line at at λ 3889.14, and with it attains as great elevations above the limb as those reached by H and K. The character of the lines,

---

* See also Plate III.

† For previous papers on prominence photography see—"Technology Quarterly," Vol. III., No. 4, 1890. "Astronomische Nachrichten," Nos. 3006, 3037 and 3053. "Sidereal Messenger," June, 1891. "Amer. Jour. Sci.," August, 1891.

however, is quite different, for while the hydrogen line is wider, and slightly diffused the line at λ 3888.73 is very narrow and sharp. I have seen no statement that the hydrogen line has shown any signs of duplicity, and, as Mrs. Huggins has had the kindness to examine the corresponding line in some very sharp photographs of stellar spectra with the same result, we have reason to consider an independent origin probable.

The results so far obtained can only be regarded as preliminary, for with the improvements now being carried out in the telescope and spectroscope, and the much greater frequency of metallic eruptions as the maximum sun-spot period is approached, it is certainly to be hoped that many more lines will be photographed. The ultra-violet spectra of sun-spots have also been worked upon with some indications of success, and there will evidently be no lack of opportunity in the new and interesting fields thus opened to investigation.

LONDON, August 13, 1891.

NOTE ON THE CHROMOSPHERE SPECTRUM.*

PROFESSOR C. A. YOUNG.

With the new spectroscope of the Halsted Observatory, which has a 5-inch Rowland grating of 20,000 lines to the inch, I have repeatedly observed of late that the bright chromosphere line, Angström 6676.9 (No. 2 in my catalogue of the chromosphere lines), is not coincident with the corresponding dark line of the solar spectrum, but is *less refrangible* by about one-third of a unit of Rowland's scale. This chromosphere line, therefore, can no longer be ascribed to iron, but must be due to some other substance as yet undetermined.

I think there can be no doubt as to the non-coincidence. The interval between the bright and dark lines varies to some extent with circumstances, being usually less in the chromosphere spectrum on the sun's eastern limb than on the western, and it is often affected by motions in the line of sight, but nine times out of ten the want of coincidence is perfectly obvious.

I may add that I have also obtained a considerable number of photographs of the ultra-violet spectrum of the chromosphere with the new instrument, and get complete confirmation of almost all Mr. Hale's results. I find not only the constant reversal of the H and K lines, but I have obtained, so far, five of the ultra-

---

* Nature, Nov. 12, 1891.

violet series of hydrogen lines; the first of them being the well-known "companion" of H (first visually observed by myself in 1880), and the other four in their regular succession above it.

The only point in which my plates fail to confirm Mr. Hale's is that I have not yet succeeded in catching the duplicity of the hydrogen α (3889). Several of his plates show at this point two lines near together; none of mine do so, and I conclude that the companion line makesits appearance only rarely. I first observed this line visually in 1883 (*American Journal of Science*, November 1883), and it has since been often seen by my assistant, Mr. Reed, as well as by myself.

Of course the opinion is no longer tenable that H and K can be due to hydrogen, since the measures clearly show that the companion to H belongs to the hydrogen series. But I am still sceptical whether they are due to calcium, at least in its terrestrial condition.

PRINCETON, N. J., Oct. 20, 1891.

NEW RESEARCHES ON THE SOLAR ATMOSPHERE.[*]

M. H. DESLANDRSE, PARIS OBSERVATORY.

I have been commissioned by Admiral Mouchez to inaugurate a new department at the Paris Observatory for spectroscopic investigations, which form the most important branch of physical astronomy, and I have directed my efforts in part toward the study of the Sun. I have the honor to present to the Academy the first results obtained in this new direction.

Method—Apparatus. I have studied the atmosphere of the Sun in a part of its radiation not yet explored. Every day in many observatories, the chromosphere and the prominences are observed by the method of M. Janssen, but with the eye only, and in the brightest part of the visible spectrum, the red, the yellow and the green. Now I have applied the same method in another region of the spectrum, which is barely visible, or even invisible, but easy to photograph, and which includes the blue, the violet, and a part of the invisible ultra-violet, as far as λ 380.

The instruments employed are the following: 1st. The siderostat of Foucault, which, in the estimation of its illustrious designer, was especially suited to solar work; 2d. An old 12-inch objective by Lerebours, which I have corrected for the chemical

---

[*] "Comptes Rendus de l'Académie des Science," 17 August, 1891.

rays by separating the two lenses; 3d. A photographic spectroscope with 1, 2 or 3 prisms of light flint.

Results. In spite of the small dispersion used I have obtained the permanent lines of the chromosphere in the blue and violet, observed with the eye by Professor Young from the summit of a high mountain, *i. e.*, the G′ and *h* lines of hydrogen, and H and K of calcium. But by photography the intensities of these lines present some important differences. The H and K lines, which are at the limit of visibility, are recorded by Professor Young as thirty times less intense than the line G′ of hydrogen. Now the numerous photographs made on the entire limb of the sun during the months of May, June and July, 1891, show clearly the lines of calcium much longer and more intense than the lines of hydrogen; they are often strong when the hydrogen lines are very faint.

Besides this I have also obtained the permanent faint line a little less refrangible than H, and recorded in Professor Young's list with the remark, "element unknown," but I have identified this line as one of hydrogen, by direct comparison with a Geissler tube.

Finally, in the invisible ultra-violet region, I have obtained two new permanent lines which correspond with the first two lines of hydrogen in Dr. Huggins' stellar series.

But the most important result is the marked predominance of the lines attributed to calcium. The corresponding vapors rise higher than do those of hydrogen, a fact which overthrows the accepted ideas on the composition of the solar atmosphere. This result is less astonishing when it is considered that the H and K lines are the broadest in the ordinary solar spectrum, and should consequently be very strong in the absorbing layer. It is moreover, in accordance with the great extension of these same lines shown in photographs of the corona spectrum made during the eclipses of 1882, 1883 and 1886 by Messrs. Abney and Schuster.*

Another property of these bright lines of calcium, important from a practical point of view, is the possibility of obtaining them with a very low dispersion. The great width of the black background on which they are projected gives them this advantage, and even partially explains their great extension. With the hydrogen lines, on the contrary, the discovery of the proninences,

---

* On a high mountain, and with an apparatus of low dispersion, the bright lines of calcium will be still longer, and thus the corona, properly so called, will be obtained. The distinction between the corona, the chromosphere, and the prominences is entirely relative, and depends upon the region of the spectrum considered, and the conditions of the experiment.

as is well known, was delayed for two years by the insufficient dispersion of the apparatus employed.

I have the honor to present to the Academy several photographs of these calcium reversals. One of these shows a prominence at 311°, June 18, 2^h 55^m M. T., moving with a gyratory motion. One extremity approaches the earth, in fact, with a velocity which, determined from the photograph according to the principle of M. Fizeau, is about 62 kilometres, the other extremity with the smaller velocity of 25 kilometres. The direction of the rotation (a point worth noting) is that of the Sun's rotation. The laws of storms in our own atmosphere apply also to the atmosphere of the sun.

Photographic Record of Form and Velocity.—These photographs require a maximum exposure of two seconds. They can serve for a regular and rapid study of the movements at the surface of the sun, movements which, according to certain ideas now in vogue, are supposed to have an influence on the terrestrial atmosphere. The forms of prominences may also be photographed.

Mr. Hale, who has long been engaged in investigating this last question, has proposed several very ingenious methods for photographing prominences with a narrow slit; but these methods apply only to single prominences, and not to the entire circumference of the sun; besides, they do not give the velocities. I have devised an entirely different arrangement, which may be described as follows:

The spectroscope, which may be of any form, turns continuously around an axis passing through the center of the sun's image, and prolonging the optical axis of the objective. The middle of the slit is on the limb of the sun, all points of which it meets successively by the rotation of the apparatus. Before the photographic plate is placed a fixed slit, which corresponds with the K line of calcium. Moreover, the plate is movable, in such a way that a displacement of the plate corresponds to an equal displacement of the middle of the slit. This result is secured by simple gearing. If then the spectroscope rotates steadily with a suitable velocity, a band equal in length to the circumference of the sun is obtained on the plate, which shows all the prominences with their exact forms. But the velocity of the prominences is not given by this process. It is also necessary to give to the apparatus a series of rapid rotations, separated by periods of two seconds, in such a way as to have on the plate, for example, 200 equidistant sections of the chromosphere on the whole circumference of the sun. Each section requiring about three seconds, the whole can be made in ten minutes. If, moreover, the plate is replaced by a piece of sensitive paper rolled on a cylinder, and the movement of the spectroscope made automatic, a simple apparatus will be obtained which will register continuously the form and velocity of the incandescent masses at the surface of the sun.

ON THE ENORMOUS VELOCITY OF A SOLAR PROMINENCE, OBSERVED JUNE 17, 1891.[*]

JULIUS FENYI, DIRECTOR OF THE HAYNALD OBSERVATORY, KALOCSA, HUNGARY.

On June 17, at 5^h 30^m, Paris mean time, a group of spots in course of development, was seen at 21° latitude, and, according to our calculations, it would pass around the western limb of the sun at 282° from the celestial pole. The phenomena observed in a group of prominences at the same place form the subject of this communication.

An elevation 18″ high and of a dazzling brilliancy, extending from 278° 32′ to 281° from the celestial pole, was with the flame at 282° 42′, the seat of an excessively violent eruption.[†]

After 5^h 42^m, P. M., Kalocsa mean time, or 4^h 36^m, Paris mean time, the detached parts of the group in question reached the considerable elevation of 109″. As yet the whole complex mass revealed neither motion in the line of sight nor motion of ascent, except the point of the chromosphere at 282° 42′, where the light spread itself outside the slit toward the red.

The violence of the erpution was shown not only by the great brightness of the red line 6677, but also by the fact that the lower parts of the prominence were visible in this metallic line up to the height of 13″; their brilliancy was equal to that of ordinary prominences in the C line.

After 6^h, Kalocsa mean time, the point at 281° shone with so great a brilliancy, that its reddish light seemed to become white; an enormous displacement of the light of the spectrum toward the blue, at a medium height above the sun's limb, indicated at the same time an approach of the hydrogen in our direction, with a prodigious velocity.

The line, that is to say, the image of the slit, appeared com-

---

[*] "Comptes Rendus de l'Académie des Sciences," 17 August, 1891.

[†] On the same day, and at the same place on the sun, M. Trouvelot observed the "luminous phenomena" published in the Note in the Comptes rendus, V. CXII, p. 1421.

pletely free from reversal; the entire form was outside the line on the side toward the blue, and was composed of luminous filaments directed along the spectrum and changing, in appearance, shining like lightning when I drew the image above the slit.

I measured the extent of the displacement by means of a filar micrometer, and, after having carefully determined the dispersion in this region I obtain the enormous velocity of 797 kilometers per second. New measures were taken: they gave 890 kilometers per second as the maximum velocity.

I commenced at that time to determine the height of this moving mass, causing the prominence to pass over the slit, and observing the transit of both the top and the lower extremity.

The result of seven transits, observed in rapid succession, gives an interesting illustration of the progress of the phenomenon:

Transits.	Height on the Limb. Lower Part.	Height on the Limb. Summit.	Extent of the Column.	Ascent per sec. of Time.		Velocity toward us per second km.
	″	″	″	″	″	
I.	——	182.7	——			337
				——	16.3	
II.	61.8	199.0	137.2			——
				45.4	18.0	
III.	107.2	217.0	109.8			——
				——	—2.7	
IV.	——	214.3	——			——
				35.6	8.2	
V.	——	222.5	——			——
				——	13.8	
VI.	142.8	236.3	93.5			——
				9.5	20.6	
VII.	152.3	256.9	104.6			449

We thus see that a suspended column, measuring 111″ from top to bottom, rose almost vertically in a single mass and with a prodigious velocity to a height of 256″.9. The velocity with which this same mass advanced toward us was also enormous, for the image remained all the time outside the C line; the image of the slit was entirely dark. The displacement of the top, measured with the micrometer before the first and during the last transit gave for the elevation indicated in the table the enormous velocities of 337 kilometers and 449 kilometers per second. The lower parts showed a still greater deviation than that of the top.

It is impossible for me to follow with exactness the progress of the ascent in all its phases, because we could not determine precisely at what instant each of these phases occurred; but we can at least indicate the mean velocities quite accurately. During each transit I counted only twenty seconds; we can thus safely assume that no one of these observations lasted longer than thirty seconds. As the prominence traversed, during the seven transits, or in 210 seconds, the distance 79′ 2″,* it must have risen with a mean velocity of at least 485 kilometres per second. Its lower extremity rose more rapidly, if we rely on the first measures taken; however, its progress was evidently retarded, while the top seemed rather to rise with a constantly increasing velocity.

This same mass also possessed a velocity by no means insignificant in the third direction; that of the meridian. According to the data obtained, this velocity would amount to about 100 kilometres per second; but this figure, which does not rest upon exact measures, is of little importance in comparison with the two components we have just discussed.

If we consider these two components as simultaneous—a supposition, moreover, which is well warranted by the phenomena mentioned—we obtain, in uniting them into a single resultant, the prodigious velocity of 1014 kilometres per second, without counting the third component, which is uncertain.

As the component in the line of sight alone so greatly surpasses the potential of the sun, we may conclude that the sun can even now project into space matter which will never return to it.

These observations demonstrate as well that it is impossible to explain according to modern theories the immense disturbances which take place in the atmosphere of the sun by a flow of gas from the interior of the globe.

We are led by these considerations to admit of forces other than atomic motions during the expansion of the gas. Why may we not have recourse to electrical forces, well known by experiment, and which nevertheless produce mysterious results in nature, either by their sudden and unexpected appearance, as in fire-balls, or by their unlimited power in storms?

It is worthy of remark that this region on the sun appeared again on July 1, at the eastern limb, in the same state of violent agitation. At $9^h 40^m$, Kalocsa mean time, a prominence appeared, extending from 70° 40′ to 72° 14′ from the celestial pole, or at + 16° 2′ heliographic latitude. It was of medium height, and of dazzling brightness; it was very near the spot, which it partly covered just as the spot came into view. (One point in the mass, at 71° 16′, was the source of a continuous spectrum; a faint band of light extended across the whole field of view; a novel sight which lasted several minutes.)

The light deviated beyond the edge of the slit in the whole extent of this region, toward the red and the blue at the same time. The corresponding velocities were 134 kilometres per second in one direction, and 181 kilometres in the opposite direction.

---

*This is evidently a misprint in the "Comptes rendus," but in a copy of the paper received from the author it is not corrected. As will be seen from the table, the total ascent of the top of the prominence was 74″.2. G. E. H.

The form of the prominence, which rose immediately to 45″, was easily visible in the red line 6677, in the D_1 and D_2 lines up to an elevation of 11″, and in the lines b_1, b_2 and b_3 to a height of 12″. Other metallic lines were not reversed; the quite common line of barium at 6140.4 was missing, and even the corona line was hardly visible; a surprising fact, when the violence of the eruption is considered. Similarly, the number of lines which I observed on June 17 was not in proportion to the other phenomena.

NOTES ON SOME RECENT SOLAR DISTURBANCES.*

(1) *The bright Solar Prominence of 1891, Sept. 10.*

REV. WALTER SIDGREAVES.

The early part of September was marked by a great revival of solar activity. The largest group of spots witnessed since June, 1885, crossed the sun's disc between Aug. 29 and Sept. 10, in approximate solar latitude 22° N. Its first appearance on the eastern limb was sketched on Aug. 29 in latitude 21° N., and its transit over the western limb was observed both on the screen and in the spectroscope, on Sept. 10, in latitude 22° N. A comparatively small but compact prominence of great brightness was seen through the latter instrument at 0.40 G. M. T. It attained its greatest height, about 35″ of arc, at 1.50; when it assumed the appearance of four blowpipe-jets intensely bright at the bends. This appeared to be the time of its greatest activity, judging by its dimensions, brightness, and rapidity of change. It was watched until 2.15, when the observer had to leave it, and at his return at 3.5 no prominence was visible; but its place on the limb was distinctly marked by the intensity of all the bright lines which had been observed during its appearance: the prominence as such was extinct. Twenty-six bright lines had been counted in all. And of these the usual lines of the chromosphere, C, F, *g* and D_3, were so greatly intensified that the most inexperienced observer could not have failed to see the form of the flame by any one of these colors. The well-known lines in the red, 7055 and 6677 of Angstrom's scale, and D_1, D_2, b_1, b_2, b_3, b_4 and *h* were seen bright almost quite up to the extreme height of the prominence; while the remaining 13 lines glowed only up to about half the average height of the chromosphere. These were not accurately identified but 9 of them were seen between λ 5300 and 5400, and probably belong to the group of iron lines in that region; the other four were seen between the *bb* group and F.

---

* From The Observatory, October, 1891.

A careful measurement of the spot drawing made earlier in the morning shows that a strong nucleus of a spot group was exactly upon the limb at the time of the spectroscopic observations.

A more detailed account of the group of spots, as observed during its passage, may be given later.* But in connection with the bright prominence it must be noted here that the entire group of spots may be divided into two parts—a preceding and a following sub-group. The first of these was not observed on the limb. It was well over it on the morning of the 10th of September. The preceding part of the following sub-group appears to have been the seat of the observed disturbance, and this was the most active center of the whole group during its passage over the solar disc. Both of the sub-groups were examined with the spectroscope on Aug. 30, Sept. 3 and Sept. 4; when nothing unusual was discovered in the first, while the preceding part of the following sub-group gave evidence of great activity by reversion, distortion, and widening of the C line, on all the three days of observation.

The terrestrial magnetic field may be described as generally more disturbed during the progress of the spot than in the preceding month, and notably at the beginning and end of its course. But there are no indications of magnetic disturbance accompanying the solar eruptions seen through the spectroscope. Even the brilliant display on the western limb, of the 10th, has left nothing that can be considered a record of itself on the magnetograph curves.

STONYHURST OBSERVATORY, Lancashire.

(2) *The Disturbances of 1891, June 17.*

H. H. TURNER.

On 1891, June 17, 10^h 9^m Greenwich Civil Time, M. Trouvelot projected the solar image on a screen, when his attention was suddenly arrested by an "extraordinary luminous appearance such as he had never seen before."

"Close to the western limb was a bright spot subtending an angle of 3° on the limb greatly surpassing in intensity the most brilliant faculæ he had ever seen. The light was not white as in faculæ, but slightly yellow, very like that of an incandescent lamp just before it acquires its maximum brilliancy . . . . . . A minute later there appeared, a little north of this object, a narrow line of

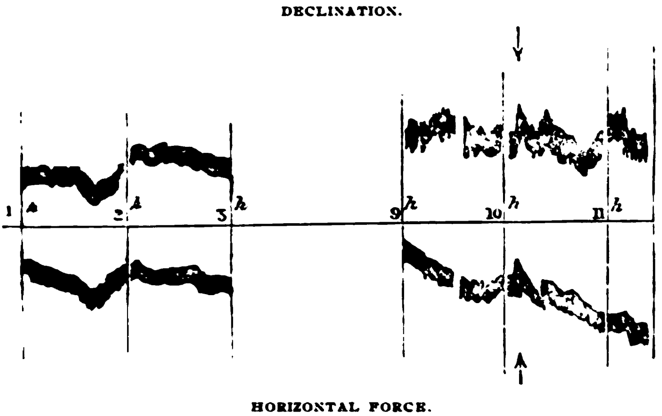
---

*See paper by Rev. A. L. Cortie, 1891, Nov., *Observatory* p. 363.

facula, parallel to the limb and at a little distance from it, and subtending an arc of 5° to 6°, shining with the same kind of light but not so brilliantly."

After observing these phenomena for a few minutes, M. Trouvelot adjusted the spectroscope on the region and found two prominences, "one at 281° and the other at 286° to 290°." (No further explanation of these figures is given in C. R., No. 25, p. 1420, but from comparison with the photographs, to be presently mentioned, it is inferred that they are angles from N. point in the direction N., E., S., W.). But it soon became evident that the phenomena were diminishing in brilliancy; which was confirmed on removing the spectroscope and again mounting an ocular. "Là, ou quelques minutes plus tôt etincelait une si éblouissante lumière, on ne voyait rien d'inusité, pas même la plus fabiel trace de facule." [We imagine that here M. Trouvelot is referring only to the place formerly occupied by the bright light at first noticed; and does not mean that the facula which appeared a minute later had also disappeared: though this is not quite clear from his words. We shall return to this point immediately.] The spectroscope was replaced and the prominences were found to have undergone some change, but to be nearly as bright as before. Only a few lines were reversed, however: C, D_3, F, and G were very bright; but besides these there was only λ 6676.8, *b*, a line in the blue, and perhaps λ 4394.8. Nothing was seen on D_1 and D_2. M. Trouvelot continued to observe the gradually diminishing spectroscopic phenomena till midday; and again on June 18 from 9^h 20^m till 2^h 35^m, when "le calme est rétabli et toute trace de protubérance éruptive a disparu." In the afternoon of June 17, observations were made quite independently by M. Jules Fényi, at Kalocsa. He refers to the disturbed region (now marked by the facula alone?) as "un groupe de taches en train de se développer à 21° de latitude, qui allait, selon notre calcul, franchir le bord occidental du Soleil à 282° du pôle céleste." But his observations were confiined to the neighboring prominences, whose enormous velocity in the line of sight struck him at once. Careful measurements gave as the value of this velocity 300 to 400 kilometers per second; and the rapid development of the prominence from a height of 111″ to 257″ indicated a velocity of about 500 km. per second transverse to the line of sight. The resultant velocity, even allowing only a moderate component in the third direction, may have at times reached 1000 km. per second! If the appearances are due to matter in actual motion with such velocity as this, it would of course escape from the Sun's attraction.

In concluding his account of the phenomenon, M. Trouvelot compares it to that simultaneously observed by Carrington and Hodgson (*Monthly Notices*, XX, pp. 13-16) on 1859, Sept. 1, which was accompanied by marked magnetic disturbances; and he asks whether such was also the case on Sept. 17. On examining the Greenwich photographic records, we find a very minute, though unmistakable, disturbance at almost precisely the time noted by Trouvelot. It is not quite clear from his account whether he began observing at $10^h\ 7^m$ ($10^h\ 16^m$, Paris time), or whether the bright spot suddenly appeared then. But it *is* clear that the disappearance was very rapid, and the whole phenomenon very short-lived. Now at $10^h\ 7^m$, within a very small limit of error, there was a sudden small disturbance of all three magnets (registering declination, horizontal force, and vertical force), as will be seen from the appended diagram for 2 of the elements.


DECLINATION.

HORIZONTAL FORCE.

The disturbance is smaller than many others on the same day, although the day itself was very quiet; but it differs from others, one of which (at about 3^h) is shown for comparison in its abruptness, which is clearly shown in all three curves. The change in declination is only about $1'$, and in H.F. 0.0005 of the whole H.F. We may compare with these the change of $17'$ in declination, and 0.0064 of the whole H.F., which took place on 1859, Sept. 1, simultaneously with the Carrington-Hodgson disturbance, and the tremendous magnetic storm which went on for some days, during which the changes were much larger still; and it becomes obvious that the phenomena of June 17 were of an entirely different order of magnitude.

Two photographs of the Sun were taken at Greenwich curiously near the time of M. Trouvelot's observation—one at $10^h\ 19^m\ 53^s$ G. C. T., and another at $10^h\ 51^m\ 53^s$. Both show the facula described by M. Trouvelot, but there is no trace of anything extraordinary; nor, indeed, should there be, according to M. Trouvelot's account, for the brilliant region had disappeared within a few minute safter $10^h\ 7^m$.

RECENT RESULTS IN SOLAR PROMINENCE PHOTOGRAPHY.

GEORGE E. HALE.

Since the presentation of my last paper on this subject at the meeting of the British Association, solar work has become of much more general interest on account of the publication of two valuable papers by M. Deslandres and Professor C. A. Young. The first of these appeared in the "Comptes rendus" for Aug. 17, 1891,* and described M. Delandres' investigations at the Paris Observatory. Professor Young's "Note on the Chromosphere Spectrum"† was first printed in *Nature*, Nov. 12, 1891. In general the results reached by both of these investigators go to confirm those already published by the writer.

I have recently had the pleasure of visiting M. Delandres at the Paris Observatory, and he has very kindly shown me the apparatus used in his research. I was much gratified to learn how completely my results were confirmed with instruments of a very different kind. In my last paper some hesitancy was expressed in assigning the line close to H, and just above it, to hydrogen, but at present there can be no doubt on this point. The opinion already ventured that the line is due to hydrogen has been borne out by photographs made here, in which the line is strong, and none of the "ghosts" of H and K are visible. The hydrogen lines both above and below H are shown on the same plates, and, apart from the ghost question, there would be no reason to expect that the intermediate line of the series would be missing. Moreover, M. Delandres has photographed the same line with prisms, in which case there could be no trouble from ghosts. Though his dispersion was too small to allow of a crucial test, the exact coincidence of the line with the corresponding one from a hydrogen tube must be regarded as practically settling the matter, when it is also considered that Professor Young has photographed the same line with a grating almost wholly free from ghosts.

---

* See page 60. † See page 59.

It is curious that in regard to the duplicity of the line hydrogen α (3889)* Professor Young's results differ so widely from my own. He has always found the line single, and therefore concludes that "the companion line makes its appearance only rarely." Out of a very large number of photographs made at this Observatory of the prominence and chromosphere spectrum, the line hydrogen α_1 is shown in but eighteen. In eleven of these, made on five different dates, the line is a sharp and beautiful double, and the duplicity is certainly not the result of poor focusing or ghosts. Professor Rowland has examined the plates, and testified to this last point. Of the other seven plates the duplicity is doubtful in three owing in one case to the breadth of the line, in another to poor focusing on the sun's limb, and in the third to under exposure. Two plates, the first made with radial slit on July 4, 1891, and the other with tangential slit on Oct. 20, 1891, (in the eruption to be described presently) certainly show the line single, only the upper component (that due to hydrogen) being present. Certain peculiarities in both of these plates should be mentioned. In that taken with radial slit on July 4 a diaphragm cut off the light for a short distance above the sun's limb, so that only the upper part of the prominence lines is shown. Strange to say, the hydrogen line close to H is hardly, if at all, visible, while the upper component of hydrogen α_1 is fairly strong. In most cases hydrogen α_1 is absent if hydrogen ϵ (near H) is not well developed, and this is so generally true that the strength of hydrogen ϵ may be taken as a criterion on which the presence of hydrogen α_1 depends. The photograph taken during the eruption of Oct. 20 is the only one so far obtained in which hydrogen α_1 is shown at the same time that the distortion of K indicates motion in the line of sight. Unfortunately hydrogen ϵ was out of the field in this photograph, and its relative strength could not be determined. These peculiarities suggest a direction for future study, though it may be that they have nothing to do with the question of duplicity.

In the remaining two plates of the eighteen which show hydrogen α_1 we meet with another condition which complicates the determination of duplicity in these instances. Both exposures were made with a tangential slit slightly overlapping the sun's limb at the point where the second eruption of Oct. 20 was subsiding. The visible spectrum of the chromosphere at the time contained a great many bright lines. In the photographs H, K, hydrogen ϵ, α_1

---

*Prof Young has suggested that for the sake of conformity with the publications of Dr. Huggins and others, the Greek letters designating the ultra-violet hydrogen series be written with subscripts; thus the line mentioned above would be α_1, the subscript distinguishing it from α (C).

and β_1 are strong, and the presence of other lines is suspected, though the rapid widening of the strip of spectrum toward the ultra-violet makes it impossible to be certain. H and K are remarkably strong, and in one of the plates hydrogen α_1 also extends across and beyond the strip caused by the slit overlapping the limb. In the center of the bright H and K lines the dark reversal is very prominent at the middle of the strip, but at the edges the dark line disappears. Both H and K are thus single and tapering at the ends, and expand at the center, where they each enclose a dark line. But it is of interest to note that hydrogen α_1 is affected in precisely the same manner, while hydrogen ε shows no sign of the central dark reversal. As the latter line appeared, however, on only one plate, it would be hasty to draw any conclusions at present. But in the case of hydrogen α_1 we certainly seem to have a true reversal, for if the separation at the middle of the strip were due to the duplicity of the line it would extend to the edges, and this does not seem to be so. The distance between the components of α_1 when double in the ordinary way, as determined on a comparator, is about two-thirds the distance between the separated portions of the apparent reversal. Moreover, the upper component of α_1 falls exactly on the more refrangible portion of the reversed line; thus the lower component of α_1 is probably not present, for if it were it would be seen to overlap the dark center of the reversal. It is hoped that further photographs will provide material for a complete study of this question.

When we examine the components of the double α_1 line in a number of plates, we find in almost every case that the (more refrangible) line due to hydrogen is quite sharply defined at the edges, and seems to fall exactly upon a bright space in the solar spectrum. At times it is even difficult to be sure whether the line is present, as under certain conditions the ultra-violet hydrogen lines in a prominence are very faint, and the bright space in which α_1 falls remains of sensibly the same intensity. The less refrangible component is nearly always fainter, broader, and less sharply defined at the edges than its companion. It does not seem probable that it is due to hydrogen, as no trace of it has been recorded in laboratory investigations of this spectrum. No evidence of duplicity of this line has been found in photographs of stellar spectra, but up to the present time sufficient resolving power has not been employed in this part of a star's spectrum. In two instances hydrogen ε (near H) and hydrogen α_1 have been bright enough to show the form of prominences photographed through a widely opened slit.

There seems to the writer every reason to ascribe both H and K in the prominences to calcium, at least in so far as we may depend upon the coincidence of the lines with those given by calcium in the arc, spark or flame. Negatives recently made here show a most perfect agreement of the dark lines in the solar spectrum with the bright lines in prominences not affected by motion in the line of sight, and Professor Rowland, using enormous dispersion, has found the dark lines in question to coincide exactly with the calcium lines given by short exposure to the arc. The calcium line at λ 4226.3, though carefully searched for, has not been found in the prominence spectrum, but Professor Rowland has recently informed me that in appearance and behavior in the arc this line is entirely different from H and K. Its absence from the prominences is therefore not greatly to be wondered at. I hope soon to determine the position of the bright H and K lines with an observing telescope of twice the focal length of that now employed. At the same time I cannot share in the doubts expressed by Professor Young in regard to the origin of the lines, and have little hesitation in ascribing them to calcium.

The relative intensities and heights of H and K have been compared in a large number of plates, the result being that K is almost invariably more intense (and higher when radial slit is used) than H. In one or two cases the intensities seem to be about equal, or even incline toward a greater intensity for H, but this is yet to be established. A prominence seems to have about the same form in both lines, and distortions due to motion in the line of sight in all plates so far examined differ but little. Where differences exist, they may presumably be ascribed to the usually greater brightness of K. These points are well illustrated in Plate IV. The expansion of H and K where the base of a prominence merges into the chromosphere has been mentioned in a previous paper. A recent photograph supplements the evidence thus afforded by the radial slit. In it the slit is tangential, and lies across the chromosphere, just in contact with the limb, though not overlapping it. On either side of the point of tangency a prominence rose high enough to be cut by the slit. In the photograph the chromosphere reversals are more than twice as broad as the narrow and more sharply defined prominence lines.

In my last paper mention was made of a solar eruption photographed by my brother and sister, W. B. Hale and Martha D. Hale, who were engaged in the regular work of the Observatory during my absence. Inquiry was made of M. Tacchini, M. Trouvelot, and others, but no record of the eruption other than that made here could be found. I have recently received a letter from Herr Julius Fènyi, S. J., Director of the Haynald Observatory at Kalocsa, Hungary, which is of such interest in this connection that, with his permission, a translation is given below:

"I think that it will be very interesting to you to learn that the sudden formation of a prominence observed at your 'scientific institute' on July 8, 1891, at 23^h 45^m, Chicago M. T., and mentioned in your very interesting article in 'Memorie degli Spettroscopisti' on 'The Ultra-Violet Spectrum of the Solar Prominences,' was by a singular chance also observed simultaneously in Kalocsa. The observation was first possible, on July 9, at 7^h P. M. Enclosed I send for comparison a copy of the drawing of the form made at the telescope at the time. The height was measured by means of transits across the slit between 7^h $4\frac{1}{2}^m$ and about 7^h 6^m, and found to be 204″, in excellent agreement with your determination of 80,000 miles. In the journal of observations it is recorded that at 7^h 19^m (Kalocsa M. T.) the projection (at 69°) had almost entirely disappeared, only a few very faint fragments remaining. As Kalocsa — Chicago = 7^h 6^m you observed the uprush according to your statement on July 9, 11^h 45^m, Chicago M. T. or July 9, 6^h 51^m Kalocsa M. T. My drawing and measure of position were finished at about 7^h 0^m, after which the transits were taken, which were soon disturbed by clouds. The observations must thus have been made at exactly the same time.

"This phenomenon, remarkable in itself for its unusually great size, arouses a particular interest because of its relation to a spot-group at that time on the other side of the sun. It is at this remarkable place on the sun where, ever since May, such magnificent phenomena and constant eruptions have happened. I am just sending an article to M. P. Tacchini on the extraordinary phenomena observed on July 24 at this place on the sun (west limb). As this region passed over the limb on July 11, I also observed an important eruption there; the point is marked on the drawing (which accompanied the letter) by a red cross. These places are of course given on the drawing only as the result of accurate calculation.

"I therefore believe that the great prominence observed on July 9 was the product of an eruption rising from *this spot region*, or perhaps not far from the nearest great spot, and that what we saw was only that part of the far-reaching mass of the prominence which extended above the sun's limb. The fact that I saw no metallic lines supports this view, as these usually appear only at the base. If this great prominence had been at the place of the eruption of July 11, it would have been distant 24°.6 from the limb; the reduction of its apparent height would have amounted to 98″. I observed with a 7-in. refractor and a 6 prism automatic spectroscope by Hilger, in the C line.

"The places mentioned are at the following heliographic positions:

"Eruption of July 11, 4^h 12^m P. M. Kalocsa M. T.; heliographic latitude + 17°.2 to 22°.8; longitude 124°:

"Prominence of July 9, 7^h P. M.; latitude 21°.7 to 29°.8; longitude 149°."

It is certainly a remarkable coincidence that simultaneous observations of an eruption lasting but about 15 minutes should have been made from stations so widely separated. The more so from the fact that the sun's limb must be examined piecemeal by the spectroscopist, and but a small portion can be seen at a single position of the instrument. By a mistake in the paper mentioned by Herr Fényi Central Time was recorded as Chicago Mean Time. Adding the necessary correction it is found that the photograph reproduced in Plate III* for comparison with Herr Fényi's drawing was made at 11^h 55^m Chicago M. T., or 7^h 1^m Kalocsa M. T. It will be seen that the photographs made in H and K, though very poorly reproduced by the process employed, show a striking agreement with Herr Fényi's drawing. The photograph, moreover, does what the eye could not do, for it shows the part played in the prominence by calcium, while for the drawing the hydrogen line C was used. A photograph of the spectrum of the prominence with radial slit was made here at 11^h 45^m Chicago M. T., or 10^m before that of the form. H and K are the only bright lines shown; even hydrogen ϵ (near H) is absent. Both H and K are distorted toward the red, and indicate a velocity of about 58 miles per second away from the earth. Drawings were made here before, during, and after the eruption, which was estimated to have lasted about 15 minutes. Two hours later the form and spectrum of the remaining portion of the base of the prominence were also photographed. Very little remained at this time, but it is interesting to note that in addition to H and K, hydrogen ϵ and α_1 (double) are present. As they extend but a short distance from the limb it is possible that their absence in the photograph made during the eruption may thus be accounted for, as the limb was then covered by a diaphragm. The eruption seen by Herr Fényi on July 11 was missed here on account of clouds. The suggestion that the

*See plate preceding p. 17.

eruption of July 9 had its origin in the spot-group which did not arrive on the limb until July 11 does not seem an improbable one. At the same time the absence of metallic lines is hardly a convincing argument in its favor, as they do not seem to be the invariable accompaniments of such eruptions.

On Oct. 20, 1891, I observed and photographed two interesting eruptions at 114°. At $10^h\ 35^m$ A. M., Chicago M. T., I was looking for prominences with an annular slit, which allowed about 90° on the limb to be seen at once, and suddenly noticed some bright filaments at a considerable distance from the limb. The annular slit was immediately replaced by the straight one ordinarily employed. With this open to its fullest extent an explosive prominence was seen rising in detached vertical filaments to an elevation of about 4′ 15″ or 107,000 miles. Light clouds soon covered the sky, and photographs of the spectrum only were made. The prominence, as observed through C, changed rapidly in form, but no lines were seen in its spectrum other than C, D_3, and F, the latter being very faint. A line was seen for a short time just above D_3, and about one-quarter the distance between D_1 and D_2 away from it, but it may have been a ghost of D_3. In the photographs of the spectrum only H and K are present, hydrogen ϵ and α_1, as might be expected from the faintness of F, being absent. The distortion of H and K in all the photographs is toward the violet, as is shown by the lower figure of Plate IV,* which is enlarged about three times from the original negative, without retouching. The velocity toward the earth, as measured from the maximum displacement of K in this plate, is about 64 miles per second. At $11^h\ 48^m$ I returned to the telescope, after having been absent a few minutes in the dark-room. The great filamentous prominence had disappeared, and in its place was seen a long chain of bright prominences about 1′ high, which changed rapidly, and showed some distortion in C. In the spectrum of the chromosphere at the base F was very bright, the *b* lines reversed, but D_1 and D_2 were unaffected. A photograph with the slit tangent at this point does not show hydrogen α_1 bright, a point to be noted in connection with the unusual brightness of F. K was of course reversed, but H and hydrogen ϵ were beyond the edge of the plate.

Observations were resumed at $2^h\ 15^m$, when I was surprised to find that the long line of low prominences had completely disappeared, giving place to a beautiful column rising to a height of about 2′, and instantly reminding me of the eruption of a great geyser. C and D_3 were somewhat distorted toward the violet,

---

* See plate preceding p. 17.

F was fairly bright, and the *b* lines were not reversed. The upper part of the prominence appeared like a cloud of spray blown out by a violent wind; it was seen to be falling rapidly, and in about fifteen minutes the end had met the chromosphere. The photograph used for the illustration in plate IV was made at 2^h 30^m. In reproducing it no retouching was allowed, so that though much of the detail and contrast of the original negative were unavoidably lost, the result is a picture in which no personal bias enters, as it is the outcome of purely photographic processes. The illustration is about three times the size of the original. It will be seen that the image in H is not nearly as good as that in K, probably on account of the greater brightness of the latter. The form is very similar to that shown in a drawing made about the same time through C. The slit was very wide, and even with the convenient broad bands in this region of the spectrum proper contrast was difficult to obtain.

At 3^h 28^m the prominence was seen to be breaking up, and a few minutes later the chromosphere at the base was found to contain a great number of bright lines, including D_1, D_2, D_3 (*brilliant*), b_1, b_2, b_3, b_4, and many others. The photographs mentioned on page 00 as showing a_1 reversed, were made at this time. The sun was so low that observation had to be given up at 4^h 28^m, and the numerous chromosphere reversals could not be recorded. When last seen the prominence was greatly broken up, and bore no resemblance to the form shown in the photograph made two hours earlier.

On the following day a group of rather bright faculæ was seen near where the two eruptions occurred. Two bright and fairly active prominences were on the limb at the same position angle. On Oct. 22 two spots with bright faculæ had advanced on to the disc at this point. With a wide slit a small bright prominence was seen on the disc near the larger spot, and extending over part of the surrounding region.

In his paper in the "Comptes rendus," a translation of which is given on another page,* M. Deslandres has objected to the methods of prominence photography proposed some time ago by the writer, because theyseem to apply only to single prominences and not to the whole circumference of the sun. Of some of the earlier schemes devised the criticism is a sound one, but when the apparatus mentioned in my last paper is completed it is believed that its range will be much less limited. In a paper published in 1890 I proposed that a series of photographs of prominences be

---

* Page 60.

taken at equal intervals of time, thus giving a means of determining their velocities in two directions. For the velocity in the third direction—the line of sight—a series of photographs with narrow slit should be taken simultaneously with the others, the exact time of exposure being noted in all cases. Thus the true motion of a prominence may readily be determined. It is evident that for motions in certain directions a correction for the effect of aberration must be introduced, as M. Fizeau has pointed out,* when the accuracy of the measures is great enough to require it.

KENWOOD ASTRO-PHYSICAL OBSERVATORY,
Chicago, December 14, 1891.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in ASTRO-PHYSICS should be addressed to George E. Hale, Kenwood Astro-Physical Observatory, Chicago, U. S. A. Authors of papers are requested to refer to page 96 for information in regard to illustrations, etc.

Dr. Henry Crew writes from the Lick Observatory of a very persistent prominence observed there on Nov. 26, 27 and 28, 1891. It appeared on the western limb of the sun, near the equator, just where two spots went off on Nov. 26. Its changes in form were very gradual, and when last seen on Nov. 28 it appeared to be breaking up. The spectrum of this prominence was photographed at the Kenwood Observatory on Nov. 26, but cloudy weather prevented us from taking any photographs of the form, which would have been valuable for comparison with Dr. Crew's drawings. His observations were made with the 6-inch telescope, as no definition is obtainable with the 36-inch during the daytime.

The reception given by Mrs. Henry Draper to the members of the National Academy of Sciences on the occasion of its recent meeting in New York was in every respect most enjoyable. In the laboratory, so long used by Dr. Draper in his spectroscopic investigations, Professor E. C. Pickering gave an illustrated lecture on the recent advances in the work of the Henry Draper Memorial. Of the magnitude and importance of this work nothing need be said here. Certainly no better or more lasting memorial could be raised to a scientist.

The universal spectroscope just completed by Brashear for Professor Young is probably the most perfect instrument of its kind in use. It is expected that a fully illustrated description of it may soon be printed as one of the papers in our series on "The Modern Spectroscope."

The Paris Observatory is to be congratulated on having a most efficient head for its spectroscopic department in the person of M. Henri Deslandres. The work already accomplished by this skillful investigator is of the highest order, and additional important results may confidently be looked for in the course of his re-

---

* See or "Comptes rendus" Sept. 7, 1891.

searches. In addition to his study of the prominence spectrum with the Foucault siderostat some successful experiments have been undertaken on stellar motion in the line of sight, and the four-foot reflector is being re-mounted for a continuation of this work.

The spectrograph at the Potsdam Observatory has been dismounted for some time, as the motions of all stars within the capacity of the telescope have been already determined. An effort is being made to secure a 30-inch refractor with a new spectroscope, in order to include much fainter stars in the investigation. Professor Vogel will probably visit this country during the coming summer to examine the construction of the Lick telescope and other large instruments.

Professor Rowland will soon publish a list of the wave-lengths of 1000 standard lines, to accompany his photographic map of the solar spectrum. Such a list will be universally welcomed by spectroscopists, as it will remove all the difficulties hitherto encountered in the use of the map. A third dividing-engine for ruling gratings is just being completed and Professor Rowland already has in mind a concave grating of so large a size that it can be used directly for stellar spectra, without a telescope. If such an instrument could be made it would possess many important advantages. At present, however, a good 6-inch concave grating is so difficult to obtain that we may have to wait a long time for anything larger.

The powerful carbon disulphide spectroscope at the Nice Observatory still stands just as it was left at M. Thollon's death. No one has yet been found to take up the spectroscopic work at Mont Gros, and it does not seen likely that the great map of the solar spectrum, which was more than half finished by M. Thollon, will be completed for some time to come. M. Cornu is devising a new spectroscope, which will be fitted to the 30-inch refractor for stellar work.

Dr. and Mrs. Huggins, with their untiring energy, are at work on the visual spectrum of the Great Nebula in Andromeda, and they hope soon to prepare a paper embodying their results. Anyone who has examined this excessively faint spectrum will appreciate the very great difficulty of the work. Dr. and Mrs. Huggins observe independently, and each makes a full record in the note-book without knowing what the other has seen. Thus entire freedom from personal bias is secured. With the pain-staking care put into their work, it is not surprising that their observations have the highest reputation for excellence and reliability.

We have recently received from Rev. Walter Sidgreaves, of Stonyhurst Observatory an enlargement on paper of the group *b* in the solar spectrum. It was made with a 14,438 Rowland plane grating, and shows remarkably good definition. The scale is somewhat greater than that of Rowland's map, which is surpassed in the number of faint lines shown. In fact, some lines seem to be present which are not found on Thollon's great map of this region. But in spite of such excellent definition "line No. 17 of Mr. Winlock's maps (Proceedings of American Academy) is so faint on all my negatives that it can only just be discovered with a very careful search." Have we here an indication of variability in the intensity of a line? It is almost to be expected that cases of certain variability would be established if a sufficiently thorough and prolonged investigation were undertaken. The endless variety of stellar spectra clearly indicate important changes during the process of evolution from nebula to star, and in the course of years we may be able to draw valuable conclusions from variations in solar lines. In addition to gradual changes, it is by no means impossible that there may be temporary variations in absorptive power due to differences in spot or prominence activity.

CURRENT CELESTIAL PHENOMENA.

Our plan in conducting this department of ASTRONOMY AND ASTRO-PHYSICS will be essentially the same as that pursued in THE SIDEREAL MESSENGER. We shall aim to give notice, one month in advance, of the predicted phenomena for each month, and also to state briefly the results of observations which are reported.

It seems best to give the times of phenomena in civil time and to adopt the standard time system in common use in the United States. Central time, which will be generally used, is the time of the 90° meridian from Greenwich, which passes through the central part of the United States. The standard times of rising and setting of the planets vary with the place of the observer. They are calculated for the 90th meridian, and latitude 44° 28′. For other places not differing greatly in latitude the approximate standard times will be obtained by adding or subtracting the difference between local and standard time at the place of observation.

The times of occultations of stars by the moon, which also vary considerably with the latitude and longitude of the observer, are given in Washington time for the meridian of Washington, the data being taken without change from the American Ephemeris.

Ephemerides of comets will be given one month in advance when possible. In every case the latest and most accurate data available will be used.

PLANET NOTES FOR FEBRUARY.

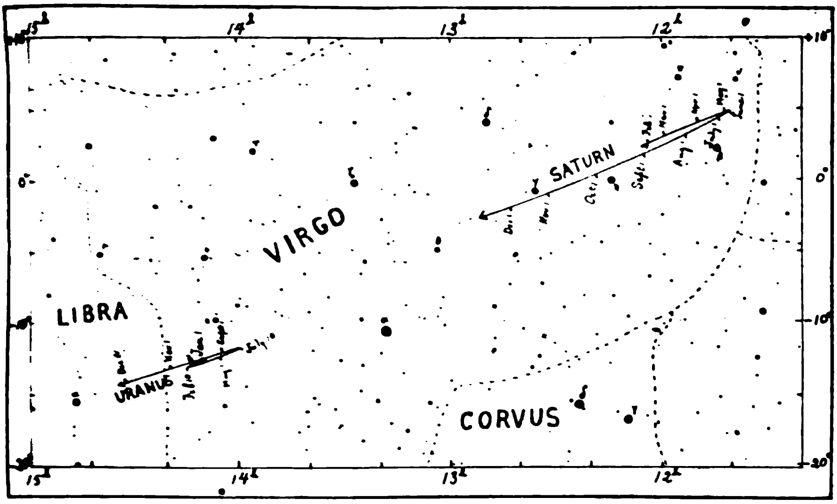
Mercury during February will be west of the sun, and too close to the rays of the latter to be seen with the naked eye. Daylight observations of its gibbous phase may be obtained by those having use of large telescopes.

Venus and *Jupiter* are the two brilliant "evening stars" in the southwest, Venus the more brilliant of the two. On the morning of Feb. 6, while they are invisible from this part of the world, these two planets will be in conjunction. They will be so close together that the unaided eye would be unable to separate them, and possibly, if an observer on the other side of the earth is able to watch them with a telescope, he will see an occultation of Jupiter by Venus. After this Venus will move eastward, so that at the end of the month they will be about 20° apart.

In another place Mr. Barnard calls attention to the fact that the new large red spot, which lately appeared in the second dark belt south of Jupiter's equator, has disappeared; also that the small dark spots on the edge of one of the northern belts have developed into a new narrow belt. The great red spot became more conspicuous this year than last and is now a striking object upon the planet. There have been changes also in the white equatorial belt. A very narrow dark belt was observed almost exactly on the equator on several nights in September. On December 17 this was invisible but the whole equatorial belt was far from white and was filled with dusky cloud forms, most of them curving backward from the belts on either side toward the equator, and toward the east limb of the planet. The great red spot and a small but brilliant white spot, just skirting its southern edge, passed the central meridian of Jupiter together at 4:44 P. M., central time, Dec. 17.

Mars will be visible in the morning, in the southeast, after 3 A. M. He will in February pass from the constellation Scorpio into that of Ophiuchus. He will be a few degrees northeast of the red star Antares, which star, however, Mars exceeds both in redness and brilliancy.

Saturn may now be observed after midnight and in February will begin to be in good position during the later evening hours. The accompanying chart will give some idea of its path among the stars during the year. He is in the constellation Virgo and will move westward until May 26, after which for the remainder of the year his motion will be eastward. In November he will pass near the fine double star *γ* Virginis.



Uranus may be found farther down toward the eastern horizon after midnight. His course among the stars for the year is platted on the same chart with that of Saturn. Just now he is moving eastward but on Feb. 9 will turn and move westward until July 9, after which, his course will again be eastward for the remainder of the year. He will thus pass three times very close to the fifth magnitude star *λ* Virginis. The three conjunctions with this star will occur Jan. 3, Mar. 20 and Oct. 14.

Neptune will still be in good position for observation during the early evening. Neptune will be stationary in right ascension Feb. 15, and after that will move slowly eastward. For chart of his path among the stars see SIDEREAL MESSENGER, page 463, Nov. 1891.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Feb. 5	19 55.2	−21 53	6 23 A. M.	10 54.0 A. M.	3 25 P. M.
15	20 59.5	−19 03	6 34 "	11 18.7 "	4 03 "
25	22 06.3	−13 56	6 38 "	11 46.0 "	4 54 "
			VENUS.		
Feb. 5	23 25.0	− 5 01	8 40 A. M.	2 23.1 P. M.	8 07 P. M.
15	0 09.1	+ 0 13	8 24 "	2 27.8 "	8 32 "
25	0 52.5	+ 5 26	8 07 "	2 31.8 "	8 57 "
			MARS.		
Feb. 5	16 22.3	−21 02	2 46 A. M.	7 21.6 A. M.	11 57 A. M.
15	16 48.6	−22 03	2 38 "	7 08.6 "	11 39 "
25	17 15.0	−22 48	2 29 "	6 55.6 "	11 22 "

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			JUPITER.		
Feb. 5......	23 27.1	— 4 47	8 40 A. M.	2 25.2 P. M.	8 10 P. M.
15......	23 35.4	— 3 51	8 06 "	1 54.2 "	7 42 "
25......	23 43.9	— 2 55	7 31 "	1 23.4 "	7 15 "
			SATURN.		
Feb. 5......	12 1.9	+ 2 25	8 45 P. M.	2 58.1 A. M.	9 11 A. M.
15......	12 00.0	+ 2 40	8 03 "	2 16.8 "	8 31 "
25......	11 51.6	+ 2 57	7 20 "	1 35.2 "	7 50 "
			URANUS.		
Feb. 5......	14 15.7	— 13 5	12 04 A. M.	5 15 3 A. M.	10 26 A. M.
15......	14 15.6	— 13 4	11 21 P. M.	4 32.0 "	9 43 "
25......	14 15.2	— 13 2	10 42 "	3 52.3 "	9 03 "
			NEPTUNE.		
Feb. 5......	4 18.8	+ 19 48	11 50 A. M.	7 16.2 P. M.	2 43 A. M.
15......	4 18.7	+ 19 48	11 10 "	6 36.7 "	2 03 "
25......	4 18.8	+ 19 49	10 31 "	5 57.5 "	1 24 "
			THE SUN.		
Feb. 5......	21 15.7	— 15 55	7 15 A. M.	12 14.2 P. M.	5 14 P. M.
15.....	21 55.2	— 12 40	7 01 "	12 14.3 "	5 28 "
25......	22 33.6	— 9 04	6 45 "	12 13.3 "	5 42 "

Configuration of Jupiter's Satellites at 7:30 p. m. for an Inverting Telescope.

Feb. 1	3 4 2 ○ 1	Feb. 9	3 2 1 ○ 4	Feb. 17	3 ○ 4 1 2
2	4 3 1 2 ○	10	3 ○ 1 2 4	18	4 1 3 ○ 2
3	4 3 ○ 1 2	11	1 ○ 3 2 4	19	4 2 ○ 1 3
4	4 1 ○ 2 3	12	2 ○ 1 3 4	20	4 1 2 ○ 3
5	4 2 ○ 1 3	13	1 ○ 3 4 ●	21	4 ○ 1 3 2
6	4 1 ○ 2 3	14	○ 1 3 2 4	22	4 3 2 1 ○
7	4 ○ 3 2 ♃	15	3 2 ○ 4 ●	23	4 3 2 1 ○
8	3 4 2 ○ 1	16	3 2 1 ○ 4	24	4 3 ○ 1 2

The Satellites of Jupiter are invisible from February 24 until April 17, Jupiter being too near the sun.

Phenomena of Jupiter's Satellites.

	h m					h m			
Jan. 16	4 20	P. M.	I.	Ec. Re.	Jan. 31	4 34	P. M.	I.	Tr. Eg.
17	5 51	"	III.	Sh. Eg.		5 23	"	I.	Sh. Eg.
19	6 57	"	II.	Oc. Dis.		7 20	"	III.	Tr. In.
21	4 52	"	II.	Tr. Eg.	Feb. 4	7 37	"	II.	Tr. In.
	6 51	"	II.	Sh. Eg.	6	6 20	"	II.	Ec. Re.
22	5 44	"	I.	Tr. In.	7	5 02	"	I.	Sh. In.
	6 42	"	I.	Sh. In.		6 36	"	I.	Tr. Eg.
	8 02	"	I.	Tr. Eg.	8	4 34	"	I.	Ec. Re.
23	4 51	"	IV.	Oc. Re.	9	4 53	"	IV.	Ec. Dis.
	6 15	"	I.	Ec. Re.	13	4 56	"	II.	Oc. Dis.
24	6 16	"	III.	Tr. Eg.	14	6 21	"	I.	Tr. In.
	6 46	"	III.	Sh. In.	15	6 29	"	I.	Ec. Re.
28	4 48	"	II.	Tr. In.	18	6 31	"	III.	Oc. Dis.
	6 38	"	II.	Sh. In.	22	5 32	"	II.	Tr. Eg.
	7 39	"	II.	Tr. Eg.		5 41	"	I.	Oc. Dis.
29	7 46	"	I.	Tr. In.		6 29	"	II.	Sh. Eg.
30	5 04	"	I.	Oc. Dis.	23	5 12	"	I.	Tr. Eg.
	8 10	"	I.	Ec. Re.		5 39	"	I.	Sh. Eg.

Approximate Central Times when the Great Red Spot passes the Central Meridian of Jupiter.

	h m			h m			h m			h m	
Feb. 1	2 34	P. M.	Feb. 7	7 58	P. M.	Feb. 13	2 38	P. M.	Feb. 19	7 33	P. M.
2	8 30	"	8	3 30	"	14	8 25	"	20	3 24	"
3	4 21	"	9	9 17	"	15	4 16	"	21	9 11	"
4	10 08	"	10	5 08	"	16	10 03	"	22	5 02	"
5	6 09	"	11	1 09	"	17	5 54	"	23	12 55	"
6	1 51	"	12	6 45	"	18	1 46	"	24	5 41	"

Mr. Marth's Ephemerides of the Satellites of Saturn.

[From *Monthly Notices*, Nov. 1891.]

In this table the times have been changed from Greenwich Mean Time to Central Standard Time. The abbreviations *Rh.*, *Te.*, *Di.*, *En.*, and *Mi.*, stand for the names of the satellites Rhea, Tethys, Dione, Enceladus, and Mimas. The letters *a*, *b*, *c*, *d*, and *e*, stand for conjunctions of the satellites in order as follows: With the preceding end of the outer ring; with preceding end of planet's equatorial diameter; with center of planet; with following end of planet's diameter; with following end of ring. The letters *n* and *s* signify that the satellite at the time of conjunction is north or south of the point designated by the preceding letter; *Sh.* means that the shadow of a satellite is near the central meridian of the planet; *Ecl. D.* and *Ecl. R.*, the disappearance and reappearance of a satellite at beginning and end of an eclipse.

Jan. 1892.		
15	4.2 pm	Di dn
	6.4	Di en
	7.7	Mi as
	9.4	Te an
	9.7	En an
	10.8	Te Ecl. D
	11.7	Titan Ecl. D
16	1.1 am	Mi an
	2.1	Rh es
	2.3	Te dn
	4.1	En en
	4.3	Te en
	4.7	Rh ds
	5.1	Titan Ecl. R
	5.3	Rh Sh
	7.0	Mi en
	7.5	Titan c 11″.1 n
	8.5	Rh bs
	10.5	Titan dn
	6.3 pm	Mi as
	7.6	Di es
	8.0	Te es
	8.5	En as
	9.8	Di ds
	10.0	Te ds
	10.7	Di Sh
	11.0	Te Sh
	11.7	Mi an
17	12.9 am	Te bs
	1.1	Di bs
	2.9	Te as
	3.3	Di as
	6.7 pm	Te an
	8.1	Te Ecl. D
	10.3	Mi an
	11.1	En es
	11.6	Te dn
18	1.6 am	Te en
	4.2	Mi en
	4.4	Di an
	5.4	En as
	5.8	Di Ecl. D
	5.3 pm	Rh en
	5.3	Te es
	7.3	Te ds
	8.3	Te Sh
	8.9	Mi an
	9.8	En en
	10.2	Te bs
19	12.2 am	Te as
	4.0 pm	Te an
	4.4	Di Sh
	5.4	Te Ecl. D
	6.8	Di bs
	7.5	Mi an
	8.9	Te dn
	9.0	Di as
	10.9	Te en
20	12.4 am	En an
	1.5	Mi en
	4.6 pm	Te ds
	4.8	En es
Jan. 1892.		
20	5.0 pm	Rh ds
	5.6	Te Sh
	5.7	Rh Sh
	6.2	Mi an
	7.5	Te bs
	8.9	Rh bs
	9.5	Te as
	10.1	Di an
	11.2	En as
	11.5	Rh as
	11.5	Di Ecl. D
21	12.1 am	Mi en
	3.6	Di dn
	5.5	Mi es
	5.8	Di en
	6.2 pm	Te dn
	8.2	Te en
	10.7	Mi en
22	1.7 am	En es
	4.1	Mi es
	6.9	Di es
	4.8 pm	Te bs
	6.1	En an
	6.8	Te as
	8.7	Rh an
	9.3	Mi en
	9.9	Rh Ecl. D
23	12.5 am	En en
	2.7	Mi es
	3.1	Rh dn
	5.7	Rh en
	4.9 pm	En as
	5.0	Titan es
	5.2	Di Ecl. D
	5.5	Te en
	7.3	Titan Sh
	7.9	Mi en.
	8.8	Titan ds
	9.3	Di dn
	11.5	Di en
	11.8	Titan c 10″.8 s
24	1.3 am	Mi es
	2.7	Titan bs
	3.0	En an
	6.5	Titan as
	6.5 pm	Mi en
	7.5	En es
	11.9	Mi es
25	12.6 am	Di es
	1.8	En as
	2.8	Di ds
	2.9	Rh es
	3.8	Di Sh
	5.4	Rh ds
	5.8	Mi as
	6.1	Di bs
	6.2	Rh Sh
	7.9	Te an
	6.2 pm	En en
	10.5	Mi es
26	4.3 am	En es
	4.5	Mi as
Jan. 1892.		
26	6.5 am	Te es
	5.1 pm	Di en
	8.8	En an
	9.2●	Mi es
27	3.1 am	Mi as
	3.1	En en
	5.2	Te an
	6.7	Te Ecl. D
	3.5 pm	Rh dn
	6.0	Rh en
	6.3	Di es
	7.6	En as
	7.8	Mi es
	8.5	Di ds
	9.5	Di Sh
	11.8	Di bs
28	1.7 am	Mi as
	2.0	Di as
	3.8	Te es
	5.7	En an
	5.8	Te ds
	6.9	Te Sh
	6.4 pm	Mi es
	10.1	En es
29	12.3 am	Mi as
	2.5	Te an
	3.1	Di an
	4.0	Te Ecl. D
	4.4	En as
	4.6	Di Ecl. D
	5.7	Mi an
	7.4	Te dn
	3.2 pm	Rh es
	5.0	Mi es
	5.8	Rh ds
	6.6	Rh Sh
	8.9	En en
	9.7	Rh bs
	10.9	Mi as
30	12.2 am	Rh as
	1.1	Te es
	3.1	Te ds
	4.2	Te Sh
	4.3	Mi an
	6.0	Te bs
	5.4 pm	Di bs
	7.6	Di as
	9.5	Mi as
	11.4	En an
	11.8	Te an
31	1.3 am	Te Ecl. D
	2.9	Mi an
	4.7	Te dn
	5.8	En en
	6.7	Te en
	8.1 pm	Mi as
	8.8	Di an
	9.4	Rh an
	10.2	En as
	10.3	Di Ecl. D
	10.4	Te es
	10.8	Rh Ecl. D
	11.0	Titan Ecl. D
Jan. 1892.		
31	11.0 pm	Titan an
Feb.		
1	12.4 am	Te ds
	1.5	Te Sh
	1.5	Mi an
	2.3	Di dn
	3.3	Te bs
	3.9	Rh dn
	4.1	Titan Ecl. R
	4.5	Di en
	5.3	Te as
	5.8	Titan c 10″.6 n
	6.4	Rh en
	6.7 pm	Mi as
	9.1	Te an
	10.6	Te Ecl. D
2	12.1 am	Mi an
	12.7	En es
	2.0	Te dn
	4.0	Te en
	5.6	Di es
	5.2 pm	En an
	5.4	Mi as
	7.7	Te es
	9.7	Te ds
	10.8	Mi an
	10.8	Te Sh
	11.5	En en
3	12.6 am	Te bs
	2.6	Te as
	3.6	Rh es
	4.7	Mi en
	6.2	Rh ds
	7.1	Rh Sh
	4.0 pm	En as
	4.0	Di Ecl. D
	4.0	Mi as
	6.4	Te an
	7.9	Te Ecl. D
	7.9	Di dn
	9.4	Mi an
	10.1	Di en
	11.3	Te dn
4	1.3 am	Te en
	2.1	En an
	3.3	Mi en
	5.0 pm	Te es
	6.5	En es
	7.0	Te ds
	8.0	Mi an
	8.1	Te Sh
	9.9	Te bs
	11.3	Di es
	11.9	Te as
5	12.8 am	En as
	1.5	Di ds
	1.9	Mi en
	2.5	Di Sh
	4.8	Di bs
	3.7 pm	Te an
	4.2	Rh dn
	5.2	Te Ecl. D

Feb. 1892.		
5	5.3 pm	En en
	6.6	Mi an
	6.8	Rh en
	8.6	Te dn
	10.6	Te en
6	12.5 am	Mi en
	3.4	En es
	5.9	Mi es
	3.8 pm	Di en
	4.3	Te ds
	5.2	Mi an
	5.4	Te Sh
	7.2	Te bs
	7.8	En an
	9.2	Te as
	11.1	Mi en
7	2.1 am	En en
	4.5	Mi en
	2.5 pm	Te Ecl. D
	3.8	Mi an
	4.0	Rh es
	4.9	Di es
	5.9	Te dn
	6.5	Rh ds
	6.6	En as
7	7.1 pm	Di ds
	7.5	Rh Sh
	7.9	Te en
	8.2	Di Sh
	9.7	Mi en
	10.4	Rh bs
	10.4	Di bs
8	12.6 am	Di as
	1.0	Rh as
	3.1	Mi es
	4.7	En an
	3.1 pm	Titan es
	4.5	Te bs
	6.4	Titan Sh
	6.5	Te as
	6.9	Titan ds
	8.4	Mi en
	9.1	En es
	9.9	Titan c
		9".9 s
9	12.8 am	Titan bs
	1.8	Mi es
	1.8	Di an
	3.4	Di Ecl. D
	3.5	En as
9	4.6 am	Titan as
	3.2 pm	Te dn
	5.9	Te en
	7.0	Mi en
	7.9	En en
	10.1	Rh an
	11.8	Rh Ecl. D
10	12.4 am	Mi es
	4 6	Rh dn
	3.8 pm	Te as
	4.1	Di bs
	5.6	Mi en
	6.3	Di as
	10.4	En an
	11.0	Mi es
11	4.8 am	En en
	4.9	Mi as
	7.4 pm	Di an
	9.1	Di Ecl. D
	9.2	En as
	9.6	Mi es
12	12.9 am	Di dn
	3.1	Di en
	3.5	Mi as
	4.3	Rh es
	6.2	Te es
	6.9	Rh ds
	8.2 pm	Mi es
	11.8	En es
13	2.1 am	Mi as
	4.3	Di es
	4.8	Te an
	4.2 pm	En an
	6.8	Mi es
	10.5	En en
14	12.7 am	Mi as
	3.5	Te es
	5.5	Te ds
	4.9 pm	Rh dn
	5.4	Mi es
	6.6	Di dn
	7.5	Rh en
	8.8	Di en
	11.3	Mi as
15	1.1 am	En an
	2.1	Te an
	8.8	Te Ecl. D
	5.5 pm	En es
	9.9	Di es
	10.0	Mi as

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A................$0^h\ 52^m\ 32^s$
Decl.................$+ 81° 17'$
Period............$2d\ 11^h\ 50^m$

Feb. 1	midn.
6	"
11	11 P. M.
16	11 "
21	11 "
26	10 "

ALGOL.

R. A...............$3^h\ 01^m\ 01^s$
Decl................$+ 40° 32'$
Period............$2d\ 20^h\ 49^m$

Feb. 8	5 A. M.
11	2 "
13	11 P. M.
16	8 "
19	5 "

R CANIS MAJ.

R. A...............$7^h\ 14^m\ 30^s$
Decl...............$- 16° 11'$
Period............$1d\ 03^h\ 16^m$

Feb. 1	3 A. M.
7	7 P. M.
8	10 "
10	2 A. M.
11	5 "
16	9 P. M.
17	midn.
19	3 A. M.

R CANIS MAJ., CONT.

Feb. 24	8 P. M.
25	11 "
27	2 A. M.
28	6 "

S CANCRI.

R. A...............$8^h\ 37^m\ 39^s$
Decl...............$+ 19° 26^m$
Period...........$9d\ 11^h\ 38^m$

Feb. 6	7 P. M.
25	7 "

S ANTLIÆ.

R. A...............$9^h\ 27^m\ 30^s$
Decl................$- 28° 09'$
Period............$0d\ 07^h\ 47^m$

Feb. 2	8 P. M.
3	4 A. M.
4	3 "
5	2 "
6	2 "
7	1 "
7	midn.
8	11 P. M.
9	11 "
10	10 "
11	9 "
12	9 "
13	8 "
14	3 A. M.
15	3 "
16	2 "

S ANTLIÆ, CONT.

Feb. 17	2 A. M.
19	1 "
19	midn.
20	11 P. M.
21	10 "
22	10 "
23	9 "
24	8 "
25	8 "
26	3 A. M.
27	2 "
28	1 "
29	1 "
29	midn.

S LIBRÆ.

R. A...............$14^h\ 55^m\ 06^s$
Decl................$- 8° 05'$
Period............$2d\ 07^h\ 51^m$

Feb. 6	4 A. M.
13	4 "
20	3 "
27	3 "

U CORONÆ.

R. A...............$15^h\ 13^m\ 43$
Decl...............$+ 32° 03'$
Period............$3d\ 10^h\ 51^m$

Feb. 7	1 A. M.
13	11 P. M.
24	7 A. M.

Phases and Aspects of the Moon.

		Central Time.
First Quarter...	Feb. 5	$3^h 39^m$ A. M.
Full Moon..	" 12	1 38 P. M.
Apogee..	" 17	9 48 A. M.
Last Quarter...	" 20	6 15 P. M.
New Moon...	" 27	9 47 "
Perigee...	" 29	5 48 A. M.

Occultations Visible at Washington.

Date 1892.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean. T.	IMMERSION. Angle f'm N. P't.	EMERSION. Wash. Mean T.	EMERSION. Angle f'm N. P't.	Duration.
			h m	°	h m	°	h m
Feb. 5	13 Tauri	6	11 18	97	12 16	237	0 58
5	14 Tauri	6	12 05	127	12 43	209	0 38
7	118 Tauri	6	5 32	38	6 11	294	0 39
7	125 Tauri	6	12 09	43	12 55	319	0 46
12	η Leonis	3	5 52	65	6 37	295	0 45
12	42 Leonis	6	15 38	93	16 38	332	1 00

COMET NOTES.

Two comets are now in view. These are Wolf's periodic comet, which has been observed ever since its discovery by Barnard May 3, and the Tempel-Swift periodic comet found by Barnard, Sept. 27. Three other periodic comets are being searched for, but at latest reports, not yet found. These are: Brooks' 1886 IV, due at perihelion any time from Dec. 1, 1891, to May, 1892; Tempel's due Feb. 28; and Winnecke's due in June, 1892.

The course of the Tempel-Swift comet during January is eastward and southward through the northern part of the constellation Taurus. Jan. 5 and 6 it will be about 3° north of the Pleiades.

Wolf's comet is in the eastern part of the constellation Eridanus, moving slowly and growing fainter. Winnecke's should be found during January and *February* in the northern part of Virgo and southern part of Coma Berenices. Brooks' 1886 IV, according to Oppenheim's search ephemerides, should be found somewhere near a line passing through Coma Berenices, Virgo, Libra, Scorpio, and Sagittarius.

Search Ephemeris for Comet Brooks, 1886 IV.

(See also Sid. Mess., Dec. 1891, p. 517.)

	Perihelion April 30. R.A.		Decl.		Light.	Perihelion May 30. R.A.		Decl.		Light.
	h	m	°	′		h	m	°	′	
Jan. 21	13	35.2	+9	52	0.11					
Jan. 31	13	56.8	7	33	0.18	12	28.6	+25	35	0.28
Feb. 10	14	18.4	5	51	0.25	12	36.2	24	35	0.28
Feb. 20	14	39.8	+4	15	0.34	12	42.6	+24	25	0.39

Ephemeris of the Temple-Swift Periodic Comet.

[From Astr. Nach., No. 3068.]

Paris Midnight.		R.A.			Decl.		log Δ	Light.
		h	m	s	°	′		
Jan	1	3	15	04	+27	20.1		
	2		20	21	27	14.4	9.5408	
	3		25	33	27	09.0		
	4		30	41	27	03.3	9.5781	4.87
	6		40	31	26	51.9		
	8		49	54	26	37.9	9.5933	
	10	3	58	47	26	24.1		
	12	4	07	17	26	10.1	9.6289	3.23
	14		15	20	25	55.9		
	16		23	03	25	41.6	9.6644	
	18		30	24	25	27.4		
	20		37	26	25	13.6	9.6996	2.14
	22		44	10	24	59.9		
	24		50	40	24	46.6	9.7342	
	26	4	56	54	24	33.6		
	28	5	02	56	+24	21.0	9.7681	1.43

Ephemeris of Comet 1891 (Wolf's Periodic Comet).

(Continued from page 516.)

Berlin Midnight.	App. R. A.			App. Decl.		log r	log Δ
	h	m	s	°	′		
Jan. 2	4	14	34	− 14	05.1		
3		14	42	13	59.1	0.2989	0.0961
4		14	51	13	52.8		
5		15	02	13	46.2	0.3013	0.1044
6		15	15	13	39.4		
7		15	29	13	32.3	0.3037	0.1128
8		15	46	13	25.0		
9		16	03	13	17.5	0.3061	0.1211
10		16	22	13	69.7		
11		16	43	13	01.8	0.3085	0.1294
12		17	06	12	53.6		
13		17	29	12	45.3	0.3108	0.1376
14		17	55	12	36.8		
15	4	18	22	− 12	28.1	0.3132	0.1458

Ephemeris of Winnecke's Periodic Comet.

(From Astr. Nach .No. 3062.)

	App R. A.			App. Decl.		log r	log Δ	$\frac{1}{r^2\Delta^2}$
	h	m	s	°	′			
Jan. 16	12	31	53	+ 13	57.5			
17		32	47	14	03.1			
18		33	39		9.1	0.3564	0.2227	0.069
19		34	31		15.3			
20		35	23		21.7			
21		36	13		28.5			
22		37	02		35.6	0.3494	0.2020	0.079
23		37	51		42.9			
24		38	39		50.6			
25		39	26	14	58.6			
26		40	11	15	06.9	0.3422	0.1807	0.090
27		40	56		15.5			
28		41	40		24.4			
29		42	23		33.7			
30		43	04		42.3	0.3349	0.1590	0.103
31		43	45	15	52.3			
Feb. 1		44	24	16	03.6			
2		45	02		14.2			
3		45	39		25.2	0.3274	0.1368	0.118
4		46	15		36.6			
5		46	50	16	48.3			
6		47	23	17	00.4			
7		47	55		12.8	0.3197	0.1142	0.136
8		48	26		25.6			
9		48	55		38.9			
10		49	23	17	52.4			
11		49	49	18	06.4	0.3118	0.0913	0.156
12		50	14		20.8			
13		50	37		35.5			
14		50	59	18	50.7			
15		51	19	19	06.2	0.3036	0.0682	0.180
16		51	38		22.2			
17		51	55		38.6			
18		52	10	19	55.3			
19		52	23	20	12.5	0.2953	0.0448	0.209
20		52	34		30.1			
21		52	44	20	48.1			
22		52	51	21	06.5			
23		52	56		25.2	0.2868	0.0214	0.242
24	12	53	00	+ 21	44.4			

	App. R. A. h	m	s	App. Decl. °	′	log r	log Δ	$\frac{1}{r^2\Delta^2}$
Feb. 25	12	53	02	+ 22	04.0			
26		53	01		24.0			
27		52	58		44.4	0.2780	9.9981	0.281
28		52	53	23	05.2			
29	12	52	46	+ 23	26.3			

Orbit of Comet e 1891 (Barnard Oct. 2). From Barnard's observations of Oct. 2, 6 and 9 as given in the *Astronomical Journal*, Vol. XI, p. 63, I have computed the following elements.

$$T = \text{Nov. } 12.78463$$
$$\pi - \lambda = 268^\circ\ 43'\ 59''$$
$$\lambda = 216\ \ 57\ \ 37$$
$$i = 77\ \ 27\ \ 42$$
$$\log q = 9.98412$$

HARVARD COLLEGE OBSERVATORY, Dec. 4, 1891. O. C. WENDELL.

New Minor Planet No. 321. An asteroid of the 12th magnitude was discovered Nov. 27 by Borrelly at Marseilles. Its position Nov. 27. 3808 Gr. M. T. was: R A. $4^h\ 06^m\ 06.7^s$; Decl. + 23° 12′ 58″. Daily motion, —60^s and 7′ southward. This is probably No. 321.

Double Shadow of Jupiter's Satellite I. In regard to Mr. Hoffman's observation of the double shadow of Jupiter's Satellite I, reported in the last MESSENGER, permit me to say that I made a similar observation on the evening of Sept. 29, It was in transit nearing egress and it appeared as a white disk against the dark southern equatorial belt; following it was the usual shadow and at an equal distance from this was a second shadow, smaller and not so dark as the true one, and surrounded by a faint penumbra. It would seem to me that there is some intimate connection between this doubling of the shadow of Satellite I, as seen by Mr. Hoffman and myself, and the elongation or doubling of the satellite itself, as seen by Mr. Barnard on Sept. 8, 1890, and Aug. 3, 1891, and which he explains on the supposition of a white belt encircling the equator of the satellite. H. S. HULBERT.

Detroit, Mich.

Companion to the Observatory. This useful little Astronomical Almanac, for such it is, is at hand for 1892. It contains many valuable data not given in the great national almanacs, such as Times of Rising and Setting of the Moon and Longitude of Moon's Terminator, List of Principal Meteor Showers of the Year, Ephemeris for Physical Observations of the Sun, Maxima and Minima of Variable Stars, List of Double Stars suitable for small telescopes, etc. H. C. W.

August Meteors. On the morning of August 11, 1891, between $2^h\ 45^m$ and 3^h, 30 meteors were counted at the Southern Female College, La Grange, Ga., Mrs. I. F. Cox, President. All the meteors were small and white, but few showed trains.

Observing Auroræ. Mr. M. A. Veeder, Lyons, N. Y., has prepared a blank for observing Auroræ, and he invites general co-operation of astronomers and amateur observers in order to collect data for the more complete study of these phenomena. This is certainly important work, and many can aid in it. Send to him for blanks and instructions.

NEWS AND NOTES.

On further consideration it has seemed best to adopt ASTRONOMY AND ASTRO-PHYSICS as the name of this publication hereafter. On page 96 will be found suggestions and directions to correspondents to which attention is especially called.

In order to give large space to the subject matter of Astro-Physics, a number of articles on General Astronomy are deferred until our next issue. It will be our aim, as heretofore, to bring out as fully as we can, in the future, notices of current work in all branches of astronomy.

It has been strongly urged by some of the earnest amateurs who have been subscribers to the MESSENGER from almost the beginning of its publication, that, in our new departure, we do not forget their wants. They desire and should have notices of work adapted to small instruments, in order to know their field of work well and to contribute to it useful observation. The management of this publication acknowledges heartily and most cordially the large and very generous support which has steadily come to it from amateur astronomers. They shall be remembered, for this publication would not have been what it is, but for their persistent and intelligent aid.

New Naval Observatory.—In his annual report to the chief of the Bureau of Equipment, Navy Department, Capt. McNair, Superintendent of the Naval Observatory submits an estimate of appropriations required for the next fiscal year, as follows:

Approaches and grounds	$11,825
New Meridian Circle	10,000
Three new dwellings for Observers. (Each, $10,000.).	30,000
Repair shop and store house for instruments	4,000
Removal of magnetic instruments and buildings	3,500
Making in all a total of	$59,325.

The appropriation made for the current year was $136,689.

The plea for observers' dwellings on the new Observatory grounds made by the superintendent, though in strong language, is wisely urged.

The report of the Secretary of the Navy for 1891 also contains matter of very general interest to astronomers. This extract will show the tenor of it. Speaking of the New Naval Observatory and the transfer of the astronomical instruments, the Secretary says: "When the transfer and installment of the instruments are completed, the government will be in possession of one of the most admirably equipped observatories in the world. The question of the proper administration of this important charge, representing one of the most important branches of scientific investigation undertaken by the government, is one that demands early attention. The system in existence hitherto, by which the selection of the superintendent has been confined to line officers of the Navy, subject like other officers to changes of duty at comparatively short intervals, prevents that continuity of administration which is essential in carrying on the work of a great national Observatory. No programme of scientific investigation, especially in the department of astronomy, can be carried out successfully by any institution, if liable to frequent interruptions by a change of its administrative head.

"I therefore recommend the adoption of legislation which shall enable the President to appoint, at a sufficient salary, without restriction, from persons either within or outside of the naval service, the ablest and most accomplished astronomer who can be found for the position of superintendent."

"I would also recommend, in view of the era of progress and scientific development upon which the Observatory is now entering, that an advisory council be organized, composed of the Superintendent of the Observatory and its senior professor and of three other persons of scientific attainments, whose duty it shall *be to* consider and report upon new instruments and their proper installation; to draw up with such changes as may be necessary, from time to time, the programme of scientific work, including observation, reduction and publication, and to make such inspections and reports as may be desirable in regard to the character of the work done by the Observatory."

This report of the Secretary of the Navy contains the best of official statement of the proper administration of the Naval Observatory that we have ever seen. The recommendations are wise and opportune, and it is to be hoped that this matter will receive the attention of Congress at an early date.

Sirian and Solar Stars. As my prediction that the proper motions of the solar stars would prove to be greater than those of the Sirian stars of the same magnitude seems likely to be verified, I venture to give another consequence of my hypothesis which Professor Pickering's observations go some distance towards confirming. Reverting to my former illustration of a telescope whose range terminates at the average distance of a 12th magnitude star, let me turn it on a part of the sky where there are few, if any, stars at a greater distance than that of an average star of the 11th magnitude. In such a region the telescope will reveal nearly all the stars, and the relative numbers of Sirian and Solar stars will give their true proportions for that part of the sky, the Sirians showing a relative preponderance among the brighter and the Solars among the fainter stars. Let me then turn the same telescope to a region where there is a dense stratum of stars lying further off than the average distance of a 12th magnitude star. A considerable number of the Sirian stars belonging to this stratum will be visible, while few, if any, of the corresponding Solars will be detected. The proportion of Sirian stars will thus appear to exceed the true amount, and the relative preponderance of Sirians will be greatest in the case of the fainter stars. This seems to me to afford the true explanation of the relative preponderance of Sirian stars in the Galaxy. It arises from the greater depth of the stratum of stars, and probably its increasing richness down to the point where the light becomes too faint for spectroscopic observation.

Dublin, Nov. 28. W. H. S. MONCK.

The Lick Observatory and its Work.—From the notice of a late meeting of the Astronomical and Physical Society of Toronto, Canada, published in the *Mail* of Nov. 21, it appears that Mrs. R. A. Proctor gave an illustrated lecture before the society, on the Lick Observatory and its Work. The stereopticon views included those of the great telescope, spectroscope, transit instrument, observatory in Summer, in Winter, in cloud, in sunshine, the offices and cottages of the observers, Mount Hamilton, the approaches to the buildings and views of beautiful scenery in different parts of the mountain taken by Mr. Burnham. It appears that Mrs. Proctor was for several weeks the guest of the professors at the observatory and that she had exceptional privileges in the use of the telescopes. Mrs. Proctor's lecture was heartily enjoyed and highly commended by prominent members of the society.

Note on the Measurement of Solar Prominences. Two interesting communications have recently been made to the French Academy regarding the aberration of light. In one of these M. Mascart* has done good service in calling attention to the fact that, as yet, we have no direct experimental proof that light travels with the same velocity throughout known space, if we may so denominate the space between us and the most distant of observed stars.

Both Arago and W. Struve were in error, the author points out, in supposing that the invariability of the "aberration constant" from one star to another was sufficient evidence from which to conclude that light travels with invariable speed everywhere in free space, because the difference between the apparent and true direction in which any luminous point is seen depends only upon the ratio of the velocity of light *in the tube of the telescope* to the velocity of the observer.

It might have been added that these velocities are to be measured from any origin of coördinates provided only that this origin is not moving with reference to the medium in which the light is propagated.

All this is strictly analogous to saying that when a sail-boat is just getting under weigh, the apparent change in the quarter from which the wind is blowing depends only upon the velocity of the wind *as it strikes the sail* and upon the velocity of the boat, but not at all upon the source of the wind.

Mascart also calls attention to a remark of Villarceau in which he shows for the first time that the "Constant (?) of aberration" ought to vary from one star to another on account of the motion of the solar system through space. Returning to our nautical analogy, this is equivalent to saying that if one wished to compute the shift of the wind toward the bow of the boat, he would not measure his velocities from a balloon, or from any object floating with the tide, but rather from a fixed buoy.

By this note of Mascart's one's attention is naturally recalled to the other communication by Fizeau,† who after pointing out that the velocities attained by the gases which make up solar prominences are quite comparable to that of the earth in its orbit (30.6 kilometers per second), goes on to remark that:

"Il résulte de ces données que, si une protubérance se développe dans le voisinage de l'ecliptique avec une vitesse de translation de gaz lumineux égale à cette même vitesse de 30.6 km. par seconde, le lieu de la protubérance subira un effet propre, c'est-à-dire un déplacement apparent de ± 20″.445, lesquelles pourront s'ajouter à l'effet précédent ou s'en retrancher suivant les circonstances de direction, en donnant lieu à des variations correspondantes des distances au bord solaire."

So far as can be seen, the author here neglects the fact that, at any given instant, each point of the solar disk and of the prominence, whether in motion or at rest, is sending to the observer rays all of which are affected by the same correction for aberration. I say the "same" correction since the change in celestial longitude or latitude from one part of the sun's surface to another would affect the aberration quite inappreciably.

If there be relative motion among the parts of the prominence, then since at any instant aberration affects all these parts to the same extent, the prominence will be projected upon the slit of the spectroscope in its true proportions.

If any apology is needed for calling attention to an error of this type it is that the error is one which may for somebody needlessly complicate the study of the solar surface, and is especially misleading when supported by a name of such well-earned distinction as that of Fizeau.

---

* Comptes Rendus, t. 113, p. 571 (1891).

† Comptes Rendus, t. 113, p. 353 (1891).

In this connection I may perhaps be pardoned for calling attention to still another error, rather insidious, and one to which students unfamiliar with the theory of the grating are especially liable. The only warning against it that I have seen is given by Professor Young (*Sun*, p. 191). The error is this: A micrometer screw in the eye-piece of a spectroscope is sometimes evaluated by looking at the slit directly through the collimator, with the view-telescope. In this way, a revolution of the micrometer head may be determined either in terms of the screw which opens the slit or in angular measure by the transit of a star.

If, now, the instrument be used with a grating to measure the angular height of a prominence, one might very naturally run the micrometer wire from the base to the top of the prominence and apply the *same* micrometer constant which he had just obtained. But such a measure would be very wide of the mark for the reason that a slight variation in the angle of incidence does not produce an equal variation in the angle of diffraction.

This will be seen immediately in differentiating the ordinary equation for the plane reflection grating

$$\sin \theta \pm \sin \gamma = \frac{\varkappa \lambda}{\varepsilon}$$

where θ = angle of diffraction,
γ = angle of incidence,
λ = wave-length at which the prominence is observed,
$\varkappa$ = order of spectrum employed,
ε = grating space.

Here $\frac{\varkappa\lambda}{\varepsilon}$ will be a constant for any given line in any given order, and hence:

$$\frac{d\gamma}{d\theta} = \mp \frac{\cos \theta}{\cos \gamma}$$

$d\gamma$ here, of course, represents the angular width of the slit which just includes the prominence, while $d\theta$ is the *apparent* width as measured by the micrometer eyepiece. The true height of the prominence will therefore be apparently increased or diminished, and in the ratio indicated according as the grating is used so as to make $\theta < \gamma$ or $\theta > \gamma$. HENRY CREW.

Lunar Eclipse of Nov. 15, 1891. This eclipse was observed at the Boston University Observatory with the 7-inch Clacey refractor, power 100.

Throughout nearly the entire eclipse the sky was clear and the seeing excellent. Near the close the sky became cloudy, and the second external contact could not be observed. The tints upon the Moon during totality were those usually observed, and styled "copper colored," though upon some portions there was a decided brick-red tint, and at times the appearance suggested a blood orange with the outer skin removed.

Several occultations were well determined, but I wish at present to call attention to those only which presented certain striking, although not new phenomena. "Optical illusion" may account for all, but optical illusions are not without cause, and it would seem that the phenomena should, in part, at least, depend upon the angle under which the star approaches the moon's limb.

DM. + 17°.572 approached the limb very obliquely. While skirting the limb, nearly parallel to it, the star was lost for an instant, and, after re-appearing, it seemed to hang upon the edge for about one second, and then to pass on to the face of the moon about four times its own diameter, and to run along still nearly parallel to the limb for about three seconds. All this time the star and the limb were clearly defined. The disappearance at $6^h\ 49^m\ 33^s.4$ W. M. T. was absolutely sudden.

DM. + 17°.573 approached the Moon at a high angle, seemed to pass upon the limb at a distance about three times its own diameter, without becoming indistinct, and disappeared suddenly at $6^h\ 54^m\ 18^s.5$.

Another star of about the ninth magnitude disappeared in the same manner as the one last named, a very little north of it, at $6^h\ 56^m\ 6^s.7$.

There were other stars whose disappearance was not entered as "sudden," but when a faint star approaches the dimly illuminated Moon it does not seem at all strange that the eye, wearied with watching, should anticipate the contact, and, as a result the star will seem to hang upon the limb of the moon for a short time before disappearing. In the three cases cited above there was nothing to distract in any way the observer's attention, and the apparent movement of the star along upon the Moon's disc was so distinct, especially in the first instance, and the observation so deliberate that, did it not seem to contradict all facts, no one would have thought for a moment of entering the observation as doubtful.

DM. + 17°.564 approached the Moon under about the same angle as DM. + 17°.573, and at near the same point, thus the conditions of the instrument and observer being the same, similar phenomena might have been expected. However the disappearance of 17.564 was absolutely sudden. To be sure it is brighter than 17.573, but its occultation occurred with fully one-half the Moon still clear, and that of 17.573 during totality.

At $6^h\ 23^m\ 16^s.3$ a star that seemed to be moving along a line tangent to the Moon at the north point was lost for a moment near the point of tangency, but soon became distinct again and so remained. The outer curve of the advancing shadow was not observed to present any distinct irregularities of outline save in one instance. At $6^h\ 10^m$ the outline of the shadow seemed to curve *inward* at a point directly eastward from the west point. The eye was removed from the tube and, on returning, the phenomena was none the less distinct, and so continued long enough to be carefully noted. This may be most easily explained by calling it an "optical illusion," but why it should appear at this time and place is not evident. If I remember correctly, I was not, at the time of noticing the inward curvature engaged in examining the outline of the shadow, but the phenomenon was so distinct as to attract the attention.

The stars above referred to were taken from the list in THE SIDEREAL MESSENGER for October, and the identification is believed to be correct, although I have not as yet found time to make the computations necessary to the removal of all doubt, since some stars were observed not given in the list referred to above. The position of the instrument is given in THE MESSENGER for June, 1891. The times were taken from a sidereal chronometer by an assistant, while another made a note of the observations.

J. B. C.

Observations of the Partial Phase of the Total Eclipse of the Moon November 15, 1891.—The following observations of the contacts of the shadow with some of the craters were made with the 12-inch equatorial. They are in Mt. Hamilton mean time:

$5^h\ 11.9^m$	Bisection of Tycho.
" 15.6	" " Copernicus.
" 24.3	" " Plato.
" 31.0	" " Manilius.
" 38 5	" " Plinius.
" 39.2	" " Posidonius.
" 51.4	" " Mare Crisium. Somewhat uncertain; that portion of the mare in shadow not seen.
" 52 9	Contact with the preceding end of Mare Crisium.
" 55.9	End of Totality. Pretty fair.

A slight haze and twilight prevented any details being seen in the shadow, though the obscured limb of the Moon was visible during the half phase. There was a slight coloring of red to the portion nearer the middle of the shadow.

MT. HAMILTON, November 15, 1891. E. E. BARNARD.

Disappearance of the New Red Spot on Jupiter; The Great Red Spot and Other Jovian Phenomena. The new oblong red spot which has been visible on Jupiter since last year, on a parallel just south of that of the Great Red Spot, has disappeared.

In THE SIDEREAL MESSENGER for October, p. 413, I have given some account of this object, and the present observations will serve to complete its history.

In the last of October of this year it had attained its maximum distinctness. It was then by far the most conspicuous and striking object on the planet and was of a strong reddish color. It then began to fade rather rapidly, and was scarcely discernible on Nov. 20. On Dec. 14 no trace of it could be seen.

At its maximum it strongly reminded one, in color and intensity, of the Great Red Spot in 1880.

Throughout the past opposition of Jupiter I have carefully observed and measured this singular spot. From these measures, there is no evidence whatever that it changed its latitude during the observations.

Following are micrometer measures with the 12-in. of the distance of the spot from the south and north limbs of Jupiter, reduced to distance 5:20:

Date.	S. Limb.	N. Limb.	Date.	S. Limb.	N. Limb.
	″	″		″	″
1891 July 13	9.5	27.1	1891 Aug. 28	8.8	26.5
25	9.0	27.4	Sept. 16	8.6	26.5
30	8.6	27.0	18	8.8	26.7
Aug. 23	9.0	26.8	Oct. 6	8.7	26.7

On November 20 the spot transitted at $8^h\ 2^m$ Mt. Hamilton mean time, and its corresponding longitude was 119°.9.

The Great Red Spot is gradually becoming more distinct in its form and intense in its color. On Dec. 14 it was strongly marked and quite red. It is now again slackening in its rotation period. During the past opposition its longitude remained quite constant for a number of months at about 3°. (See SID. MESS. for Oct., 1891.) An observation on Dec. 14 made its transit at $5^h\ 5.3^m$ Mt. Hamilton mean time and the resulting longitude = 6.4°. At this observation one of the bright round spots was on the same meridian with the center of the Red Spot and just skirting its south edge.

The remarkable rapidly moving black spots which appeared on the thin faint belt north of the north equatorial band during the past opposition, have ended their existence by forming a new heavy belt from the thin faint one on which they first appeared, an exact repetition of the performance of the black spots which appeared in the same latitude in 1880. The present phenomenon, however, lacked much of the remarkable transformation of 1880. The new belt at the observation of Dec. 14, this year, was identical in appearance with the north equatorial belt.

At the last observation a number of very singular oblong masses were visible stretching across the south polar region in a high south latitude.

MT. HAMILTON, Dec. 15, 1891. E. E. BARNARD.

Peculiar Appearance of Jupiter's Fourth Satellite. On the afternoon of the 12th instant, Satellites III and IV crossed the disc of Jupiter in company; not a very frequent occurrence. Transit and egress took place at 5:19 and 6:22 W. M. T. respectively. The following reports respecting a peculiarity marking the egress of IV were read at the last meeting of the Astronomical and Physical Society of Toronto. Mr. G. E. Lumsden of Toronto, who observed with a 10¼-inch With mirror, stated that III emerged from the disc without noteworthy feature; that after it was clear he saw IV on the disc near the limb, as an elliptical dark object with a heavily shaded edge towards the planet's center, but that for nearly an hour after egress he could not be positive that he saw IV at all, though he detected certain brownish light, straggling, as it were, between Jupiter and III. Emergence was not observed. The sky was very hazy, but at no time sufficiently so as to entirely obscure planetary detail; the Great Red Spot, though badly defined, was fairly well seen. Satellites I, II, and III were very distinct, yellow in color and of equal brightness. About 7:35 IV was glimpsed as a reddish-brown ball half way between the planet and III and, apparently, at an enormous distance beyond them. Not much difference was detected in the aspect of the moons up to 8:30, when observation ceased. Even at that time IV looked like a satellite, coming out of eclipse,—as a brownish ball. Mr. J. C. Donaldson, LL. D., of Fergus, sixty-five miles north of Toronto, who had a clear sky, wrote: "On coming back to the telescope (a 3½-inch refractor, by Cooke), about 6:35, I fancy I saw that IV had emerged from transit, and I could not help noticing the great contrast in color between it and III and Jupiter itself, IV being of a dark bluish color, apparently so dark, in fact, that when I tried a 2¼-inch glass upon it I could scarcely detect it at all. In the larger glass the sight was very interesting, the two satellites looking almost like a close double-star of complementary colors, III being of a golden yellow, and IV of a dark blue color." In the discussion which followed it was suggested that the bluish color seen by Dr. Donaldson might have been due to the use of a refractor. One of the members was curious to know whether the possible projection of IV against the shadow of III could have had anything to do with the appearance of the former; in other words could IV, as seen from the earth, be brought into contact with III's shadow cone, which was more or less illumined by the planet in front of whose face the shadow fell. G. E. L.

I may say with regard to the above that, as satellite IV had just emerged from transit across the face of the planet, it was between the sun and Jupiter, (the transit of its shadow occurred a few hours later), and, being the outermost satellite, could not possibly come into contact with the shadow of any of the other satellites.

I have in my observing book several notes which indicate the varying color and brightness of this satellite, one on the same night with the observations of Mr. Lumsden and Dr. Donaldson. I will give some account of these next month.

H. C. W.

Dark Transit of Jupiter's Satellite III.—I noticed a dark transit of Jupiter's Satellite III, Dec. 19, at 8:15 P. M., Detroit, (Mich.) local time. The Satellite was intensely black and was closely following the great red spot, but owing to the exceedingly poor definition, I was unable to determine whether it was actually projected on the red spot or not. After egress, the satellite appeared very small and faint, certainly not brighter than 8th magnitude, and of a dull reddish brown color. H. S. H.

Dark Transit of Jupiter's Satellite III. On the evening of Dec. 19, $5^h 10^m$ (Central Time), I observed the transit of Satellite III. I anticipated a well-defined bright image but instead there appeared an ill-defined *dark* image which rapidly grew more distinct, and as its path was on the southern dark belt, the satellite, although plainly seen, was not as clean cut and striking as if it had traversed a lighter back ground. Observation continued during the entire transit. After emergence the full round disk was well shown against the sky, but far less brilliant than any of her other three sisters. Power 300. Lat. 38° 29′: Long. 85° 45′. WILLIS L. BARNES.

Charlestown, Ind.

Solar Parallax.—In No. 3066 of the *Astronomische Nachrichten*, Dr. Auwers has published the results obtained from the heliometer measures made by the German Transit of Venus Expeditions in 1874 and 1882. The stations and measures were as follows:

1874.	Tschifu,	96	measures.	1882.	Hartford,	128	measures.
	Kerguelen Island,	65	"		Aiken,	48	"
	Auckland "	97	"		Bahia Blanca,	112	"
	Mauritius	50	"		Punta Arenas,	158	"

From the 307 measures during the transit of 1874 the resulting parallax comes out 8.873,″ and, from the 444 measures in 1882, 8.883.″ Combining these Dr. Auwers gives as the result $\pi = 8.880''$ ± 0.022.″

This result is larger than any other obtained from the transit of 1882, excepting possibly that from the French observations, which we have not at hand at this moment. Professor Harkness obtained from 1475 photographs of the transit of 1882, by the United States Expeditions, $\pi = 8.842''$ ± 0.012″. From the British observations of contacts Mr. E. J. Stone obtained 8.832″, and from the Brazilian observations, Mr. Cruls obtained 8.808″. The results from the transit of 1874 ranged from 8.75″ to 8.93″.

Recently Dr. H. Battermann, at Berlin, has determined the solar parallax from occultations of faint stars by the moon during eclipses and near new moon. He gets from 250 occultations, from April, 1884, to October, 1885, $\pi = 8.794''$ ± 0.016″. H. C. W.

Diameters of Sun and Venus. In *Astr. Nach.*, No. 3068, Dr. Auwers gives a discussion of the heliometer measures of the diameters of the sun and of Venus, by the German Transit of Venus expeditions. He gets for the diameter of the sun, at its mean distance, 1919.26″, from measures by twenty-nine observers. The probable error of this result is ± 0.09″. The personal equation of the observers has, however, a wide range, from + 1.03″ to − 0.88″, so that the mean error of a single measure when those of all observers are combined, is ± 0.69″, while that for a single observer is ± 0.49″.

The diameter of Venus from seventeen complete measures by 11 observers comes out 63.406″ at a distance whose logarithm is 9.422261, or 16.76″ at the mean distance of the sun. Applying corrections for personal equation Dr. Auwers gets 16.801″ as the most probable value for the diameter of Venus at distance unity. H. C. W.

Dark Structures in the Milky Way. During the last year *Knowledge* has been giving some most excellent full page plates of stellar photographs, by Mr. Barnard of Lick Observatory, Dr. Max Wolf of Heidelberg, and others. Almost every number has contained one or more of these large and beautifully printed plates, showing some interesting regions of the sky, especially in and about the Galaxy. The December issue has a fine specimen, an enlarged photograph taken by Dr. Max Wolf with a Kranz Aplanatic camera of 5¼ inches aperture and a focal length of 30⅛ inches. The exposure-time was $11^h 7^m$. The process was direct photo-engraving and the region was the Milky Way about ξ Cygni. The interesting tree-like structure in this picture made by adjacent dark spaces is very noticeable.

The Great 40-Inch Telescope. By recent private letter from Messrs. Alvan Clark & Sons, Cambridgeport, Mass., we learn that they have every reason to believe that they will soon be able to begin work on the great 40-inch refractor for southern California. The crown disk is already in hand and it is thought to be the finest piece of glass that these skilful opticians have ever seen. The delay in obtaining the flint disk is due to the unsuccessful attempt of Mr. Mantois of Paris, in moulding it. He has another block ready for firing. Under date of Sept. 10 he wrote as follows:

"Je me suis mis de suité au travail de l'autre bloc dont je vous avais parlé et qui etait reste in arrives. Je vais le pousser avec toute l'activité possible et bientot vous aurez de bonnes nouvelles."

It is the purpose of the Clarks to begin grinding the 40-inch lenses as soon as the flint disk is received. The prisms for the Bruce Photographic Telescope are already well under way.

BOOK NOTICE.

Worcester's Comprehensive Dictionary. New Edition. 688 pp. Messrs. J. B. Lippincott & Co., Publishers. Philadelphia, Pa.

Especial attention is called to the new edition of this Dictionary which is provided with Denison's patent index. I do not see how this book could be improved. It is most convenient in form and size and the index makes it a very ready reference-book. The page is clear, of good print, and ample illustration. It is suited to our use as well as any other larger or smaller lexicon. The last page of it contains the pronunciations of the names of 192 stars and constellations, mostly of Arabic origin, which so severely troubles everybody as to make them usually afraid to call prominent stars by their well-known names.

PUBLISHER'S NOTICES.

The subscription price to ASTRONOMY AND ASTRO-PHYSICS in the United States and Canada is $4.00 per year, in advance. For foreign countries it is $4.40 per year. Payment should be made in postal notes or orders or bank drafts. Personal checks for subscribers in the United States may be used.

Currency should *always* be sent by registered letter.

Foreign post-office orders should be drawn on the post office in St. Paul, as Northfield is not a foreign money order office.

All communications pertaining to Astro-Physics or kindred branches of Physics should be sent to George E. Hale, Kenwood Astro-Physical Observatory, Chicago, Ill.

All matter or correspondence relating to General Astronomy, remittances, subscriptions and advertising should be sent to Wm. W. Payne, Goodsell Observatory, Northfield, Minn.

Manuscript for publication should be written on one side of the paper only, and *special care should be taken to write proper names and all foreign names plainly*. It is requested that manuscript in French or German be type-written. If requested by the authors when articles are sent for publication, *twenty-five* reprint copies, in covers, will be furnished free of charge. A greater number of reprints of articles can be had, if desired, at reasonable rates.

Rates for advertising and rates to news agents can be had on application to the publisher of this magazine.

GENERAL ASTRONOMY.

NEW SERIES, No. 2. FEBRUARY, 1892. WHOLE No. 102

ARE THE COMETS, OR ANY PORTION OF THEM, EVER REPELLED BY THE SUN?*

GEORGE W. COAKLEY.†

This question may be determined by considering the relative forms of orbits, with reference to a center of force, described under the influence of attraction towards such center, or of repulsion from it.

In the "Text-Book of General Astronomy for Colleges and Scientific Schools," by Professor Charles A. Young, of Princeton, Articles 402, 403, etc., there is a demonstration of the fact that a body, acted upon by a center of force, whether of attraction or repulsion, and varying according to any and all laws with regard to the distance from that center, will always describe equal areas in equal times, and will also be confined to a single plane. But the contrast in the forms of the orbit, between the case of attraction towards the center of force, and that of repulsion from it, is not sufficiently noticed in that demonstration, nor completely exhibited by the limited figure employed. The following figures are, therefore, intended to emphasize this contrast of form in the two kinds of orbit, without repeating what Professor Young has sufficiently proved with regard to the equality of areas, and the identity of the orbit's plane. In Fig. I. let S represent the Sun, or any other center of attraction, varying according to any law whatever as to mass and distance. Let AB represent the direction and velocity of a body, or the space that would be described uniformly in the unit of time, any arbitrary unit. If the body is not affected by any external force, it would proceed in the next unit of time to describe the equal distance BB' in the same direction. But if S now exerts an attractive force which would alone carry the body to the distance BB'' towards S in this second unit of time, then the body will describe the diagonal BC of the parallelogram $B'B''$. If no further action of S upon the body is exerted, then at the end of the third unit of time it will

---

* Communicated by the author.

† Professor of Astronomy and Mathematics, University of the City of New York.

describe, in the direction BCC' a distance CC' equal to BC. But if the center of force at S should, in this third unit of time, cause the body to describe the distance CC'', when acting alone, then the body will describe, in this time, the diagonal CD of the parallelogram $C'C''$. In like manner the diagonals DE, EF, etc., would be described in the fourth, fifth, etc., units of time:

It is clear that these successive diagonals will form a polygonal line *enclosing* the center of attraction, S, within it. This line will be *concave* towards the center of force, in every possible case of attraction.

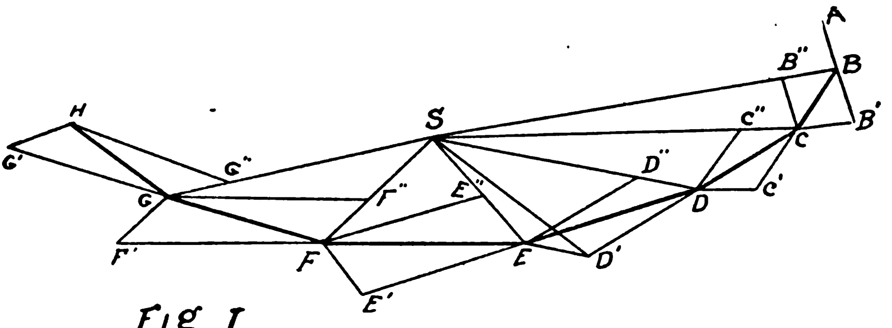


Fig. I.

If now the unit of time be chosen, successively smaller and smaller, the successive impulses of attraction towards S will be more and more frequent, the sides of the polygonal line becoming constantly shorter. Finally, if the intervals of time become infinitesimal, the sides of the polygonal line will also be infinitesimal, and it will melt into a continuous curve, when the attractive force is continuous, the curve being, if we choose to consider it so, the *limit* of the polygonal line; and the continuous action of S, the limit of its successively decreasing impulses. This curve, it is evident, is in all cases of attraction, *concave towards the center of force*.

In Fig. II. let S be any center of repulsion, and let AB represent the distance and direction described by a body in any unit of time when not acted on by any external force. Then in the next unit of time it would, under similar circumstances, describe, in the same direction, an equal distance BB'. But if, at the beginning of this second unit of time, the body were repelled from S, in the direction SBB'', to the distance BB'', in the unit of time under the action of S alone, then the body would describe the diagonal BC of the parallelogram $B'B''$.

In a similar manner the body, in the third, fourth, etc., units of time, would describe the diagonals *CD, DE*, etc., of the parallelograms *C′C″*, *D′D″* etc.

Hence the polygonal line *ABCDE*, would be described, having the center of force, in all cases of repulsion, on the outside, or the *convex side* of the polygonal line. It is evident also, that when the intervals of time are made infinitesimal, the sides of the polygonal line become also infinitesimal, or melt into a continuous curve, still convex to the center of repulsion.

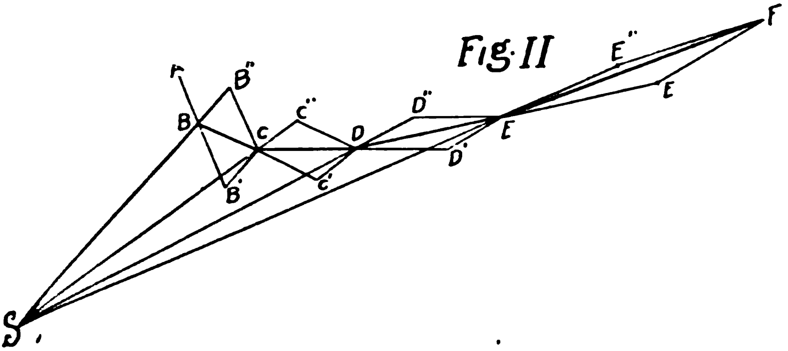


Fig. II

In the case of attraction we also know that the concave curve may become re-entrant, as a circle, ellipse, or other closed curve, with the center of force somewhere within the enclosure; or it may be a curve like the parabola, with branches on each side of its axis, proceeding to infinity and ultimately practically parallel; or, again, it may be a curve, like the hyperbola, with branches on each side of its axis diverging always towards infinity. But in every such case of attraction, the center of force is *within* the curve.

In the case of repulsion, however, no closed curve is possible. It is always either an exact hyperbola, of the conic sections, or some curve, more or less resembling the hyperbola in form, with the center of force always exterior to the curve.

As illustrations of these general laws of attraction and repulsion with regard to any center of force, and the forms of the orbits described under their influence, it may be permitted to state some of the results obtained by assuming certain particular laws of attraction and of repulsion. It is well known that the Newtonion law of attraction, applied to the Sun, and any smaller mass, may give either a circular orbit, with the Sun at the center, or an ellipse of any excentricity, with the Sun at one of the foci, or a parabola, or hyperbola, with the Sun at a focus, *within the orbit.*

The planetary orbits, as well as some of the orbits of comets, illustrate the closed, or elliptical forms, and some of the cometary orbits may possibly illustrate also the parabolic and hyperbolic forms, but in all these cases the orbits are concave to the center of force.

In a preceding number of THE SIDEREAL MESSENGER, No. 97, August, 1891, will be found the proof that if the Sun be regarded as a center of repulsion, whose intensity is directly as the sum of the masses, and inversely as the square of the distance, or the Newtonian law, except that attraction is replaced by repulsion, then the only orbit possible with this law is the hyperbola of the conic sections, but the Sun occupying the focus *external* to the hyperbolic branch described. Hence the orbit, in this case, is convex to the Sun, or to the center of force.

By a process entirely similar to that employed in that article of THE MESSENGER, the cases both of attraction and repulsion when the intensity of the force varied directly as the mass, and also directly as the distance from the Sun, were investigated. It was found, as was well known previously, that in the case of attraction according to this law, the orbit is an ellipse with the Sun *at the center*, instead of at one of the foci, and that the time of a revolution is constant for ellipses of all sizes.

It was also found that in the case of repulsion by the Sun, directly as the mass, and directly as the distance, the orbit is the conic hyperbola, with the Sun also at the hyperbola's center, instead of at either focus; and hence the Sun is outside the orbit in this case, or the orbit is convex to the center of force. This is evident since the hyperbola's center lies midway between the vertices of its two opposite branches.

The next two cases, one of attraction, the other of repulsion, investigated in a similar manner, were on the supposition that the laws of attraction and repulsion respectively were directly as the mass and inversely as the *cube* of the distance.

The equation of the orbit found, in the case of attraction according to this law, is

$$r = \frac{a}{\cos(n\theta)},$$

where $r =$ the radius-vector, $a =$ the perihelion distance, $\theta =$ the variable angle made by r with the axis, which is the line from the Sun to the perihelion point, and $n < 1$ in the case of attraction.

On projecting the curve, with any value of $n < 1$, as $n = \frac{1}{2}$ for example, it is readily seen to be concave towards the Sun.

Curiously enough, in the case of *repulsion*, according to this law the equation of the orbit is found to be of the same form, viz:

$$r = \frac{a}{\cos(n\theta)}$$

with similar meanings of r, a and θ, but with $n > 1$. This curve also, being projected, with any value of $n > 1$, gives a curve always convex to the Sun. In fact the curve representing the Sun's attraction according to the inverse cube of the distance, resembles somewhat a parabola with infinite parallel branches proceeding from the perihelion point, though it is not the ordinary parabola of the conic sections; while the curve representing the Sun's repulsion with the same law resembles the hyperbola, with its constantly diverging arms, though this also is not the ordinary hyperbola of the conic sections.

Having now demonstrated, and illustrated in several cases the important laws, that every orbit relative to the Sun as a center of *attraction* is necessarily *concave* to that centre of force; and secondly, that every orbit relative to the Sun as a centre of *repulsion* is necessarily *convex* to the same centre of force; it remains to apply these laws to the well known forms of the cometary orbits in order to answer the question at the head of this paper. Of course no astronomer will maintain that the nucleus and head of a comet that has just passed around the perihelion point of its elliptical, parabolic or even hyperbolic orbit, with the Sun at the focus of the orbit, within the curve, has not been subject to the Sun's *attraction* at every point of its path. The nucleus and head, it will be granted, have described a curve wholly *concave* towards the Sun. Not only so, but every point of its path has been determined, and can be computed solely by the great Newtonian law of the Sun's attraction. Any variation of this law, in kind, or in amount, would determine a wholly different curve. It is well known that after three geocentric right ascensions and declinations of the nucleus of a comet have been observed with considerable accuracy, even if they are only a few days apart, an astronomer can compute the path which the comet will travel among the fixed stars, and thus have an ephemeris, or catalogue of its daily position, by which he can follow it as long as the telescope will show it. He points his telescope each night upon the place marked in his ephemeris, and which places have been computed solely on the supposition that Newton's law of attraction is invariable. Had there been any defect in that law it would be impossible to find the comet on pointing the telescope to the place marked in the ephemeris. For the comet would have departed from the computed orbit, and pursued a quite different path, in obedience to the new law of attraction, or repulsion. It is presumed therefore that all intelligent astronomers will agree that Newton's law of attraction between the Sun, and the nucleus and head of the comet, has been implicitly obeyed by these parts of the comet, from its first distant appearance in the telescope to its perihelion passage, and afterwards until it has disappeared beyond the reach of the telescope.

Moreover, when a comet is first seen at the greatest distance at which it may be discovered by the telescope it usually presents a round, nearly circular disk, and the whole comet then moves down towards its perihelion, just as a planet would do if describing an orbit with the same excentricity. There is at that time no sign or suspicion of any repulsion by the Sun of any part of the comet. But on a nearer approach to the Sun, while running down to its perihelion, the phenomenon of a train, or so-called tail, is developed, generally directed away from the Sun. It is principally to account for this phenomenon that the theory of repulsion by the Sun, on at least a portion of the cometary matter, has been proposed. If this phenomenon can be explained in accordance with known laws, there would seem to be no sound scientific reason for invoking any repulsion on the part of the Sun, especially as all the other astronomical forces are the *attractions* arising from Newton's law of Gravitation.

For the sake of argument however, let it be granted that the matter forming the train projected behind it, while the comet is running down to its perihelion, is repelled by the Sun, instead of being attracted. What would be the consequence? The nucleus and head of the comet are being accelerated at every moment in their journey towards perihelion. But these repelled particles of the train are not only not being accelerated in the same direction, because not attracted, but are being retarded constantly by the Sun's repelling force. They must, therefore, become wholly detached from the comet in a short time after the beginning of the solar repulsion. Besides, they must begin at once to move on a curve *convex* towards the Sun, and to describe a path that would give them a *wholly different perihelion*, in position and direction, from that of the nucleus and head of the comet. After passing this perihelion of the *convex orbit*, these repelled particles must be driven off by the Sun into infinite outer space, never again to return to his vicinity by any action he could exert. For to suppose these particles repelled at one time, and at another to be attracted by the Sun, seems entirely too arbitrary to be dignified with the name of science. The particles of the comet's train, thus supposed to be repelled by the Sun, must therefore be considered to have entirely abandoned the solar system. They could by no possibility form parts of those *meteoric ring-systems* regularly revolving around the Sun in closed elliptic orbits, which furnish the various *periodical showers* of shooting-stars. A few of the writer's friends have interposed the following objection to the view just stated, with regard to the dissipation of the repelled particles of the comet's train. It is conceivable, says one, that though these particles are repelled by the Sun, far enough away to form the train, yet they are attracted by the nucleus and head of the comet with sufficient force to be carried along with the head, and thus pass around the comet's perihelion. The answer to this objection is two-fold. First, that must be a singular sort of matter which is at the same time repelled by the Sun, and attracted by the head of the comet, which is itself attracted by the Sun, according to Newton's law. But as this answer may not weigh as much with the repulsion theorist as perhaps it ought, this additional answer may be made:

Consider how small the *mass* of even the largest comet is; generally considered less than $\frac{1}{5000}$ of the earth's mass. Professor Young's statement of the earth's mass, that of the Sun being the unit, is $\frac{1}{331100}$. He also estimates the mass of a comet as about $\frac{1}{100000}$ of the earth's mass. Taking, however, the former estimate, will make the comet's mass less than $\frac{1}{1600000000}$ the Sun's mass. The head of Donati's comet is given as 250,000 miles in diameter by Professor Young. Hence, even most of the nearer positions of the train of this comet were at least as far from its center of gravity as our moon is from the earth. Now it is known that the Sun's attraction on our Moon, at the earth's mean distance from the Sun, is about twice that which the earth exerts on our satellite, at a distance less than one-fourth of a million miles. When, therefore, Donati's comet was as far from the Sun as the earth is, if he attracted these particles of the train with his normal force, that attraction would be at least 10,000 times as great as the attraction of the comet's head for these same particles, and many times greater still for the yet more distant particles of the train. So much for the relative amount of *attraction* by the Sun and by the comet itself on the material forming its train. But in Professor Young's Astronomy, before referred to, is the statement, Art. 731, that, according to the views of Bredichin, there are three different types of comets' tails, the long, straight rays, as seen in Donati's comet by Professor Bond, "the curved, plume-like train, like the principal tail of Donati's comet," and the "short, stubby brushes violently curved." The trains of the first type are considered to be due to a repulsive action from the Sun, "twelve to fifteen times as great as the gravitational attraction;" the trains of the second type are supposed to be due to a repulsion from 2.2 times gravity to half that amount; those of the third type are due to repulsive force "only a fraction of gravity, from $\frac{1}{10}$ to $\frac{1}{2}$."

It follows, therefore, that, even when the comet is as distant from the Sun as the Earth is, the very smallest of these supposed repulsive forces, $\frac{1}{10}$ that of solar gravity, is still at least 1000 times as great as the comet's attraction for the repelled particles of the train that are only at a comparatively small distance from the head. When, furthermore, the comet runs down to within a short distance of the perihelion point, the inverse square of its diminished distance from the Sun, will greatly increase the ratio of his repulsion to the comet's attraction for these particles. It is therefore quite impossible for any attraction of the comet's nucleus and head upon even the nearer portions of its train, and still less fôr its attraction on the more distant portions, to overcome this enormous repulsion of the Sun for these particles. It is certain, therefore, that they can never pass the comet's perihelion point together with the nucleus and head, nor at any time subsequently on the theory of repulsion; since they must, in such case, move off in an orbit *convex to the Sun.* Hence it follows that all the particles of the comet's nucleus and head that have passed the perihelion of its orbit must be of a different nature from those that were repelled by the Sun previous to that epoch. They must be such particles of the comet as are subject to the Sun's *attraction only*, and not to his *repulsion.* For otherwise, as has been shown, they could never come up to and double the cape of the perihelion. All the particles that were of such a kind as to be subject to the Sun's *repulsion* instead of his *attraction*, must have been *sifted out* by that repulsion, and dissipated forever into outer space. But, strange to say, after the comet's perihelion passage, a new train or tail is developed, usually turned away from the Sun, like the one before perihelion passage. To account for this recourse is had again to the same theory of repulsion. But why should these particles of the comet, which, before coming to perihelion, were not subject to repulsion, because this would have prevented their passage, be now changed in their allegiance to the Newtonian law? The truth is, a new explanation of the trains or tails of comets must be found, not involving the supposition of any repulsion. The proper consideration of the forms of orbits, necessarily described under any central *repulsive force*, and under a central *attractive force*, demonstrate the absurdity of supposing any portions of a comet to be repelled by the Sun.

There is no question that there is something in the pretty regular turning of a comet's train away from the Sun, both before and after perihelion-passage, that looks very much like repulsion by the Sun of some portions of the cometary matter. But it does not follow from this *appearance* that there is any real repulsion. So also it looks very much as though the Sun rose up every morning from below the eastern horizon, travels along the vault of the heavens, in a western direction, and sets every evening in the west, while the Earth below him stands still. And this view was actually maintained for many ages. But now every one knows that this is only an appearance and not the reality. So also, the heaping up of the waters of the ocean on the side of the Earth opposite to the Moon, looks as though the Moon repelled the waters of the more distant hemisphere, while she attracts those of the nearer hemisphere, and so tends to raise a tide immediately under her, by attraction, and another opposite to her, by repulsion. But astronomers know that there is no repulsion in the case, but only a *difference of attraction* on the Earth as a whole, at its centre, and a greater attraction on the waters of the nearer hemisphere, with a less attraction on the waters of the remote hemisphere. It seems strange that astronomers have not long ago taken the hint from our own *tides*, and applied this same theory of the Sun's *Difference of Attraction* on the nearer and remoter portions of a comet, to explain its *figure of equilibrium*. The *smallness* of a comet's *mass*, the *greatness* of its *volume*, and the *rapid diminution* of its *distance* from the Sun while approaching its perihelion, or its *rapid increase* of *distance* while receding from the same point, are the important factors in this explanation; together with one more point, which is this. The actions of the Moon and Sun on the waters of our globe are small and nearly equal *practically* in the two opposite hemispheres, first because of their great distance from the Earth compared with the diameter of our globe; secondly because of the Earth's comparatively large mass, more than 5000 times that of any comet; and thirdly because of the nearly constant distances of the two tide-raising forces. On the contrary, the comet's large volume and small mass, and its varying distance from the Sun, conspire to make his tidal disturbance large, and variable with the distance, and largely different from each other on the comet's opposite sides, the one nearer and the other more remote from him.

Regarding the comet, as in the older and truer view, as a mere mass of very rare gas or vapour, the Sun's tidal disturbing force would penetrate, with varying force, to its very centre, when the comet was at its greatest distance. The greater disturbance in the nearer half of the cometary mass, than in the more remote, would tend to transport more of its material to the hemisphere nearest the Sun, and thus transfer the centre of gravity, the nucleus, in that direction. This in turn would give greater power of attraction to the nucleus upon the surface nearest the Sun, and diminish its control on the more remote parts of the comet in the opposite direction. The writer may be permitted to refer to the volumes of the American Association for the Advancement of Science, for his paper "On the Tidal Theory of Comets," presented at Cambridge, Mass., in 1880.

There is a difficulty connected with the passage of a comet, and *its train*, around the perihelion point of the orbit, which still seems to need clearing up. Some of the older writers on the subject usually represented the whole comet, nucleus, head, and train stretching away from the Sun in a straight line, for millions of miles, like a stiff rod, passing around the perihelion point, always in that same relative position, head and nucleus towards the Sun, and the distant train straight out from the perihelion point, and then sweeping around *faster than the head*, so as to get into position *away from the Sun*, after the perihelion passage. But this sort of motion, as pointed out by Sir John Herschel, is a mechanical impossibility. For the parts of the comet nearest the perihelion have necessarily the greater velocity, and those more distant a correspondingly less velocity, the velocity in cometary orbits varying nearly as the inverse square root of the radius-vector. The more modern view seems to be, though it is nowhere very confidently asserted, that the old train, before perihelion-passage, has been entirely dissipated by the Sun's repulsion, and that the train seen after perihelion-passage is a new one, subsequently developed by a new repulsion. The absurdity of this second supposition has perhaps been made plain enough.

On the tidal theory of the forms of comets, the train is behind the nucleus and head, in time while approaching perihelion, because, being more distant from the Sun, it is moving more slowly, in obedience to the inverse square root of the radius-vector. But it is moving, *as nearly as may be*, along the same orbit pursued by the head. It reaches the perihelion *later* than the head and nucleus. In fact, so great is the increase of *velocity* of the comet's head, when near perihelion that it, as it were, jerks away from and severs entirely its connection with at least the more remote portions of the train.

After perihelion passage of the comet's head, the same tidal perturbation of the comet's figure by the Sun, now at its maximum on account of its least distance, develops the same elongated figure, with the comet's centre of gravity, its nucleus, nearest to the Sun. Some portions of the old ante-perihelion train are never able, though following along the same general orbit, because still *attracted* by the Sun, to overtake the head, nucleus, and new train, that have preceded it in perihelion-passage. Even when the head, or main portion of the comet, has reached the *aphelion* of its elongated ellipse, the portions of the old train left behind have not yet reached that point, and are slowly climbing towards it with retarded motion, while the head has commenced its accelerated motion towards the perihelion once more. Of course the old train can never overtake the head; it is always behind the latter.

At the next perihelion-passage of the comet's head, a new portion of the new ante-perihelion train is similarly detached. Thus there are at least two cloud-like masses of cometary matter, following in the orbit of the comet's head. At the next perihelion-passage there will be a third cloud of cometary particles detached, and so on, after each successive revolution. These cloud-like detached particles will ultimately be distributed along the orbit, over a large arc, or in some cases throughout the entire orbit. These are the meteoric masses, describing elliptical orbits about the Sun, derived from the successive disintegrations of a comet at each passage of its perihelion, and with sometimes one or more comets pursuing the same orbit. In this way the November meteoric bodies, or the August meteoric bodies, and others, may be explained. It is then only requisite that the orbits of these bodies should nearly or quite intersect that of the Earth, to bring about a periodic swarm of shooting stars.

If it be granted, as is most probably the case, that these meteoric masses, are somehow derived from the disintegration of the trains of comets, then it is quite certain that they were never repelled by the Sun. For these masses revolve in regular ellipses, concave towards the Sun, which occupies the focus of their orbits just as in the case of the planets. The orbits of these bodies, moreover, have been computed by the same Newtonian law of attraction by which the orbits of the other members of the Solar System have been determined. This is perhaps the most positive demonstration that no parts whatever of a comet are repelled by the Sun, but that all are attracted in accordance with the great Newtonian law. No closed curve, like the elliptical orbits of the meteoric masses, could possibly be described under the influence of any repulsive force. If therefore, these meteoric particles are *attracted*, and not *repelled*, as is certainly the case, then no good reason can be assigned why those particles forming even the extreme portions of a comet's train should be repelled by the Sun.

THE EFFECT OF PRESSURE UPON THE TRANSMISSION OF RADIANT ENERGY THROUGH GASEOUS MEDIA.*

SEVERINUS J. CORRIGAN.

Equation (15) shows that the quantity of heat, Q, emitted from unit surface, and transmitted through a gaseous medium is, when the temperature, t_2, of the source of heat, and t_1, that of the enclosing walls are constant, a function of the pressure, P_1; *i. e.*, $Q = \varphi\ (P)$, and it is obvious that, if these temperatures be varied, the pressure remaining constant, the quantity of heat radiated will also be varied, or, in other words that Q will be also a function of t_2 and t_1; *i. e.*, $Q = \varphi(t_2,\ t_1)$; therefore, when both of the temperatures, and also the pressure, vary, the quantity of energy radiated, in unit time, from unit surface will be a function of t_2, t_1 and P, and we can write $Q = \varphi\ (t_2,\ t_1) . \varphi\ (P)$, (24). The resultant quantity, Q, is, therefore, composed of two components, viz.: $\varphi(t_2\ t_1)$ and $\varphi(P)$. The second, as has been shown, is dependent upon the orbital motion of the atoms composing the molecules of the gas, around a common centre of attraction, in the same manner and according to the same law that governs the motions of the planets around the Sun, and of two suns or stars around their common centre of gravity. Its value is, as has been shown by equation (15), expressed by $\varphi(P) = P^{\frac{1}{4.5}}$.

---

* Continued from No. 101, page 7.

The first component $\varphi(t_2, t_1)$, due to temperature, can be regarded as indicating a *perturbative* action upon the *orbital* motion represented by the second factor of the second member of equation (24), or to a vibratory movement of each system of atoms, *i. e.*, each molecule, in a *longitudinal* direction, this motion being due to an impulse emanating from those vibrating particles of the "source of heat" that are in contact with the gaseous medium, *i. e.*, the surface particles. For the explicit value of the first function I have taken the following:

$$\varphi(t_2, t_1) = Ca^{t_1}(a^{t_2 - t_1} - 1),$$

which is based upon Dulong and Petit's well known empirical formula, and in which C is a constant depending upon the nature of the radiating surface, while, a is a constant having for its value 1.0051 when the temperatures are measured according to Fahrenheit's scale. It differs from Dulong and Petit's value which is 1.0043, but their formula was deduced from experiments upon a body heated to less than 450 degrees Fahr., while, in the cases which I have investigated, the temperature exceeded 2100 degrees.

The value, 1.0051, I have deduced from some of Professor Draper's investigations upon the radiation of light from bodies at temperatures of from 1900 to 2600 degrees Fahr.

The value of C for one square inch of polished copper is, approximately, .00002647 of a thermal unit, *i. e.*, of a pound-degree Fahrenheit, per second. Its value for other substances can also be determined experimentally.

The quantity of energy radiated from a heated body, under varying conditions of temperature and pressure, can, therefore, be expressed by the following equation:

$$Q = \varphi(t_2, t_1) . \varphi(P) = Ca^{t_1}(a^{t_1 - t_2} - 1) . P^{\frac{1}{4.5}} \qquad (25).$$

That is, if we know the quantity of heat or energy radiated, in unit time, from unit surface of a "source of heat" at a given temperature, t_2, the temperature, t_1, of the enclosing walls being also known, and the enclosed gas being under a given pressure, P, we can find by means of equation (25), the quantity radiated at any other temperatures and pressures. I have used this equation for the purpose of obtaining the absolute quantity of energy radiated in unit time, from the filament of a 16 candle-power incandescent electric lamp in which the pressure of the enclosed air was reduced to $\frac{1}{1000000}$ of the normal atmospheric pressure, and the result, in units of electric energy, *i. e.*, in volt-amperes, or watts, or in equivalent thermal units, or in units of energy, *i. e.*, either ergs, or horse-power, is almost exactly the same as those obtained by many tests made by several electric-lighting companies. For instance, the glossy metal-like surface of the filament of the latest 16 candle-power "Edison" lamp radiates 54 volt-amperes, or watts, of electrical energy, equivalent to .054 of a thermal unit, or .072 of a unit of electrical horse-power. Taking the temperature of the filament at 2100 degrees Fahrenheit, which is, very nearly, the temperature of *perfectly white* light, the temperature of the glass bulb at 150 degrees, and the pressure of the enclosed air at $\frac{1}{1000000}$ of the normal atmospheric pressure of 30 inches of mercury, equation (25) will give, as the quantity radiated, 55.8 volt-amperes, or watts, *i. e.*, .0558 of a thermal unit, or .075 of a unit of electrical horse-power; a very close agreement between the results of actual practice and those of theory.

Therefore I think that the validity of equation (25) and of all the preceding ones through which they have been derived, and of all the principles on which they are based, is established.

Any statement purporting to furnish an absolutely true, complete and accurate explanation of all the known phenomena of "radiation," would be, I think, premature and unwarranted, and if such statement could be properly made, it would require far more space than could be devoted to it in ASTRONOMY AND ASTRO-PHYSICS, or in any other publication whose province is the same. But the existence of an *orbital* motion of the atoms of a gas, and also of a longitudinal vibration of the system of atoms or the molecules, is, I think, established. The combination of a rotational movement with a longitudinal one, *i. e.*, of both a *transverse* and a *longitudinal* vibration of the energy-bearing or transmitting molecules furnishes, probably, the key to certain phenomena of "radiation" which have been heretofore not clearly explicable. In "radiation" there is probably no transference of matter, only motion being propagated, and the only molecules that need be considered in this connection are those which are in contact with the surface of the radiating and also of the receiving body.

The resultant path of the revolving atoms can be represented when the velocity in the longitudinal direction is much greater than the orbital velocity, by a wave-like reversed curve, for one-half of the duration of the complete longitudinal vibration, and by a like curve running in the opposite direction, for the other half. Could the body to which heat is radiated be a *perfect* absorber, there would be a reversed curve, or a wave in only one direction as shown in Fig. 1, in which S represents the "source of

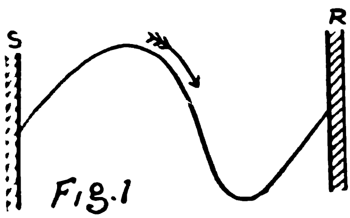


Fig. 1

heat," and R the receiver or absorber. In this case there will be a curve in only one direction, indicated by the arrow, because the motion of the revolving atoms will be destroyed or rather be wholly given up to atoms composing the receiver, R, so that there can be no return curve or wave. In the case where the receiver cannot absorb heat, *i. e.*, where it is a perfect reflector, the action is represented in Fig. 2; the longitudinal vibration being complete, there is a return curve or wave as shown by the arrows; the figure represents the fact that as much heat is sent back or *reflected* to the "source" as has been radiated from it, or, in other words, that the source has lost no heat.

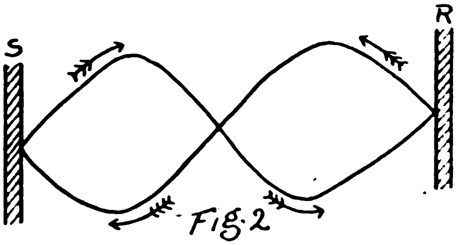


Fig. 2

The molecules which have given up their motion are replaced by others more active, thus producing the phenomenon called "*convection.*" In the above diagrams only one wave is represented moving in the same direction, but the number is dependent upon both the orbital and the longitudinal velocities, and it is really almost inconceivably great.

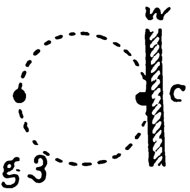


Fig. 3

Could there be a condition in which a mass of gas, such as the atmosphere, would not be acted upon by "radiations" from "sources of heat," the condition would be represented by Fig. 3, in which the atoms revolving in the orbit represented by the circle make simple contact with the wall W, at only one point, C, and the amount of impact is infinitely small. But if, as is always the case, the molecules or systems of revolving atoms are given a vibratory motion in a longitudinal direction, by an impulse imparted to them by the molecules of some heated body, the condition would be represented by Fig. 4, in which S represents the radiating surface and R the surface of the receiver.

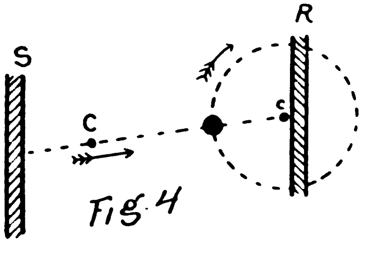


Fig. 4

We can see that, by the shifting of the system of revolving atoms longitudinally from S to R, the centre, C, moving as indicated by the arrow, the atom would make more than a simple contact with the receiving surface, R, and that the latter would, in fact, receive the full force of the impact and be heated thereby.

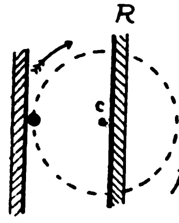


Fig. 5

Fig. 5 conveys the idea that the same effect that is shown in Fig. 4, *i. e.*, the heating of a receiving body, can be produced even if there be no shifting of the system of atoms, or the molecule longitudinally; in other words, if there be no body radiating heat, the effect being produced by the moving of the receiving surface, R, to the left, the centre of the system, or C, remaining stationary. It will be seen that in this case, as in the former, the atom can make full impact upon R and heat it.

This is only one way of expressing the well known fact that *compression* will generate heat. The heating of meteoric masses is a notable case in point; the meteors, rushing with a very great velocity, into our atmosphere, compress the molecules thereof, and the revolving atoms composing these molecules, beat against the surfaces of the meteors, heating these bodies to incandescence.

It is neither impossible nor improbable that the two revolving atoms of each system are in a state of polarity, one positive and the other negative, thus being mutually attracted by reason of their polarity but kept apart by the "centrifugal force" due to their *orbital* revolution, and, under this hypothesis, each system can be regarded as a little magnet. The property, possessed by a magnet, of generating or inducing electrical currents when moved toward or from a conducting coil, is well known, and the greater the velocity of the approach and the recession, the greater will be the current. Therefore, if we regard the retina as representing the coil in which currents are induced, and each system of polarized atoms as the magnet, the approach and recession of the system to and from the retina, may generate therein molecular disturbance which, being conveyed, by the optic nerve, to the brain, produces therein that sensation which is called "light." "Heat" appears to be a purely *mechanical* effect due to the impact of the revolving atoms upon those of the receiving body and, as has been shown above, it is a function of the *orbital* velocity, *i. e.*, its amount depends not only upon the temperature of the "source" but also upon the pressure of the transmitting gaseous mass, or in other words upon the second factor of the second member of equation (25). But the intensity of "light" does not seem to vary with the pressure, but only with the temperature of the "source," it appears to be, particularly, a function of the first factor of the right hand member of equation (25), that is, it seems to depend principally upon the rapidity of the vibrations of each system of revolving polarized atoms or magnets, in a longitudinal direction.

The opinion of the late Professor J. Clerk Maxwell, that "light" is an electro-magnetic phenomenon is well known, and is held by many other physicists.

Of the *absolute* nature of the polar forces we can, probably, learn nothing; like "gravity" or any other force, we can know them only by the effects which they cause; we are not debarred from advancing a hypothesis as to their existence and probable effects, but, for the establishment of the truth of such hypothesis we must depend solely on the agreement between the propositions thereof, and the facts derived from observation of the phenomena of "radiation."

It should be noted that, in the theory which I have above advanced, the so-called molecular forces which generate heat, and the other forms of energy which are regarded as due to the motion of the infinitesimal particles of matter, are considered as producing a vibration of the *atoms* which constitute the molecule, as well as a vibratory movement of the *molecule* itself, which latter vibration seems to have been the only one heretofore regarded. According to my theory the simplest form of molecule would be one composed of only two atoms revolving in one plane (the orbit being a circle for instance) but the number of component atoms may be indefinitely great and the number of planes or orbits in which they move may be likewise indefinite, but there must be a common focus around which these atoms, the components of the molecule, revolve.

If we regard the orbit as a circle (which can be done, since, whatever may be the normal orbit, the pressure upon the gaseous mass, due to gravity, must tend to constrain the orbit to, at least, an approximately circular form), we can conceive of any number of such circular orbits lying in all planes throughout the whole 360 degrees of a circle, but having a common focus or centre; we can also conceive of the existence of an indefinitely great number of sets of two atoms revolving in each plane; therefore, according to this view, a molecule would be a spherical shell composed of an indefinitely great number of revolving atoms moving around a focus within the shell, and, since each orbit or each system of atoms is subject to change under the action of extraneous forces, expanding when the linear velocity in the orbit is increased by an impulse from the moving atoms of other molecules, or by any other means, and contracting when said velocity is decreased by impact against the atoms of neighboring molecules or otherwise, a mass composed of molecules so constituted would possess those properties which the phenomena of "radiation" seem to indicate as indispensable attributes of a perfect transmitting medium.

By thus considering each molecule as composed of separate bodies revolving around a common focus, Dalton's law, which asserts that "in a mixture of different gases, when there is equilibrium, each gas behaves as a vacuum to all the rest," is clearly explicable, because, according to this view, there is sufficient room for the co-existence and the motion of the atoms composing the molecules of each gas, around their respective foci.

The diagrams given above are intended to convey only a general idea of the action of the revolving atoms producing the phenomena of "radiation," and a more specific statement in regard to the nature of the atomic movements and orbits will now be set forth.

We can conceive that the linear velocity of an atom moving, when the gaseous mass is in equilibrium, in an approximately circular orbit, as augmented, either by impact from the vibrating particles of a source of heat," or by compression; and we can determine the nature and amount of the change effected in the elements by such an augmentation of the linear velocity. To do so we need only to consider the simple and well known mathematical relations which exist between the elements of any orbit described by a body subject to the action of a centripetal force which varies inversely as the square of the distance; it is plain that such an orbit must be one of the "conic sections," and the atomic orbits are not exceptions.

The equations which express the relations between the elements of any orbit are the following:

$$p = \frac{V^2 r^2 \sin^2 \psi,}{k} \qquad (a)$$

$$a = \frac{k}{\frac{2k}{r} - V^2} \qquad (b)$$

$$e = \sqrt{1 - \frac{p}{a}} \qquad (c)$$

$$q = \frac{p}{1+e} \qquad (d)$$

in which V, represents the linear velocity of the body, r, its radius-vector, ψ, the angle between the radius-vector and a tangent to the orbit at the extremity of said radius, p, the semi-parameter, a, the semi-transverse axis, e, the eccentricity, and q, the shortest distance, of the moving body from the focus, while k, represents the unit of attractive force which, for our purpose, can be regarded simply as unity, as relative values only are to be considered. The angle, ψ, is, in the case of a circular orbit, always a right angle, but if we conceive the moving body to receive an impulse from without, not only will the linear velocity be augmented but the direction of the motion or the angle ψ, will also be changed. If V represent the linear velocity in the circular orbit, and V_1 the velocity (at a right angle to the former) imparted by the impact of an extraneous body, the angle, ψ, and the resultant velocity, V_2, will be found from the equations:

$\tan\psi = \frac{V}{V_1}$, and $V_2 = \frac{V}{\sin\psi}$; the value of V_2, so found, is to be used for V in the equations (a) and (b).

A numerical example may serve to elucidate the matter: if we consider only relative values we may take V, or the linear velocity in the circular orbit, and also the other variable elements as each equal to unity; if we now suppose a velocity V_1, equal to V, or to 1, to be imparted to the revolving atom by an impact from without, the angle, ψ, will become equal to 45°, and the resultant, V_2, will have the value 1.414+; then, from the first four equations, we will find that the semi-parameter, p, will be equal to 1, the semi-transverse axis to ∞, the eccentricity to 1, and the nearest approach to the focus, 0.5; in other words, by such increase of velocity, the orbit will become a parabola; for a less augmentation of the linear velocity, it would have become an ellipse, and for a greater, the orbit would have been changed into a hyperbola, as will appear if other values of V_1 be used.

A graphical illustration may serve to render the matter plainer; in Fig. 6 the circle represents the orbit of equilibrium in which the atom at S revolves, when not acted upon by an extraneous force, around the focus C, the revolution being in the direction of the arrow; if an impulse from outside be given to the atom at S, in the direction indicated by the arrow, this atom will move with increased velocity (in the case we have considered) through the arc of a parabola SQR, and, could the velocity become infinitely great, the atom would move in the straight line *SCR*, through the focus *C*. Observing Fig. 6, we see that if *R* represent a receiving body, the atom moving in the orbit of equilibrium, or the circle, will not impinge upon the receiver, but that, if the velocity be increased so as to change the orbit into any one of the other "conic sections," it will strike more or less directly against the receiving body, as is indicated by the dotted extensions of *SQR* and *SCR* through the same, and by the impact the receiving body will be heated. Furthermore, since the atom does not move around a much more massive body as is the case with the planets, but around a center of attraction whose position depends upon those of the component atoms, being midway between them when they are of equal mass, the approach of either atom toward the focus must cause a shifting or vibration of the latter; therefore Fig. 6 illustrates more *explicitly* the conditions shown in a *general* manner in Figs. 3, 4 and 5. It also elucidates the cause and *modus operandi* of the expansion of a gas by the action of applied heat, the atomic orbit being enlarged thereby, as is shown by the dotted lines. The action of gravity upon a gaseous mass, like our atmosphere, compresses the molecules so that the atomic orbits are restricted to an approximately circular form, and are not the normal ones due to the masses and original velocities of the component atoms; therefore there must be a tendency to expansion in all such masses. We can, therefore, conclude that, in any case, the expansive force of a gas is not due to any repellent force inherent in the gaseous mass, which is the generally accepted idea, but simply to the *orbital* motion of the atoms under the action of a *centripetal* force which operates like that of gravity. In this paper only *relative* velocities and distances have been considered, but the reader can gain some idea of the *absolute* values of these quantities from the fact that of the vibrations producing a "deep red" light there are, approximately, four hundred millions of millions per second, with a wave length of $\frac{1}{19800000000}$ of an inch. Work, done by a moving body, is proportional to one-half the mass multiplied by the square of the velocity of the body. In the case of the atoms the smallness of their weight is compensated by their enormous velocity.

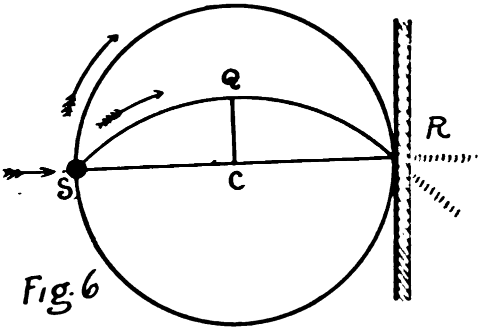


Fig. 6

The conclusions to which the above investigation has led me, can be summarized as follows.

We can conclude, first, that a simple gas is composed of innumerable molecules each of which is formed by two equal atoms, or by some number of atoms which is a multiple of two, the number and grouping defining the chemical characteristics of the gas, and that these atoms are in a state of almost inconceivably rapid revolution around a common centre of attraction lying between them, this motion of revolution being due, as is that of the planetary bodies, to an attractive force which, like that of "gravity," varies inversely as the square of the distance of the bodies from the centre of attraction:

Secondly, that the pressure of a gas upon the walls of a containing vessel (in the case of the "atmosphere" the earth's "force of gravity" can be regarded as the restraining wall), is due to the incessant impact of these revolving atoms upon said walls, and that the pressure aforesaid, is inversely proportional to the 4.5th power of *d*, or the distance apart of the atoms composing the molecules of the gaseous mass, which fact is expressed by the equation, $P = \frac{1}{d^{4.5}}$, whence $d = \frac{1}{P^{\frac{1}{4.5}}}$.

Thirdly, that the quantity of energy, Q, transmitted by and through a gas, from any "source of heat," the temperature of the "source" and of the enclosing walls being constant, varies inversely as *d*, or directly as the 4.5th root of the pressure, *i. e.*,

$$Q = \frac{1}{d} = P^{\frac{1}{4.5}}$$

Fourthly, that, when the pressure of the gas and also the temperature of the "source of heat," and that of the enclosing walls are constant, the " quantity of heat" Q, transmitted in unit time, will be expressed by the equation, $Q = Ca^{t_1}(a^{t_2 - t_1} - 1)$, in which t_2 represents the temperature of the "source" and t_1 that of the enclosing walls, while C is a constant depending upon the surface of the radiating body, and a, is a constant whose numerical value is 1.0051.

Fifthly, that, when both the temperatures and the pressure vary, the quantity of energy or heat, transmitted through the gas, in unit time, can be expressed by the equation

$$Q = Ca^{t_1}\left(a^{t_2 - t_1} - 1\right) . P^{\frac{1}{4.5}}$$

in which the first factor of the second member represents the longitudinal vibration of each system of revolving atoms and the second factor the orbital revolution of these atoms around their common center of attraction, the resultant being a wave-like motion of said atoms.

Sixthly, that the difference between the specific heat of a gas at constant pressure, and that of a gas at constant volume, is due to the orbital motion of the atoms composing the molecules of the gaseous mass, and that for a perfect gas, the numerical value of the ratio between the specific heats is 1.5; also that the error of Boyle's law, which law is expressed by the equation $P = M$, when the volume is constant, results from neglecting the factor, n, which represents the *orbital* velocity of the revolving atoms, the proper expression being $P = Mn$, when the volume is constant, and furthermore, that the ratio between any two pressures, P_1 and P_2, should be expressed by the equation:

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{1.5} = \left(\frac{M_1}{M_2}\right)^{1.5}$$

These conclusions also suggest some ideas of a purely speculative nature; for instance, it seems unnecessary to assume the existence of any other than a gaseous medium for the transmission of radiant energy, in other words, there seems to be no necessity for the hypothesis of the existence of a special medium such as "ether." There is no reason to suppose that an absolutely perfect vacuum is ever procurable, for the mass, and therefore the density and the pressure of a gas can be reduced toward infinity, yet there will always be a finite quantity of gaseous matter remaining, and equation (15) shows that the diminution of the quantity of energy transmitted from a given source in a given time is *very*, *very* far from being proportional to the reduction of pressure or density:

Thus, if a body be emitting a given quantity of heat in air at a normal pressure, it will radiate at a pressure of $\frac{1}{1000000}$th of an atmosphere a quantity equal to $\frac{1}{12}$ of that given out at the normal pressure; while if the reduction be carried to $\frac{1}{1000000000000}$, the quantity will be $\frac{1}{464}$, a very large amount when the enormous reduction of pressure, or density is considered; matter so tenuous could not offer any appreciable resistance to bodies moving through it, and yet it would be capable of transmitting comparatively large quantities of radiant energy. That the relation between the pressure and the quantity of energy or heat radiated, as shown by experiment, follows so closely the law expressed by equation (15) is, I think, conclusive proof that the transmitting medium for radiant energy, or heat, is a purely gaseous one.

The idea is also suggested, that what is called space is not void, but that it contains gaseous matter in a state of extreme tenuity, the atoms composing this matter being in rapid orbital motion and transmitting energy, thermal, luminous, electrical, and chemical; that from these like atoms are formed all the bodies of the universe, chemical and other characteristics depending upon the grouping and motions of the atoms; we know that all forms of matter can be reduced to the gaseous by the application of a sufficient quantity of heat, or force, and that, therefore, if the original "energy of motion" of the atoms of the gas be lost to them, by transference to the atoms of other bodies or masses, the former will cease to revolve and will become the constituents of *solids*. The revolution of the atoms can, I think, be regarded as the *knowable* fountain-head of all energy, or force, but the answer to the great question, "Whence have sprung these atoms and the forces by which they are impressed, which put them in motion and cause them to revolve?" is known only to Him "without Whom was made nothing that was made." But it does not necessitate an undue strain upon either the imaginative or the reasoning faculty, to conceive that space is filled with these revolving components of the molecules of a gaseous mass; to see, mentally, portions of them parting with their motion or heat, thus, eventually *approaching* the solid state, and forming stars or suns, planets and satellites, the revolution of the atoms being resolved into a like revolution of the resultant bodies around "centres of gravity;" in other words, it is neither difficult nor unreasonable to regard the "nebular hypothesis" as, in the main, true: but, to a knowledge of the absolute nature and origin of matter and force, we cannot hope to attain until the "finite" can comprehend or encompass "The Infinite."

TRANSPARENCY OF THE CRAPE RING OF SATURN, AND OTHER PECULIARITIES AS SHOWN BY THE OBSERVATIONS OF THE ECLIPSE OF JAPETUS ON NOVEMBER 1st, 1889.[*]

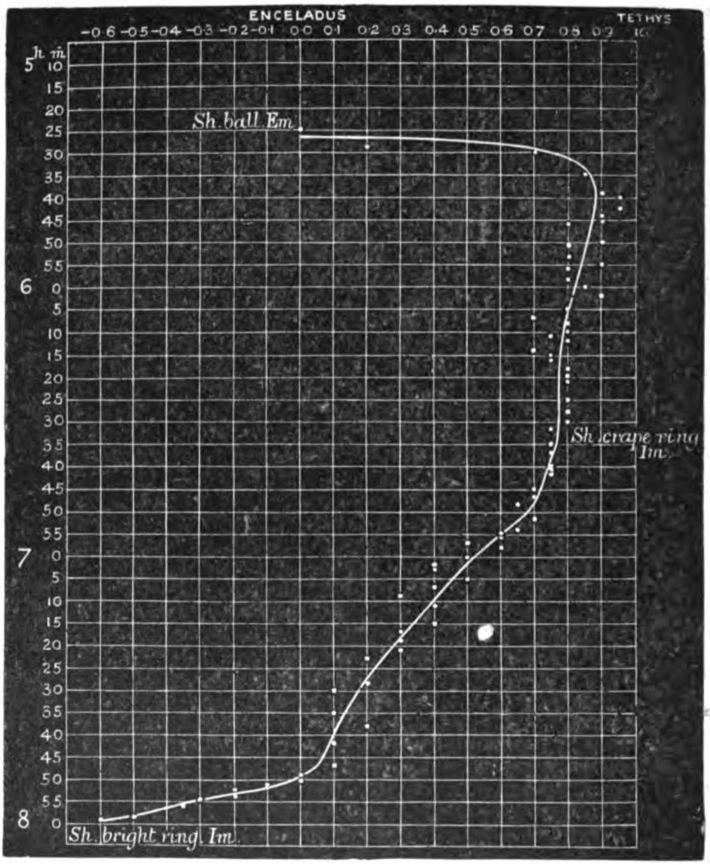
BY E. E. BARNARD.

On the first of November 1889, I observed the eclipse of Japetus in the shadow of the ball and ring system of Saturn with the 12-inch equatorial. These observations were embodied in a paper published in the Monthly Notices of the Royal Astronomical Society for January, 1890.

---

[*] Communicated by the author.

In calling attention to this phenomenon in Monthly Notices for June 1889, Mr. Marth says: "The inclination of the orbit of Japetus to the plane of the ring being nearly 14°, while the orbits of the other satellites have inclinations of less than 1°, the rare eclipses of Japetus by the ring system offer the only chance of deciding several questions which may be settled with the help of observed eclipses. No such observation has ever yet been made. Favorably placed observers ought, therefore, to take full advantage of the rare chance they may get on November 1. There will not be another such chance for at least the next sixteen years."



Light Curve* of the Eclipse of Japetus, in the Shadows of the Globe, Crape Ring and Bright Ring of Saturn, 1889 Nov. 1.—*From Monthly Notices, Vol, 50, p. 108.*

One of the problems to be settled at that eclipse was the transparency of the crape ring.

---

* See *News and Notes* for explanation of the above light curve.

For various reasons, no other observer in the world saw the eclipse of Japetus.

The observations of that eclipse with the 12-inch equatorial have given us more information about the crape ring of Saturn, perhaps, than could possibly have been obtained by a hundred years of ordinary observing.

The night was fine and clear and especially favorable. The planet rose at 12^h 50^m. At first the seeing was only ordinary, but it increased in excellence until in the latter stages of the observations it was superb. By the time the satellite had entered the shadow of the crape ring, the planet had attained a high altitude and was excellently placed for observing.

When Saturn rose at the Lick Observatory, Japetus was already in the shadow of the ball—having passed through the first half of the shadows of the rings. Near the predicted time the satellite re-appeared from the shadow of the ball into the sunlight shining between the ball and rings. It quickly assumed its normal light, and after remaining thus for an hour and twenty minutes, it began to fade and so continued for an hour, having during that time entered and passed through the shade of the crape ring. It then entered the shadow of the bright rings, and rapidly disappeared.

From a great number of comparisons of the light of Japetus with two of the other satellites, a curve was drawn showing the light variations. This was published in the paper referred to.

This curve clearly showed what effect the crape ring had upon the light of the satellite. It showed that after passing through the sunlight shining between the ball and rings, Japetus entered the shadow of the crape ring. As it passed deeper into this, the absorption of sunlight became more and more pronounced, until finally the satellite entered the shadow of the bright ring. The crape ring was therefore transparent—the sunlight sifting through it. From the gradual absorption of light, it also showed that the crape ring was denser or less transparent as it neared the bright ring.

An inspection of the curve, and the observations, showed conclusively that there was no separating space, or division, between the inner bright ring and the crape ring as has frequently been represented in drawings. The transition from the one to the other, however, appears to be rather abrupt, as shown by the steepness of the curve at the time of contact with the shadow of the bright ring.

The observations also show that, so far as the penetration of the solar rays is concerned, the bright ring is fully as opaque as the globe of Saturn itself.

From the observations, I have deduced the following, Mt. Hamilton Mean Times.

		d	h	m
Japetus first seen (re-appearance from shadow of Ball)	1889 Nov.	1	14	37.4
Japetus last seen (contact with the shadow of Bright Ring)	1889 Nov.	1	17	11.0
An inspection of the light curve gives	1889 Nov.	1	15	47.2

as the most probable time of contact with the inner edge of the shadow of the crape ring.

For comparison, I append the predicted times of the above phenomena as given by Mr. Marth:

		d	h	m	
Re-appearance from Shadow of Ball..............................	1889 Nov.	1	14	41	Bessel
" " " " "	1889 Nov.	1	14	59	Struve
Contact with Shadow of crape ring.......................... ...	1889 Nov.	1	15	41	
" " " " bright ring............	1889 Nov.	1	17	17	

The observations are as accordant with theory as could be expected, since Mr. Marth states that 1″ in the heliocentric longitude of the satellite corresponded to an error of 36 minutes in the time. The two predictions for the re-appearance from the shadow of the ball, come respectively from using Bessel's and Struve's data for the diameter of the ball.

From the time required for the total emergence of Japetus from the shadow of the ball, and for its disappearance into the shadow of the bright ring, the satellite cannot be less than 1400 miles in diameter.

Unfortunately the contacts with the projection of the Cassini Division could not be observed here as the Sun rose before that phenomenon occurred.

From the light curve published in the number of the Monthly Notices referred to, I have obtained the following values which may be taken as fractions of a magnitude to represent the change in the light of Japetus due to the interposition of the crape ring between it and the Sun—or in other words, the absorptive power of the ring.

TABLE OF LIGHT VARIATION. FROM THE LIGHT CURVE.

	h	m	m		h	m	m		h	m	m
Sidereal	6	10	0.780	Sidereal	7	0	0.520	Sidereal	7	47.5	0.050
		15	0.770			5	0.456			50†	— 0.030
		20	0.769			10	0.390			52.5	— 0.150
		25	0.765			15	0.348			53	— 0.260
		30	0.764			20	0.275			54	— 0.300
		35*	0.760			25	0.225			55	— 0.330
		40	0.748			30	0.168			57	— 0.400
		45	0.720			35	0.130			58	— 0.500
		50	0.678			40	0.098		7	59	— 0.600
	6	55	0.599		7	45	0.065				

* Enters shadow of Crape Ring. † Enters shadow of Bright Ring.

These figures between 6^h 35^m and 7^h 50^m—during which time the satellite was passing through the shade of the crape ring—seem to indicate that the density of the crape ring increases proportionally to the distance from its inner edge, and the density at any point p will be

$$D = x$$

where x is the ratio of the distance of p from the inner edge in terms of the width of the crape ring, or, in the above table, an absorption of about 0.01 magnitude for each minute of time. If we assume a mean of the variations between $6^h\ 35^m$ and $7^h\ 45^m$, it will $= 0^m.412$ and will fall at $7^h\ 10^m$.

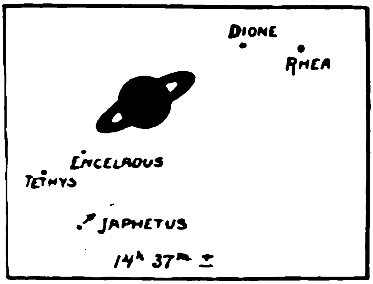
Applying this formula to the observations between the above times, the values contained in the following table under the head *C* will result—*O* being the values derived direct from the light curve:

TABLE REPRESENTING THE ABSORPTIVE POWER OF THE CRAPE RING.

	Time	O	C	O-C		Time	O	C	O-C
	h m					h m			
Sidereal	6 35	0.760	0.762	− 0.002	Sidereal	7 15	0.348	0.362	− 0.014
	40	0.748	0.712	+ 0.036		20	0.275	0.312	− 0.037
	45	0.720	0.662	+ 0.058		25	0.225	0.262	− 0.037
	50	0.678	0.612	+ 0.066		30	0.168	0.212	− 0.044
	6 55	0.599	0.562	+ 0.037		35	0.130	0.162	− 0.032
	7 0	0.520	0.512	+ 0.008		40	0.098	0.112	− 0.022
	5	0.456	0.462	− 0.006		7 45	0.065	0.062	+ 0.003
	7 10	0.390	0.412	− 0.022	Mean deviation				− 0.005

The entire absorptive power of the ring seems to be about 0.7 magnitude, which would, perhaps, be reduced somewhat if the light passed through the ring at a larger angle.

A formula which would more accurately represent the absorption could doubtless be found, but it is a question if it would have any truer signification than that given above.



The phenomenon of the eclipse can be accounted for on two suppositions. First, the crape ring is thinner toward the ball of Saturn; or second, there are fewer particles in that direction area for area. Perhaps both conditions prevail.

The increase of density towards the bright rings would rather favor the idea that the crape ring has its origin in the diffusion of particles from the bright ring.

I have assumed throughout these remarks, the theory that the rings are composed of individual particles.

As a matter of interest, I enclose a diagram of Saturn and five of the satellites at the epoch of the appearance of Japetus from the shadow of the ball. Enceladus and Tethys were the two satellites used for comparison of the light of Japetus during the eclipse. According to Professor Pickering, the difference in light between these two satellites is one magnitude.

In conclusion it is scarcely necessary to say that the observations of this eclipse settle forever the question of the transparency of the crape ring.

Mt. Hamilton, December 19, 1891.

ASTRO-PHYSICS.

FALL OF A SOLAR PROMINENCE INTO THE OPENING OF A SPOT.*

M. E. L. TROUVELOT, MEUDON OBSERVATORY, FRANCE.

On August 6, 1891, I was observing a large group of spots situated at some distance from the western limb of the Sun, toward which it was carried by the Sun's rotation. This group, which was composed of three spots in close proximity, exhibited some peculiarities which attracted my attention.

From the southern edge of the penumbra of the central spot of the group extended long and brilliant filaments which, at first separated, came closer together, as the distance increased, to form a bundle; this, crossing the umbra and penumbra of this spot as well as the southern penumbra of the third spot situated at the north of the group, passed on to sink and lose itself in the depths of its opening. The luminous filaments which crossed the central spot of the group were still sufficiently separated to allow the opening of the umbra of this spot to be recognized through the intervals between them; but beyond, the compact bundle allowed nothing more to be seen.

On August 8th the filamentous bridge uniting the two spots of the group was observed between passing clouds. On the 9th the group, very close to the Sun's limb, still showed the filamentous bridge, in spite of the unsteadiness of the image. Spectroscopic observation allowed the position of the central spot of the group to be determined, and it was found to be at 264° on the limb. Above this spot a few prominence jets were seen, in spite of the unfavorable state of the sky.

On August 10th, at 10^h 35^m, the group of spots, which was then on the limb of the Sun, was no longer seen; but by the aid of the spectroscope it was easy to recognize the position of the spots. Brilliant eruptive jets shot out from a point situated at 264°, corresponding with the position of the umbra of the central spot of the group. All these incandescent jets were enclosed by an immense luminous arch, which, rising from a point situated at 258° on the limb, passed on to rejoin the chromosphere at another point situated at 270°, after having described a curve attaining an elevation of 2′ 40″ at its highest point.

This arch was composed of numerous filaments, formed of bril-

---

* "Comptes rendus de l'Académie des Sciences," 5 October, 1891.

liant knots joined end to end. The base of the arch at 258° was much broader, and composed of brighter and looser filaments than those which composed the other much narrower base. By its position, which corresponded exactly with that of the luminous bridge observed on the group of spots, by its greater width at the south than at the north, as well as by its form and filamentous structure, there can be no doubt that this prominence arch and the filamentous bundle observed on the spots were one and the same object, seen from different points of view.

These luminous filaments, rising to considerable elevations, uniting into a bundle, and passing on to precipitate themselves exactly into the distant opening of another spot, present a singular circumstance, which it would be difficult to attribute to chance.

My spectroscopic observations have taught me that, among the spots which cross the Sun's limb, there are some which are the seat of violent eruptions, and which throw jets of incandescent matter to great elevations, while there are others which exhibit no activity, and cross the limb without showing the smallest trace of an eruption. From the point of view of activity, Sun-spots may thus be divided into two classes: those which show traces of activity, and those which appear to lack them. It would seem that the study of spots from this point of view might lead to interesting results.

From the examination of the prominences observed August 10th above the group of spots in question, it seems evident that the filamentous arch owed its origin to the eruptive force escaping by the opening of the central spot of the group, situated just below this arch; a force which manifested itself by brilliant jets which rose from this opening. As not the least trace of eruption was noticed above the spot into which the narrow end of the arch descended, we may conclude that this spot was in a state of repose.

Must we attribute the fall of this prominence into the opening of the spot to the effect of chance, or to a kind of sucking phenomenon, or to some sort of attraction exerted on certain prominences by spots in a state of repose? Observations which I have often made on the Sun of phenomena of the same order, cause me to favor this last supposition.

REMARKS ON THE INFLUENCE OF THE ABERRATION OF LIGHT ON SPECTROSCOPIC OBSERVATIONS OF SOLAR PROMINENCES.*

M. FIZEAU.

Several recent communications have been presented to the Academy on the characteristic phenomena of the solar atmosphere, and especially on the circumstances of the appearance, development, and movement of the prominences, studied by means of spectrum analysis.

The authors of these communications, M. Trouvelot, M. Deslandres and M. Fényi, pursuing the path opened by M. Janssen, have observed and described several prominences remarkable for their brilliancy, their dimensions, and their changes in form; then, applying the principal of the displacement of lines by the movement of the luminous body, they have deduced the velocities of translation in the line of sight.

Without entering into the details of the observations with which we are dealing, the results as a whole tend to confirm the generally accepted opinion, that the prominences are due to vast gaseous eruptions, in which hydrogen predominates, and which rise rapidly, sometimes to enormous elevations above the solar surface, to return there at the end of a few hours; this seems to be the general conclusion from the quantities obtained in the measurement of the phenomena.

It seems then that, in these circumstances, great gaseous volumes are to be considered, animated with great movements, the velocities of which in various directions, are at once comparable with the velocity of light, the planetary movements, and, in particular, the movement of the Earth in its orbit.

One is thus led to investigate within what limits the well-known laws of aberration can here interpose, giving rise to those apparent displacements of stars, the images of which, either with the naked eye or telescope, almost always cause them to be seen displaced from their true position.

And, indeed, if one takes into account the reciprocal situations of the observer, placed on the earth, and the Sun, toward which the instruments are directed, it is evident that the simple and sensibly constant effect of aberration will be a diminution of 20″.445 in the longitude of the Sun and the prominences which rise from its surface, and that, moreover, this apparent displace-

---

* "Comptes rendus de l'Académie des Sciences," 7 Sept., 1891.

ment is due to the velocity of the earth in its orbit, which is 30.6 kilometres per second.

It results from these data that, if a prominence rises in the neighborhood of the ecliptic with a velocity of translation of the luminous gas equal to this same velocity of 30.6 kilometres per second, the position of the prominence will undergo a certain change, that is to say, an apparent displacement of ± 20″.445, which will be added to or subtracted from the preceding effect according to the circumstances of direction, giving rise to corresponding variations in distance from the Sun's limb.

In truth, the velocities of the prominences are not uniform, and rarely attain the supposed value; but the nature of the phenomenon does not seem doubtful, and these great movements of the solar atmosphere, the existence of which is, however, not here contested, must give rise to apparent movements which depend upon the laws of aberration, and which must be taken account of in the more precise determination of the actual movements.

In what precedes, we have adopted the simplest hypothesis of the constitution of the prominences, that of the material transportation of hydrogen and metallic vapors rendered visible by their high temperature. An analogous reasoning applies, with still greater probability, to the hypothesis of the visibility of the prominences produced by an extraordinary development of electrical phenomena, similar to our storms and auroras.

That which gives to this point of view a special degree of probability, is the constant intervention of electricity in experiments where the hydrogen lines are observed.

Up to the present time, in spite of numerous attempts, hydrogen burning or heated, compressed or rarefied, does not seem to have shown its characteristic lines without the employment of electricity in the form of spark, current or discharge.

Now the prominences are always rose-colored, by the various lines of hydrogen, and particularly by the predominance of the red line C. Moreover the rapidity of changes in form, the sudden modifications in brightness, the longitudinally striped, undulated, broken appearance, with distorted parts completely isolated, and separated from the Sun's limb, have often been described. All these appearances agree without difficulty with the electrical hypothesis, and especially with the varied phenomena presented by the aurora borealis, in which there are striped appearances, fringed edges, luminous propagations sometimes slow, sometimes rapid, but generally with mean velocities, not as swift as lightning, nor as slow as the discharge of St. Elmo's fire or ball-lightning.

From this point of view, which seems to be at present adopted by many physicists and astronomers, the luminous appearances of the prominences must not be considered as due to movements of matter, but as resulting from the non-instantaneous propagation of electrical phenomena through the gaseous masses, which may have their own movements, but do not impose them on the electrical and luminous phenomena. These, completely independent of the first, can commence at the base, the middle, or the top of the prominence, and spread either up from below, or down from above, by successive movements which cannot fail to give rise, by the effect of aberration, to apparent displacements, similar to those mentioned above, but still more complex and more difficult to foresee.

It is proper to add here that, by the employment of wide slits, a general custom for exploring the forms and extent of prominences, the exact isolation of simple rays is given up, and one is liable to take for a displacement of lines by the motion, luminous manifestations of different intensity and appearance, which might be produced in different parts of a prominence.

Let us remark, in concluding, that if the intervention of the phenomena of aberration in certain studies of spectrum analysis is necessary for the exactness of measures, this intervention seems to be limited to a small number of phenomena, and notably that studies relative to the motions of the stars are not at all affected by it.

ON ABBERATION.*

M. MASCART.

In 1810 Arago† communicated to the first class of the Institute a memoir which was not published until some time after, on stellar refraction. In it the following remark occurs: " . . . The constant of aberration, which M. Delambre has found by the discussion of a large number of eclipses of satellites (Jupiter), is absolutely the same as that which Bradley has deduced from his observations.

"The first consequence that may be drawn from this remarkable agreement is that light travels uniformly, or at least

---

* From Comptes rendus, Nov. 2, 1891.

† Arago, Comptes rendus, V. XXXVI, p. 38, 1853.

without any *sensible* variation, in the whole space comprised by the orbit of the Earth; the eccentricity of the orbit of Jupiter allows this result to be extended so as to comprise the immense distance which it encloses. It is also natural to suppose that stars of different magnitudes are at different distances, and, as their absolute aberrations deduced from direct observations are sensibly the same, Bradley has concluded that the motion of light is uniform at all distances, and that the aberration of all celestial bodies can be calculated with the same constant."

After having given the details of his experiment, Arago ended by some conclusions, of which the first is:

"The aberrations of all the heavenly bodies, whether they send us their own or reflected light, can be calculated with the same constant, without the smallest difference in this respect, as I have deduced from my first experiments."

W. Struve, in a beautiful and important investigation on aberration, gives 20″.4451 for the constant, which is the mean of results differing but little among themselves, as determined from the observations of seven stars; but he adds "that it is necessary to assume for the seven stars the same constant of aberration, and consequently the same velocity of light."

The opinion of Bradley and O. Struve seems to have been unreservedly adopted by astronomers; it leads to the consequence that, if observation shows that aberration is exactly the same for all stars, the propagation of light must be uniform in all stellar space. This interpretation seems to me quite unwarranted by the results of observation.

The experiments made at the surface of the Earth by the method of Arago and that of our fellow member, M. Fizeau, determine the velocity of light in air, and consequently *in vacuo*, on the whole trajectory of the Earth. The eclipses of Jupiter's satellites, by deviations from the predicted times, give the time required for light to traverse the diameter of the Earth's orbit. The concordance of the result with that which can be deduced from the dimensions of the solar system, determined by other methods, also proves that the propagation of light is uniform in the interior of the terrestrial orbit. The eccentricity of the orbit of Jupiter perhaps allows this same result to be extended a little further, but not, as Arago has it, to the immense interval which this orbit encloses.

Aberration depends only on the ratio of the velocity of the observer to that of light in the region occupied by the instrument, and any modifications which may influence the propagation of the light waves between the star and the Earth do not affect it. The constant of aberration may, however, change from one star to another, as Yvon Villarceau has shown, on account of the motion of the solar system. Variations in its amount will thus be of great interest.

Finally the displacement of the lines in stellar spectra gives only the relative velocity of the star and the Earth in the line which unites them.

If we reason rigorously, the deductions of direct experiments and astronomical observations which depend upon the velocity of light must thus be confined to the space comprised within the terrestrial orbit; only by induction can we go beyond it. It is hardly necessary to add that this induction seems legitimate; but, however probable it may be, it is a pure hypothesis to consider the progagation of light as uniform in celestial space.

THE LARGE SUN-SPOT GROUP OF AUG. 28--OCT. 4, 1891.*

REV. A. L. CORTIE.

The following notes on some telescopic and spectroscopic phenomena observed in this large group of spots are intended to supplement the note by Father Sidgreaves in the October number of the *Observatory*.† The group was born on Aug. 28 at the eastern limb, its mean heliographic co-ordinates being lat. 18°.5 N. and long. 221°.0. It died on Oct. 4, on the western limb, in lat. 22°.0 N. and long. 226°.7. It thus both formed and died on the visible hemisphere. Moreover it was the largest group of spots observed since June, 1885, and one of the largest since the great November spot of 1882. Fourteen drawings were obtained of the group at Stonyhurst. During its first passage over the disk, Aug. 28–Sept. 10, it consisted mainly of two very large irregular spots. The following of these was by far the largest spot of the group, and underwent the greatest internal changes. It did not, however, survive to a second rotation; for then the preceding spot alone appeared, being accompanied in its passage across the disk by occasional outbreaks of small spots scattered over a wide area.

At its birth the group was surrounded by bright compact faculæ, one scimitar-shaped jet lying S. of the preceding spot being

---

* From The *Observatory*, November, 1891.

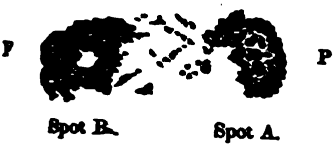
† See also ASTRONOMY AND ASTRO-PHYSICS, January, 1892, p. 66.

especially remarkable. At its death the faculæ were still very bright, but were vastly more extensive.

The area of the group at its birth on Aug. 28 was 77 millionths of the visible hemisphere. As it crossed the disk it steadily developed, and attained its greatest area of 1834 millionths on Sept. 7. At its reappearance after one rotation on Sept. 25, the area had diminished to 545 millionths. The diminution continued until the extinction of the spot on Oct. 4.

The group displayed some remarkable proper motions, the two members repelling one another, except for a slight approach on Sept. 3. At their birth on Aug. 28 the two spots were 3°.6 apart in longitude, which was increased to 5°.9 on Aug. 29; to 10°.4 on Sept. 2; to 11°.8 on Sept 4; and to 13°.0 on Sept. 7. Between Sept. 7th and the 9th, the following spot changed its retrograde motion to one of approach, but its companion gave at the same time such a leap forward, that on the 9th their distance apart reached its maximum of 16°.5. This forward motion of the whole group took place just after it had attained its greatest area.

Fig. 1.



Considering the motions of the individual spots, that of the preceding member of the group was very rapid, as it advanced from long. 222°.8 to 233°.8 between Aug. 28th and Sept. 9, or 11° in 12 days. Its most rapid drift of 4°.7 in two days took place between Sept. 7th and 9th. The drift of the following spot in the contrary direction was not at all great; but 3°.1 in the 10 days, Aug. 28–Sept. 7, and from long. 219°.2 to 216°.1. Both the spots rose in latitude, the mean drift of the group being from 18°.5 N. to 22°.2, while the individual drifts were from 19° to 21°.8 and from 18°.0 to 22°.5 for the preceding and following spots respectively. Their common advance in longitude Sept. 7–9 was accompanied by a slight fall in latitude, so that their paths were almost parallel. The end of the first rotation was marked by the metallic prominence of Sept. 10 immediately over the following spot, which was then exactly on the limb.

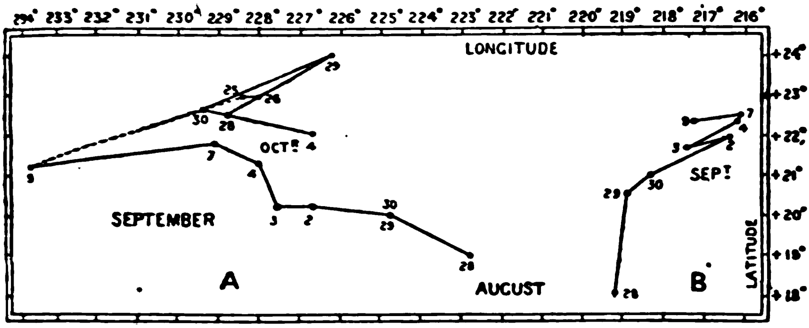
At the beginning of the second rotation the preceding spot, which now alone remained, was found on Sept. 25 in lat. 23° and long. 228°.3. Excluding possible oscillations, it had therefore, when on the invisible hemisphere, drifted 1°.8 higher in latitude, but retrograded 5°.5 in longitude. Until Sept. 28 it remained almost stationary, but from the 28th to the 29th it suddenly rose

1°.5 in latitude and advanced 2°.6 in longitude. Next day it as suddenly dropped to almost exactly its original position in latitude, and retrograded 3°.1 in longitude. This seems to have been its expiring effort, as on Oct. 4 it was represented by a group of minute scattered dots. Therefore while the following and larger spot remained comparatively stationary, the preceding spot drifted rapidly forward in longitude in the first rotation, and retrograded in the second rotation, so that when it died it was but 3°.9 in advance of its first position.

In the spectroscope the most important spot of the group was the one marked B in the figure. The following are some of the details of the variations in the hydrogen C line over the spots when they were on the visible disk. The observations were taken during a vacation visit to the Stonyhurst Observatory, at the kind invitation of the Director. On Aug. 30, at 11 A. M. G. M. T., in a hazy sky, and employing a dispersion of 6 prisms of 60°, the line was seen to be reversed and displaced towards the violet in the preceding portion of the nucleus of the following spot. There was also a less brilliant reversal of the line noted in the faculæ which was situated between the two spots, while in that which followed the group the line was broken though unreversed.

The next observation was on Sept. 3d in excellent definition, so that the full battery of 12 prisms of 60° and a high magnifying-power were employed. The following of the two spots was seen to be broken up into a number of separate nuclei, with penumbral and faculous matter filling up the spaces between. As on Aug. 30, so now too, the C line was unaffected by the preceding spot. But in its companion some remarkable reversals and displacements of the line were observed. By carefully bringing the slit over various portions of the spot, it was possible to locate the chief seat of disturbance as being situated in the northern half of the spot, and in the faculous and penumbral gap which intervened between this and the southern half. At 11:30 the line was broken in the penumbral gap, and a small portion was twisted and blown towards the violet. It was pear-shaped, with the stem adhering to the dark line. It gave the impression of fluttering about, as if blown by a wind. The estimated displacement was 0.7 X-metre, and the appearance lasted for about three minutes. It was not seen again, but subsequently the line became very much widened on both sides. At 11:53 the line was reversed in that nucleus which was situated in the N.F part of the spot. At 12:15 it became less dark in this same nucleus, and in the penumbral gap had a thin hair adhering to it and turned towards the red. The motion therefore of the dark hydrogen had been reversed from an uprush to a downrush. The thin hair-like line formed an angle of about 30° with the main line. Lower down this latter was reversed as a bright dot probably in a region of faculæ, and below this again was greatly thickened in some penumbræ. Hence five different appearances of the line were to be seen in the same field. At 12:35 the thin line had vanished, a thickening of the main line having taken its place. When the group was sketched next morning at 9:45, it was seen that the aspect of the spot had changed in that very portion in which the disturbance had been observed in the spectroscope. On Sept. 6th, at 3 P. M., the C line over this same spot was less dark but otherwise unaffected.

Fig. 2.



On Sept. 28th, at 12 P. M., the C line was reversed in the nucleus of the preceding spot, which now alone survived. It is noteworthy that as in the case of its companion, so now too, a reversal of the hydrogen line heralded its speedy dissolution. Nor must we omit to call attention to the fact that the independent observations of the reversals and twistings of the C line on Aug. 30 and Sept. 3, and the observation of the metallic prominence on Sept. 10, agree in placing the seat of greatest activity as occurring in the same portion of the following spot of the group. As the scope of the details just described is only to supplement the observation of the metallic prominence, all reference to the observations of the remaining lines between B–D in the spectrum of the group has been omitted, as they will, it is hoped, be more appropriately published elsewhere.

St. Beuno's College, St. Asaph, 1891, Oct. 17.

ON THE DISTRIBUTION IN LATITUDE OF THE SOLAR PHENOMENA OBSERVED AT THE ROYAL OBSERVATORY OF THE ROMAN COLLEGE, DURING THE FIRST HALF OF 1891.*

M. P. TACCHINI.

Below are the results which relate to each zone of 10° in the two hemispheres of the Sun:

PROMINENCES.

1891.	First Qr.	Second Qr.
90° + 80°...	0.003	0.003
80 + 70 ...	0.000	0.006
70 + 60 ...	0.006	0.003
60 + 50 ...	0.053	0.052
50 + 40 ...	0.115	0.134
40 + 30 ...	0.073	0.105
30 + 20 ...	0.115	0.087
20 + 10 ...	0.050	0.073
10 . 0 ...	0.038	0.023
	0.453	0.486
0° − 10°...	0.018	0.017
10 − 20 ...	0.050	0.052
20 − 30 ...	0.112	0.087
30 − 40 ...	0.079	0.122
40 − 50 ...	0.206	0.078
50 − 60 ...	0.067	0.125
60 − 70 ...	0.003	0.015
70 − 80 ...	0.009	0.009
80 − 90 ...	0.003	0.009
	0.547	0.514

FACULÆ.

1891.	First Qr.	Second Qr.
40° + 30° ...	0.027	0.057
30 + 20 ...	0.280	0.335
20 + 10 ...	0.200	0.272
10 . 0 ...	0.040	0.006
	0.547	0.670
0° − 10°...	0.053	0.019
10 − 20 ...	0.200	0.127
20 − 30 ...	0.187	0.133
30 − 40 ...	0.013	0.051
	0.453	0.330

SPOTS.

1891.	First Qr.	Second Qr.
40° + 30°...	0.000	0.000
30 + 20 ...	0.214	0.304
20 + 10 ...	0.357	0.321
10 . 0 ...	0.036	0.054
	0.607	0.679

SPOTS.

1891.	First Qr.	Second Qr.
0° − 10°...	0.000	0.015
10 − 20 ...	0.036	0.100
20 − 30 ...	0.250	0.128
30 − 40 ...	0.107	0.078
	0.393	0.321

ERUPTIONS.

1891.	First Qr.	Second Qr.
50° + 40°...	0.000	0.000
40 + 30 ...	0.000	0.000
30 + 20 ...	0.200	0.000
20 + 10 ...	0.200	0.500
10 . 0 ...	0.000	0.000
	0.400	0.500
0° − 10°...	0.000	0.000
10 − 20 ...	0.200	0.500
20 − 30 ...	0.200	0.000
30 − 40 ...	0.000	0.000
40 − 50 ...	0.200	0.000
	0.600	0.500

It may be seen that, during the first half of 1891, the solar prominences have been more frequent in the southern hemisphere, as in 1889 and 1890, with the maximum of frequency always in the zones (± 40° ± 50°), while the spots have maintained their great predominance to the north of the equator, like the faculæ, with maxima at lower latitudes, as compared with the prominences. All the phenomena are very infrequent in the neighborhood of the solar equator.

Resume of Solar Observations made at the Royal Observatory of the Roman College during the Third Quarter of 1891.†

The number of observing days was 31 in July, 31 in August, and 19 in September. The following results were obtained:

---

[*] "Comptes rendus de l'Academie des Sciences," 7 Sept., 1891.

[†] From "Comptes rendus," Nov. 30, 1891.

1891.	Relative Frequency Of Spots.	Relative Frequency Of Days without spots.	Relative Size. Of Spots.	Relative Size. Of Faculæ.	No. Groups Per day.
July	18.65	0.00	76.26	82.03	4.03
August	8.84	0.06	49.06	70.81	2.94
September	17.52	0.00	114.45	61.10	4.10

By comparing these data with the results of the observations made during the preceding quarter, it will be seen that the solar activity has considerably increased, for the extent of the spots is twice as great. It is also shown that the minimum of faculæ corresponds to the maximum spot extent.

The season has been equally favorable for prominences. The following results have been obtained:

1891.	Number of observing days.	Mean number.	Prominences. Mean height.	Mean extent.
July	30	8.37	40.2″	1.4
August	30	6.77	41.0	1.9
September	23	9.26	41.4	2.2

As in the case of spots, we have thus established a sensible increase in prominence phenomena. The greatest height observed for a prominence was 142″, in the month of August; there have been but few metallic eruptions, although interesting peculiarities were observed in several prominences, especially during the month of August.

THE CHROMOSPHERE LINE ANGSTRÖM 6676.9.

A. L. CORTIE.

With regard to Professor Young's observations as to the non-coincidence of the bright chromosphere line[*] (*Nature*, November 12, p. 28) with the corresponding dark line 6676.9 of Angström's scale, it may be interesting to note that Professors Liveing and Dewar have observed a barium line at 6677, which is therefore slightly less refrangible than the dark solar line. In his catalogue Professor Young also gives a barium line at 6018.0, which is identified with Kirchoff 933.8. In the course of the observations of Sun-spot spectra taken at Stonyhurst with a twelve-prism spectroscope, no dark solar line has been noted in this position except in two uncertain instances over spots. It would be an important fact should two barium lines be found in the chromosphere without corresponding dark lines.

---

[*] See also ASTRONOMY AND ASTRO-PHYSICS, January 1892, p. 59.

In the period of maximum solar activity the bright line 6676.9 was on several occasions seen in the spectroscope, while the height of the chromosphere was being measured at Stonyhurst on the C line of hydrogen. At these times C was always very bright, and generally displaced in the prominences in which 6676.9 was seen. The latter line was not seen in the observations taken between March 9, 1886, and September 10, 1891. Although both Young and Thollon attribute the line to iron, no iron line is given in this position by either Angström or the catalogues of the British Association. Dunér, quoted by Thollon, considers the line variable with the state of solar activity, but Angström seems to have made an error in drawing it as a fine thin line, as Kirchoff, Burton, Fievez, Smyth, Thollon and Higgs give it as a strong dark line. Finally, Young, Burton, and the Stonyhurst observers identify it with Kirchoff's ray 654.3, and Thollon with 641, which latter is a calcium line. There would, then, appear to be some differences of opinion with regard to this important line (cf. *Monthly Notices R. A. S.*, Vol. li., No. 1, p. 22.)

ST. BEUNO'S COLLEGE, St. Asaph, November 19.

NOTES ON THE USE OF THE SPECTROSCOPE FOR SKETCHING SOLAR PROMINENCES, AND FOR OBSERVING THE SPECTRA OF THE SPOTS AND PROMINENCES.*

WALTER SIDGREAVES.

In the June number of the *Journal* a general division of the work on the Sun that might be undertaken with the spectroscope was given under five headings. The Director of the section hoped to accomplish during the summer vacation more than the cloudy condition of the atmosphere has allowed him to realize. Nevertheless a series of experiments with a student's spectroscope of a single 60° prism of dense glass by Hilger, may serve their purpose sufficiently, which is, not to guide those who are already well equipped for the work, but to help others of our associates who may be willing to join the section as soon as they see that they can contribute to its success by collecting material for the study of solar physics.

The spectroscope was fitted to the eye end of a telescope, which is easily mounted on a strong iron pedestal in the college garden near the Observatory. The object glass, by Alvan Clark, is of

---

* *Jour. British Astr. Assoc.*, Oct., 1891.

$5\frac{1}{2}$ inches aperture. A much smaller objective would do equally well, if mounted on a tube and axle strong enough to carry the spectroscope and requisite counterpoises. The instrument is fitted with the ordinary equatorial gear, but has no clockwork, and depends upon its slow motion rod for retaining the image. So that the results obtained will show what may be done with the least of needful appliances.

The prominences were easily seen, and their heights could have been measured with the aid of a divided scale in the eye-piece. The spectrum of a spot showed very well, and its lines could be examined while the spot travelled across the field along the slit. The addition of clock movement to the instrument would have rendered the observing quite easy.

For work upon the prominences a position circle would be needed in addition to the divided glass scale, in order to measure the base as well as the height of each, and to tabulate their heliographic latitudes.

A remark here may be of service to observers of the solar prominences. Within the limits of dispersion sufficient to show the bright lines of the chromosphere smaller dispersion should give a more accurate measure of the height of a prominence than greater dispersion. For the line is brighter with the smaller dispersion, and is, therefore, not only visible to a greater height where intensity fades, but will bear a greater magnification. And the ocular magnification is the only help to the measurement, dispersion adds nothing to the apparent length of the line.

For observations of the spectra of the spots and prominences, a good map of the solar absorption spectrum, suited to the degree of dispersion employed, is almost indispensable. At the end of the second volume of the "Publicationen des Astrophysikalischen Observatoriums zu Potsdam" (Engelmann-Leipzic 1881), two excellent maps are given for moderate and for small dispersions. With the help of these and of their accompanying wave-length catalogues, the observer can readily identify any lines that are affected by a spot or by a prominence. He would, however, probably find but little work of this kind on the prominences, which, so far as we know at present, only rarely show other bright lines than D_3 and the Hydrogen reversals. The tips of the absorption lines as seen with the slit lying radially over the Sun's limb should be carefully scrutinised, with a very well adjusted instrument, for a small reversal, as the bright line may reach up to only a small fraction of the normal height of the chromosphere.

The spectra of the spots afford more work for the observer. When the image of a spot is on the slit, its spectrum appears as a thick, or fine dust line according to the size of the spot, but readily distinguishable from these flaws by its flocculent appearance, and is infallibly recognized by its movement with the clock variations when the slit is set parallel to the equator.

The following observations seem to be well within the means of a small dispersing spectroscope:—

1. To note, according to some scale of difference, the general density or darkness of the band, and whether the density appears to be maintained throughout the length of the spectrum, or to be greater in some parts than in others.
2. To note whether the solar lines appear to be of uniform thickness where they cross the spot, or to taper like a spindle towards the penumbral regions.
3. To look for thickening of any lines as they cross the spot band, notably the prominent lines C, D_1, D_2, E, &c., expressing the widening in the degrees of comparison, "widened," "more widened," and "most widened" where *more widened* would mean between one-half and the whole width of the line as seen on the Sun off the spot.
4. To note any alteration of intensity of the line over a spot, whether entirely obliterated, or even reversed.
5. To note any distortion of a line, and to which end of the spectrum the bend lies.

In all these observations an accurate adjustment of the instrument is of the greatest importance. To detect a very short reversal of a line in the chromosphere, the Sun's limb must be very sharply defined, together with the perfect definition of the absorption lines. When this is obtained, the spectrum of a spot will also show a well-cut band with clearly marked shadings responding to every degree of density in the nucleus and penumbra. The following method of finding the true adjustment is both convenient and speedy. The solar image is first brought to an approximate focus on the slit. Then the eye-piece is adjusted to give sharply defined edges to the color band. Thirdly, the absorption lines are brought to focus with the collimator. This last movement spoils the definition of the edges; but by moving both the collimator and the eye-piece simultaneously or alternately, the lines are quickly brought to focus coincidently with a sharp definition of the edges of the band. Lastly, the slit is set radially over the Sun's image, with the limb cutting it in the middle, and the telescope rack is moved until the edge of the color band given by the Sun's limb appears as a sharply cut line. This last movement gives the true position of the solar image, which is not precisely that of its best definition on the slit plates.

The chromosphere and prominences are always measured here with the slit radially over the Sun's limb by a finely divided scale on clean glass cemented to the cross-line-plate of the eye-piece. The spectroscope is mounted eccentrically on the position circle at such distance from the center that only a very small band of the solar spectrum is visible in the field. And the band is reduced to nothing when the details of a prominence are to be examined with an open slit. This adjustment of the open slit is quite as effective as the tangential position, and is better suited to our method of measuring the heights of the chromosphere and prominences.

The spot spectra are always observed with the slit set parallel to the equator in order that any variation of the clock movement may not throw the spot off the slit. The true orientation of the slit is found by turning the position circle or holder until the chromosphere remains visible in the line C, while the image of the Sun's northern or southern limb travels the length of the slit.

With a telescope of long focal length the Sun's image is large enough to show a spot on the slit plates, and then it can be easily brought on to the slit by the slow moving gear. With smaller telescopes the plan is to sweep the slit across the solar image by means of the N. P. D. rod until a spot band flashes along the spectrum. But if a grating or a single prism be employed for the spectrum, the method suggested by Mr. Townsend, of Stamford Lodge, Sevenoaks, is clearly the simplest and the most efficient process. He turns his grating to serve as a white light reflector, and opens the slit as wide as possible, so as to view the Sun's disk through the eye-piece of the spectroscope protected with a dark glass. The spot selected for observation is then retained between the jaws of the slit by the AR rod while the slit is closed to the required fineness. One of the faces of the single prism can be employed as a first surface reflector in the same manner. This method is so convenient and efficient, both for finding a spot and for the orientation of the slit, that where a train of prisms is employed, a separate reflector for the purpose would be a valuable addition to the instrument, whether as a solar or as a stellar spectroscope.

STONYHURST OBSERVATORY, Lancashire.

THE MODERN SPECTROSCOPE.

II.

The Star Spectroscope of the Lick Observatory.[*]

JAMES E. KEELER.

In designing a spectroscope for so large a telescope as the thirty-six-inch refractor of the Lick Observatory, the weight of the instrument is not a consideration of special importance. Adding another hundred pounds, more or less, to a telescope already weighing several thousand, has no prejudicial effect upon the stability of the mounting or the performance of the driving clock, and the size of the spectroscope is practically determined by the opitical power desired or by considerations of convenience in handling. In the case of the thirty-six-inch refractor, the weight of the parts requisite to give sufficient rigidity is considerably increased by the unusually great ratio of focal length to aperture, as the length of the collimator must be nineteen times the desired effective aperture of the spectroscope, and hence the most important parts must be supported at a considerable distance outside the focal plane of the telescope.

The weight of the Lick Observatory spectroscope is nearly 130 pounds; with the two brass rods forming the connection with the telescope it is perhaps 75 or 80 pounds more.

A perspective view of the instrument, (from a photograph by Mr. Barnard) is given on Plate V, and a scale drawing, with reference letters, on Plate VI. In the latter figure the observing telescope is shown with its axis parallel to that of the collimator.

The lower part of the eye-end of the great telescope is surrounded by a revolving jacket, which is furnished with slow motion screws, clamp, and position circle. On each side are cast three strong clamps, bored slightly larger than the brass rods, *A*, *B*, which support the spectroscope. The rods (or rather tubes, for although closed at the ends, they are hollow), are 3 inches in diameter and 6 feet long. They are inserted for 2½ feet of their length in the clamps on the revolving jacket, and project 2 feet 3 inches beyond the focal plane of the telescope. The distance between their centers is 23¼ inches. On the upper end of each rod is a short circular nut, and near the lower end is a projecting pin, which serves to always bring the spectroscope into the same position with respect to the telescope. When all the clamps are

---

[*] Communicated by the author.

tightened, the rods form a very rigid support for the spectroscope.

The brass frame, *C*, of the spectroscope is cast in a single piece. It is secured to the rods by four clamps, the arrangement of which is shown in the figure. The lower half of each clamp is a single piece; the upper half is made with a tight-fitting hinge, so that it can be turned back on the frame. The clamps have a small amount of lateral motion, so that they can adjust themselves to the distance between the rods, and one of them can be rotated on an axis perpendicular to the plane of the rods, an arangement which prevents the spectroscope frame from being strained on tightening the clamps. The clamps were properly adjusted on first mounting the spectroscope, and since then no change has been necessary.

In mounting the spectroscope, the eye-end of the great telescope tube is first supported by a prop. The rods are then inserted and fixed. The spectroscope is placed upon the rods and allowed to slide down until it rests upon the stops provided for the purpose on their lower ends, and all the clamps are tightened. Balancing weights equivalent to the weight of the spectroscope are then removed from the lower part of the telescope tube, completing the operation, which requires the work of two persons for about twenty minutes.

The collimator, *G*, slides in the case, *D*, which is connected with the frame by opposing screws, so that the collimator axis can be directed to the center of the great objective. The collimator can be moved through a range of about 100 millimeters by turning a large milled head, *z*, its position being indicated by an index moving along a millimeter scale. The collimator objective has a focal length of 20 inches and an aperture of 1½ inches. It is made of Jena glass, and the lenses are cemented together with Canada balsam to diminish the loss of light by reflection.

The slit, *s*, is provided with a rack and pinion for focusing, and a clamp. Its jaws move equally in opposite directions from the center by turning a right and left-handed screw. By turning a small pinion, not shown in the figure, the length of the slit can also be varied. *q* is a diagonal eye-piece which moves between stops, so that when pushed in the slit can be viewed from behind, and when withdrawn the rays from the slit pass without obstruction. This eye-piece is essential in so large an instrument, for ensuring that the image of the celestial object under examination is properly adjusted on the slit plate. *r* is a pinion head for moving the 60° totally-reflecting prism along the slit plate. When moved fully in toward the center, the reflecting angle of the prism extends a little beyond the center of the slit.

The slit and its accessories are protected from accidental disturbance by a thin tube, *H*, which also serves to hold the tube, *t*, for cylindrical lenses.

The strong cross-piece which carries the observing telescope has two pivots, one on each side of the spectroscope frame. At *F* is the graduated circle, 12 inches in diameter, divided on the edge, on silver, to 10′ and read by two opposite verniers to 10″. The circle is held by the clamping nut, *p*, and when the latter is loosened, it can be turned so as to bring any desired graduation to the index of the vernier when the observing telescope is directed to the slit. In general the reading of the circle for this position of the observing telescope is made 0°, and the reading for any other position gives directly the deviation of the ray observed; *h* is the clamp and tangent screw for slow motion of the observing telescope, and *o* is a reading lens and shade. The vernier at *o* is illuminated by the electric lantern, *i*.

The smaller head shown at *p* secures the outer end of the long spindle which forms one of the bearings of the observing telescope.

Two observing telescopes are provided. The one shown in the figure has a Jena glass objective of 1½ inches aperture and 10 inches focal length. The other, which is twice as long, is used with a grating for solar spectroscopy. The micrometer, and other accessories, are made to fit both of these telescopes. The short telescope, *E*, is more convenient when prisms are employed, or for observation of faint objects with low magnifying powers.

The micrometer, *m*, carries a fine wire, a coarse wire, and a pointer. The head is divided into 100 parts, and one revolution (when the small telescope is used) is equal to 3′ 10″.8. A quicker motion would be preferable. The number of whole revolutions is indicated on a dial.

A small incandescent electric lamp in the lantern, *i*, illuminates both the upper vernier of the graduated circle and the wires of the micrometer. It is connected by flexible wire with the binding posts, *f*. The color of the light which enters the micrometer box can be varied, so as to approximately match that of any part of the spectrum, by means of a revolving disc, *i*, containing colored glass, and its intensity is regulated by turning the short tube, *k*, which contains a small reflecting prism.

The two eye-pieces which are generally used on the short telescope are achromatic and they have magnifying powers of 7.3 and 13.3 diameters. An eyepiece giving a power of 7 on the long telescope is also provided.

The observing telescope is counterpoised by the weight, *I*. Additional counterpoises are supplied for the long telescope and the reversion apparatus.

Three prisms are used with the spectroscope, two of them being single prisms of 30° and 60° refracting angles respectively, and the third a compound prism of high dispersion. Each prism is cemented to a separate table, or circular plate of brass, which stands upon three short foot-screws. Two long clamping screws hold this plate firmly against the grating table, *a*. The prisms are therefore readily interchangeable, and require no attention after a final adjustment of the foot screws has been made. Each prism is provided with a light cover, *b*, which is blackened inside and out to prevent reflections.

The grating table *a*, is attached to the end of a long conical spindle, which passes through the hollow pivot of the observing telescope arm, and carries at the other extremity *D*, a disc, *c*, with ratching on its circumference. By means of a tangent screw, *d*, a slow rotary motion can be given to the grating table. *e* is a small lever by which the tangent screw can be thrown out of gear, and the grating table can then be rotated freely by hand.

Just below the grating table, the spindle is encircled by a collar, to which is attached the tail-piece of the minimum deviation apparatus, *g*, and the collar is clamped to the spindle of the grating table by a screw *h*. By the construction of the apparatus the tail-piece is made to always bisect the angle between the axes of the collimator and the observing telescope. When a prism is to be used it is first set to the position of minimum deviation for any line of the spectrum, by means of the tangent screw, *d*; the clamp, *h*, is then tightened, and the tangent screw is thrown out of gear. The prism will then be automatically kept in the position of minimum deviation for all parts of the spectrum.

When the grating is used, the minimum deviation apparatus is unclamped, and the grating is held in position by the tangent screw. It is then, of course, entirely independent of the observing telescope. The Rowland grating has 14438 lines to the inch, and gives very brilliant spectra of the higher orders on one side. The mounting by which it is held to the grating table does not differ from the form in common use.

At *K* is shown the apparatus for producing comparison spectra. But little explanation is required. *w* are the forceps for holding metallic electrodes. *w* is a rack-and-pinion for moving the spark in the line of the forceps. A motion at right angles to this direction is obtained by rotating the forceps-holder in its collar. *v* is a short tube holding a lens, by which an image of the spark is formed on the slit, and as the angular aperture of this lens is greater than that of the collimator objective, the entire collimator aperture is filled with light from the spark. *y* is a tube in which *v* slides. A neutral-tint compensated wedge can be inserted in the rectangular aperture shown in *y*, if it is necessary to reduce the light. The forceps-holder can be removed, and replaced by a somewhat similar arrangement, having no rack-and-pinion motion, for holding spectrum tubes.

A box (not shown in the figure) containing an elaborate reversion attachment, can be inserted between the observing telescope and its supporting arm. The single reversion prism, which is of the form described by Dr. Carl Braun in the publications of the Haynald Observatory, is rotated by a very fine micrometer screw, acting on the end of a long arm. The apparatus is somewhat similar in principle to the prismatic sextant of Pistor and Martins, the micrometer screw replacing the graduated arc of the latter instrument, but the reversion prism allows an object in the line of sight to be seen after but one reflection. The reflecting face of the reversion prism is slightly inclined to the refracting edge, so that the direct and reflected spectra do not coincide, but are in close juxtaposition. The relative brightness of the two images can be varied. This apparatus answers well for bright objects.

The Lick Observatory spectroscope has an effective aperture of 1.06 inches, when used in connection with the 36-inch refractor. When it is not in use on the telescope it rests upon a truck, and the full aperture of the spectroscope, 1.50 inches, becomes available for laboratory work. The truck is fitted with drawers for holding accessories. There are no photographic attachments.

All parts of the instrument (except one of the prisms) were made by Mr. J. A. Brashear, of Allegheny, Pa., and the workmanship is of the highest class. The design has also proved to be satisfactory for all purposes of eye observation.

PLATE V.

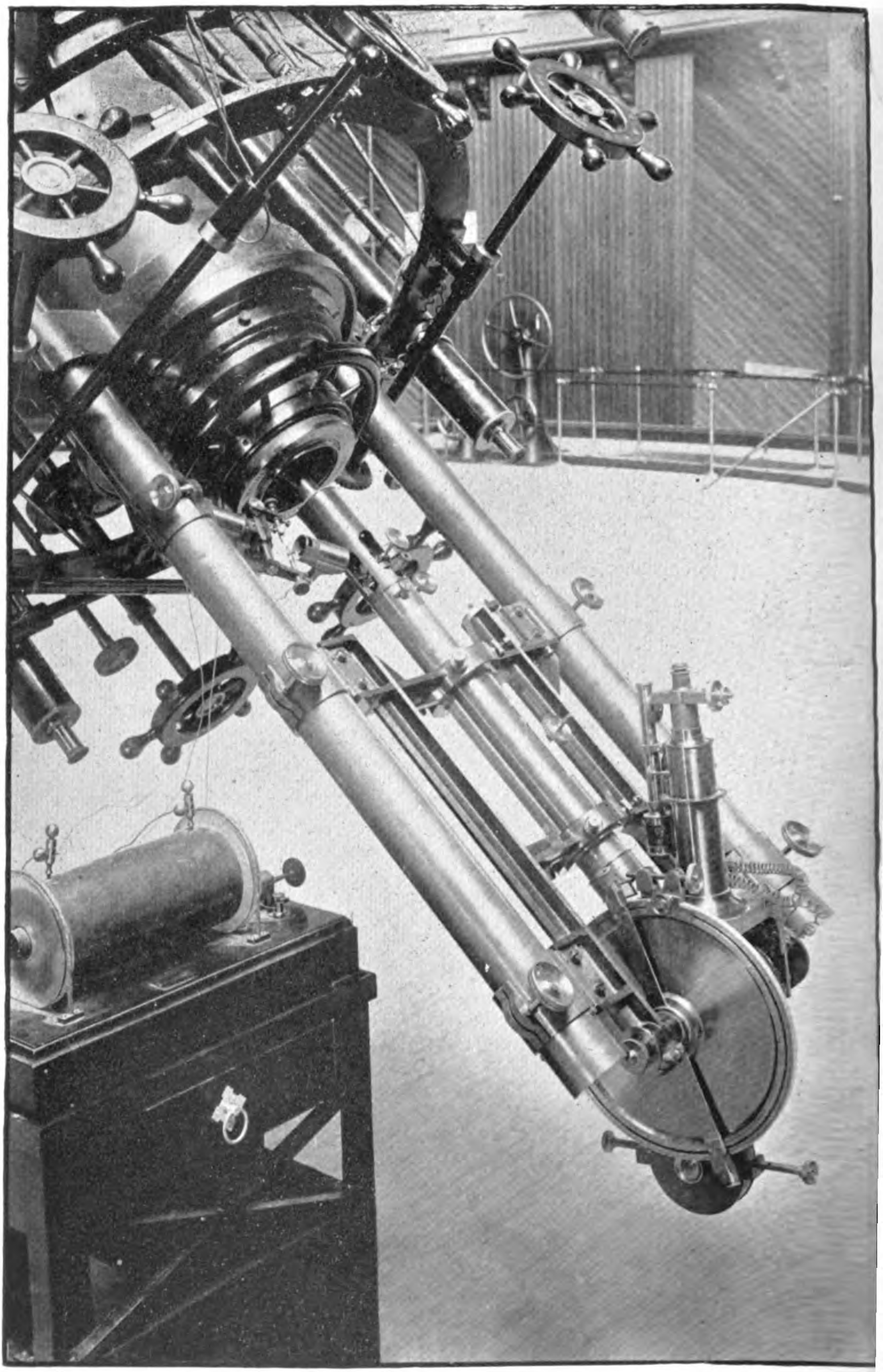


Plate accompanying Professor Keeler's paper on the Star Spectroscope of the Lick Observatory.

PLATE VI.

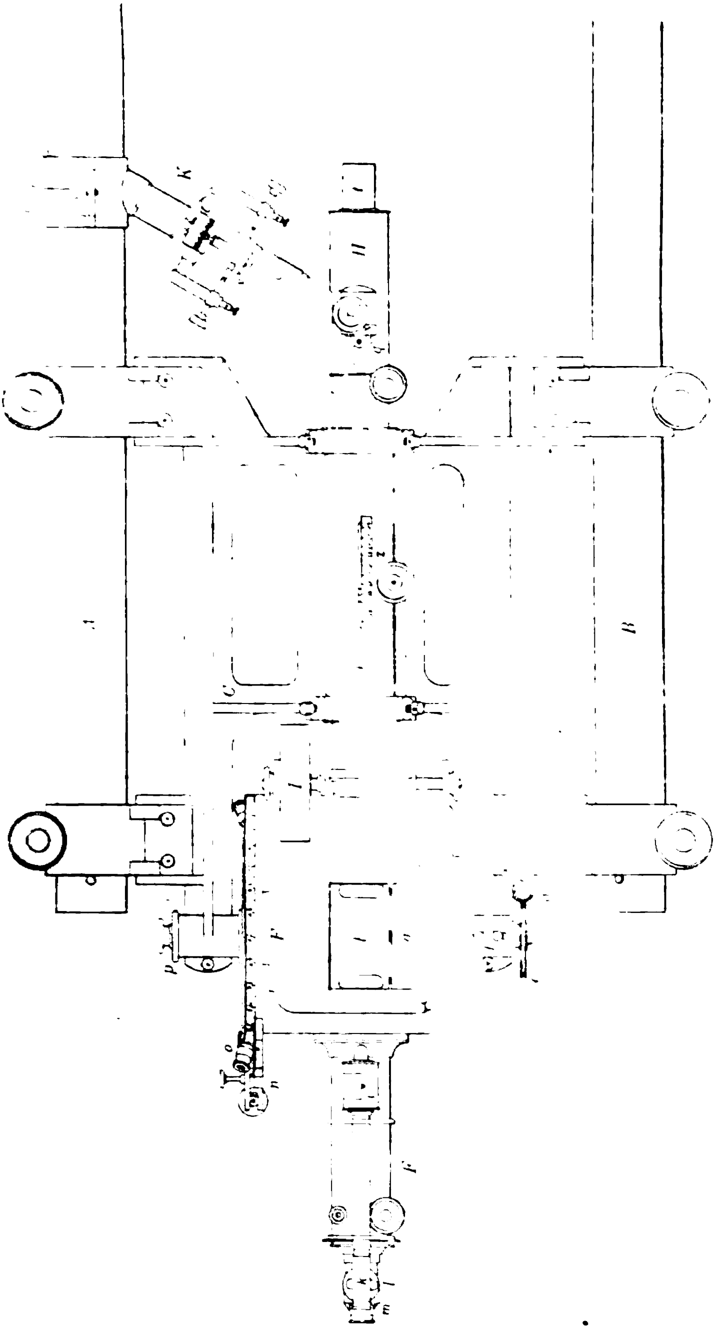


Plate [illegible] showing Professor Keeler's [illegible] the Star Spectroscope of the Lick [illegible]

PLATE V.

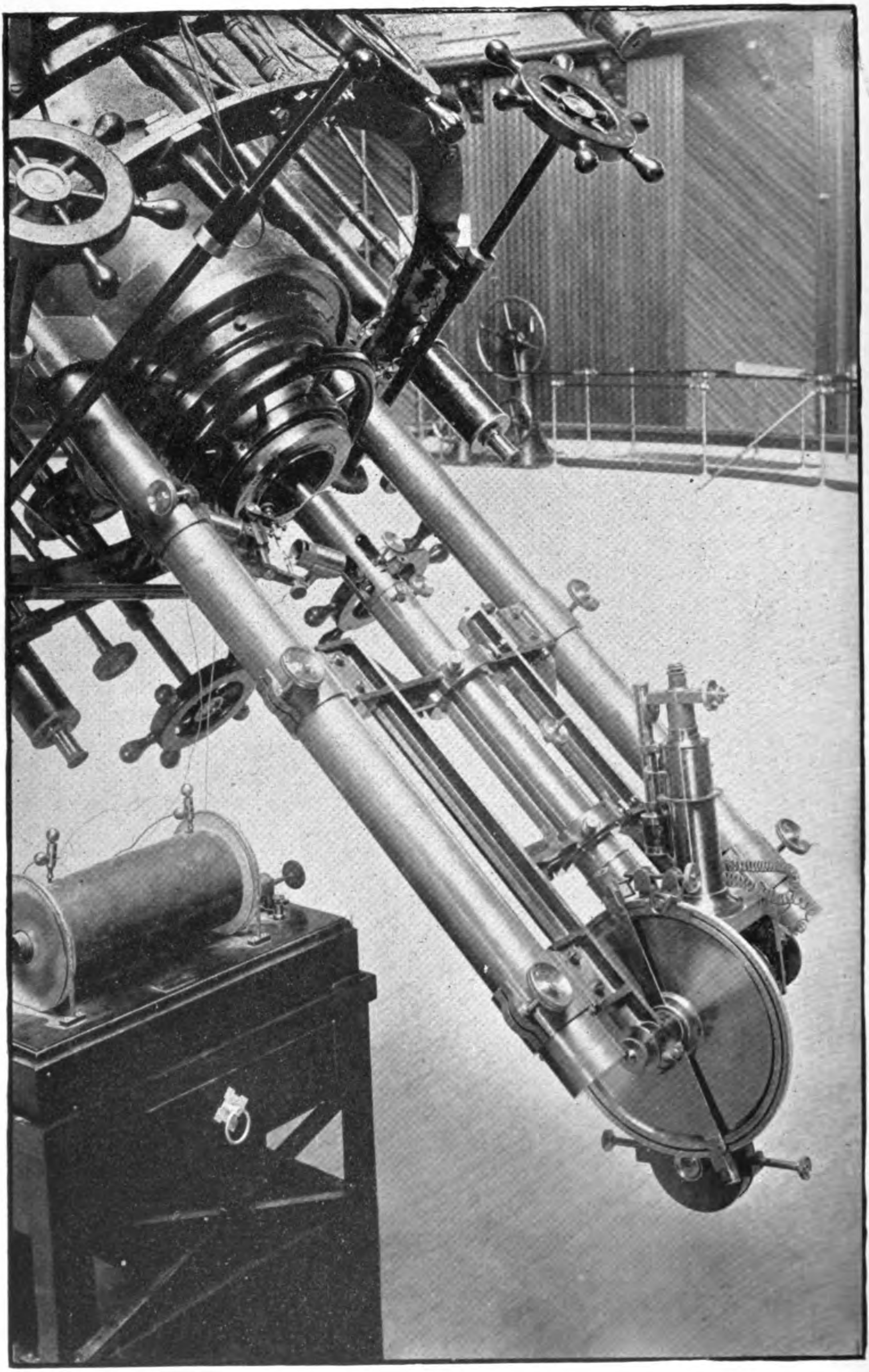


Plate accompanying Professor Keeler's paper on the Star Spectroscope of the Lick Observatory.

PLATE VI.

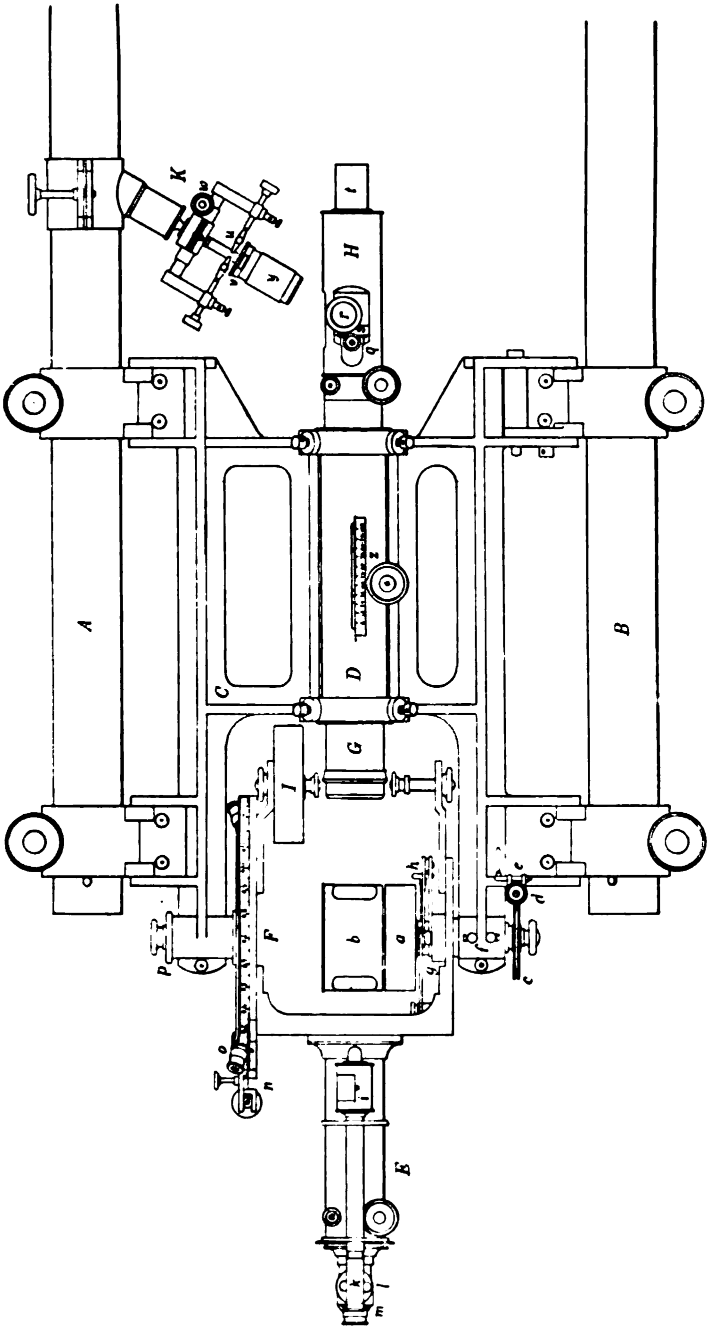


Plate accompanying Professor Keeler's paper on the Star Spectroscope of the Lick Observatory.

STARS OF THE FIRST AND SECOND TYPES OF SPECTRUM.*

E. W. MAUNDER, F. R. A. S.

The question of stellar evolution has been much discussed during the past few years, and not a few new facts bearing upon it have been recently brought forward, and the consideration of some of these has led me to think that some conclusions which have been very generally accepted require not a little modification.

It is, of course, well-known to all that stellar spectra are by no means of one uniform appearance, and that they show strongly marked and striking differences, four leading types being readily recognized. These types, if we follow Secchi's numeration, may be briefly described as follows:—

TYPE I.—Color of the stars, usually white or bluish. *Examples:* Sirius, Vega, Altair. Characteristics: the hydrogen lines are very strongly marked, being broad, dark, and diffused at the edges, but the lines of the metals are inconspicuous.

TYPE II.—Color of the stars, mostly yellow. *Examples:* the Sun, Arcturus, Capella, Aldebaran. Characteristics: the hydrogen lines are present, but are not specially pronounced; whilst the metallic lines are numerous and distinct.

TYPE III.—Color of the stars, mostly orange. *Examples:* Betelgeuse, Antares, α Herculis. Characteristic: a number of shaded bands are seen, which are each darkest at the end nearest the violet, and shade off towards the red.

TYPE IV.—Color mostly red. *Examples:* 19 Piscium, 152 Schjellerup, no very bright stars. Characteristic: the presence of shaded bands due to carbon, which shade off in the opposite direction to those of the preceding type.

It was very natural that so soon as this classification was recognized, these several types should be interpreted as representing different successive epochs in the life history of a star. Generally speaking, it has been supposed that the Sirian or first type indicates the earliest period, that of highest temperature, that as a star cools, it enters on the Solar or second stage, and with yet a further cooling, on a stage represented by one of the two orders of shaded spectra. With this idea, it has been very customary to speak of the Sirian stars as being on the average much larger than stars resembling our Sun in spectrum. Thus the late R. A. Proctor, writing in reference to them, says, "the stars belonging to this type are certainly in many cases, and probably in all,

---

* *Jour. British Astr. Assoc.*, Oct., 1891.

very large orbs," and he often spoke of them as "giant suns," a practice in which many other writers have imitated him.

This was a very natural inference, for on the assumption referred to above, that a first type spectrum indicates that the star possessing it is in the earliest stage, that of highest temperature, we should infer: (1.) That Sirian stars had on the average a greater mass than Solar stars, for the larger the star, the slower would be the process of cooling. (2.) Sirian stars would on the average be less condensed than Solar stars, and having a larger mass, must needs have a much larger volume. (3.) Having a much larger surface than Solar stars, and being at a higher temperature, they should emit, on the average, a very much greater amount of light.

It must be borne in mind that these differences cannot, on the assumption referred to, be slight or insignificant in the mean. Since the whole history of stellar evolution is summed up in but three or four stages, each stage must represent enormous periods of time, and the difference between a star in the height of the first period, and the same star in the height of the second, must be very great indeed, both as to the degree of condensation, temperature and total radiation. If there are the materials for instituting a comparison between the actual brightness of stars of the different types, the first type should come out as the most luminous, beyond all possibility of doubt.

The materials for such a comparison within our reach are very slight, but such as they are, they do not point to any such predominence in brightness (total radiating power) of the Sirian stars. First we have a few stars of which the parallaxes are known, and, knowing their distances and their apparent magnitudes, we can compute the absolute light-giving power of each. The result of the comparison is given below, the Sun being taken as unity. The magnitudes have been taken from the Oxford Uranometria, the Sun being assumed to be 26½ magnitudes brighter than an average first magnitude star.

SIRIAN STARS.

β Cassiopieæ	12.3	Procyon	23.7	α Draconis	1.7
α Persei	83.0	Regulus	108.0	α Aquilæ	25.8
Sirius	42.4	α Lyræ	2048.1	α Cephei	67.8

SOLAR STARS.

α Cassiopeiæ	59.7	Aldebaran	71.3	π Herculis	28.0
η Cassiopeiæ	5.1	Capella	217.7	ε Cygni	1.2
β Andromedæ	41.5	Pollux	166.1	Arcturus	6226.9
Polaris	188.5	η Herculis	6.4	Sun	1.0
α Arietis	58.9				

Two things strike the attention at once. First, the striking inferiority of the Sun to even the feeblest of these stars. This may be due, and not improbably is, to an under-estimate of its brightness. Or it may be due, and this is also not unlikely to be the case, to a general over-estimate of stellar distances. Next the great disparity in light-giving power of the various stars. Vega and Arcturus tower far beyond all the rest. Dr. Elkin's parallaxes have been used for both these stars, and in both cases he has found a much smaller value than his predecessors have done. Still, whilst making all allowances for the uncertainty of our knowledge of stellar parallax, the comparison seems to show that, if one class has the advantage over the other, the superioirty lies with the Solar stars; for including Vega and Arcturus, we find the mean first type star to have a radiation of 268.1, the mean second type of 544.0. Omitting those two stars, the figures become 45.6 and 70.5 respectively. Certainly no such decided and unmistakeable superiority as we should naturally expect, is shown by the Sirian class.

Another and rougher method of comparison is to see how the stars of the two types are distributed for different orders of magnitudes. I have given a rough comparison in *Knowledge* for April last, which seems to show that Sirian stars become more numerous the fainter are the stars we are dealing with. This conclusion is confirmed by Professor Pickering's discovery that the Milky Way, which is especially a region of small stars, is especially rich in Sirian stars. It appears, then, either that Sirian stars are on the average smaller than Solar stars, or else that they are situated at greater distances from us.

Yet another mode of comparison is afforded us by double stars. Here we have two stars at the same distance from us; difference in apparent brightness is therefore equivalent to difference in real light-giving power. Unfortunately we know but little of the spectra of double stars, but, if in default of better information, we are guided by their colors, a very remarkable circumstance becomes apparent. Where the two stars are of the same color, they are always of the same, or nearly of the same, magnitude. But where they are of different colors, the difference of magnitude becomes much more marked; and in nearly every case the smaller star is blue, the larger one white or yellow. In a few cases the smaller star is not blue but red, but in no case is the larger star blue.

Accepting, as in some cases they certainly are, the yellow stars as of the Solar type, and the blue as Sirian, we are again brought to conclude that so far from the Sirian stars being the largest and brightest, the very reverse is the case, and it is the Solar which have the better right to be entitled "Giant Suns."

It has been urged that the succession of the different stellar types might be just as plausibly taken in the reverse order, so that the Solar stars were they ounger, and not the Sirian. The conclusion just reached might be taken as confirming such a view, were it not for certain facts which strongly point to the first type stars being much less condensed than those of the second type. For in the case of binary stars, for which the elements of the orbit have been computed, we can compare, on the assumption that the intrinsic brightness per unit of surface for all the stars is the same, the density of one pair with that of another. The result, as the following table will show, gives 0.3026 as the mean density for the Solar class, the density of the Sun being taken as unity, and only 0.0211 for that of the Sirian. One most remarkable exception to the general greater density of Solar stars, however, is furnished by the instance of γ Leonis, which appears by this comparison as by far the lightest of all binaries, though it is of the second type. Still, even allowing for this evidently exceptional star, the Solar stars are on the average 14.3 times as dense as the Sirian, a difference too great and too systematic to be accidental. Further, Dr. Huggins has shown us stars actually involved in the great nebula of Orion, and showing the typical nebular lines; so that they would seem to be in the very process of forming out of the nebula. Yet the Orion stars are of the first type.

SIRIAN STARS.

OΣ 4	0.101	ω Leonis	0.022	ξ Scorpii	0.013
OΣ 20	0.006	θ Ursæ Maj	0.002	γ Ophiuchi	0.001
14 Orionis	0.022	γ Virginis	0.017	μ Draconis	0.021
12 Lyncis	0.003	25 Can. Ven	0.017	ζ Sagittarii	0.002
Sirius	0.011	η Coronæ Bor	0.109	δ Cygni	0.001
Castor	0.001	μ^2 Boötis	0.040	β Delphini	0.010
ζ Cancri	0.037	γ Coronæ Bor	0.002	λ Cygni	0.005

SOLAR STARS.

Σ 3062	0.323	42 Comæ	0.047	Σ 2107	0.079
η Cassiopeiæ	0.956	Σ 1757	0.803	Σ 2173	0.219
36 Andromedæ	0.012	Σ 1819	0.196	τ Ophiuchi	0.009
Σ 228	0.143	α Centauri	0.121	70 Ophiuchi	1.103
OΣ 149	0.164	γ Leonis	0.0002	γ Coronæ Aust	0.134
Σ 1037	0.073	ξ Boötis	0.914	OΣ 387	0.047
Σ 3121	1.882	44 Boötis	0.061	OΣ 400	0.034
ξ Ursæ Maj	0.181	OΣ 298	0.600	4 Aquarii	0.026
OΣ 234	0.075	α Coronæ Bor	0.077	τ Cygni	0.020
OΣ 235	0.059	ζ Herculis	0.018	π Cephei	0.005
				Sun	1.000

Further, the Algol variables, where we have a comparison star, revolving almost in contact with its primary, and we may infer, but recently separated from it, are all, so far as we know, of the first type. These stars are evidently in an early and but little condensed condition. So too, the "spectroscopic doubles" hitherto discovered, have all been of the first type. We may conclude, therefore, from such evidence as lies before us as yet, that if these two types of spectrum indicate successive stages of development at all, the ordinary idea that the Sirian is the earlier stage, must be accepted. And yet, as we have already seen, the Sirian stars should on that assumption have by far the greater total radiation; whereas the reverse would rather appear to be the case.

The colors of double stars emphasize this difficulty. If both members of a pair were formed at the same time, then the smaller should enter the earlier on the second stage of development, and we should expect to see many instances of Sirian primaries and Solar companions. And the greater the difference in size between the two, the further should the smaller body be advanced as compared with the larger. We really find the very reverse to be the case. We never find the primary blue and the satellite yellow; but the greater the difference in size between the two the more frequently is it the case that the principal star is yellow and its dependent blue. Nor can we get over the difficulty by supposing that the small star was formed much later than the larger. Whenever formed, it could not have started in an earlier state of condensation and temperature than its parent orb possessed at the time when it gave it birth.

Yet another fact has recently come to light which points yet more strongly in the same direction, viz., the prevalence in certain limited regions of special types of spectrum, such as those of the fourth type, or of the "Wolf-Rayet" stars, or fifth type. The discovery which Professor Pickering has now announced, that the Milky Way is specially rich in first type stars, is a fact of the same order; so also is the prevalence of a particular variety of that type in Orion. But the most conclusive circumstance of the kind is the discovery that the stars in the Pleiades are practically all of the same type. Forming, as they manifestly do, a real group, and therefore lying all, practically, at the same distance from us, and embracing amongst their number stars of a great range of magnitude, we see they must be of very different sizes. Yet we find practically but one type of spectrum. Is it reasonable to suppose that throughout the group the smaller stars are just so much younger in actual interval of time from their formation than the larger, that smaller size has been exactly balanced by shorter time and that in this way the entire group preserves to us an appearance of uniformity? Is it not much more natural to suppose that they all show the same spectrum, because, forming one group, they contain the same materials and in similar proportions?

There seems indeed to me but one way of reconciling all these different circumstances, viz., to suppose that spectrum type does not primarily or usually denote epoch of stellar life, but rather a fundamental difference of chemical constitution. If so, we can readily understand why special types should affect special regions, and why in the case of double stars the two should be of the same type when both are nearly of the same size, and the smaller the hydrogen star when the difference of magnitude is considerable. The spectroscope has indeed shown us that the same elements exist in Sun and stars as we are familiar with here, but to tack on to this fact the assumption, so often tacitly made, that they are distributed throughout the universe *in the same proportions*, seems to me wholly unwarranted and contrary to probability. If they are not thus equally distributed, then we ought to find some stars rich in hydrogen and some in metals, and the resulting differences in their spectra will afford us no ground for concluding the one to be in an earlier condition than the other. The difference will be one of chemical and fundamental constitution, not of epoch of stellar history.

Of course our knowledge on the various points to which I have alluded is as yet very meager, and further researches may entirely change the aspect of affairs. For example, we may find that our present types are far too general, we may be grouping together as of the same class of spectrum stars which a more careful examination may show to differ from each other in some easily overlooked but most important detail. Professor Pickering has already carried the classification of spectra much further than it has been carried before. So it may well turn out to be the case that there is only a superficial resemblance between the spectra of giants, like Sirius and Vega, and of the little stars which swarm in the galaxy, or of the tiny acolytes of unequal doubles. Lockyer has already urged a division of the solar type into two classes, one indicating a stage earlier than the Sirian, and the other later; an arrangement which would explain some of the facts I have here touched upon. But arguing from the facts we at present possess, I am inclined strongly to believe that the first and second types of spectrum indicate rather real differences of stellar constitution than differences in the stage of development.

The cases of the third and fourth types I consider different. We have much fewer facts to go upon with regard to them, but the evident connection between variability and third type spectrum inclines me to think that that class of spectrum, at least, may be really indicative of the particular stage in its history which the star has reached.

THE IRON SPECTRUM AS A COMPARISON SPECTRUM IN SPECTROGRAPHIC DETERMINATIONS OF STELLAR MOTION IN THE LINE OF SIGHT.*

PROFESSOR H. C. VOGEL,
DIRECTOR OF THE ASTRO-PHYSICAL OBSERVATORY, POTSDAM.

In the *Sitzungsberichten der. K. Akad. d. Wissenschaften* for March 15, 1888, an account is given of my first observations, by which it has been shown possible to reach a more certain basis for the determination of the motion of the stars in the line of sight by the spectrographic method than by direct observations, even with equal instrumental means. The expectations raised by these first results with a temporary apparatus as to the accuracy attainable in the determination of stellar motions, have not only been borne out in the course of time, but even much surpassed.

The more exact knowledge of the motions of the brighter stars in the northern sky, gained of late by spectrographic determinations, in general confirms the results of former direct observations as to the direction of the motion, but serves to considerably alter our notion of the velocity, which in the direct observations was generally much over-estimated.

I have given in *Astr. Nachrichten*, No. 2896, a description of the construction of the apparatus used to make final determinations, together with an account of the method of measuring spectrograms of stars of the second type. It was found very early in the course of the research that the accuracy of the results very largely depends upon the method of measuring the spectrograms; for this reason I have been busily engaged in ascertaining the most advantageous method. Great difficulties as to this point had to be overcome, especially in the case of stars of the first type with broad hydrogen lines, but even here I have succeeded in giving to the measures a precision nearly equalling that attained in stars of the second type. The method, which was described in

---

* Translated from the *Sitzungsberichte der Berlin Akademie der Wissenschaften*, 4 June, 1891.

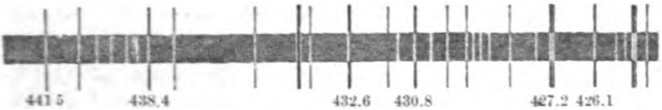
Astr. Nachrichten, No. 2995 with the account of the observations of α Virginis, is very simple, and at the same time secures to the observer the greatest possible freedom from prejudice. In all these investigations, however, the hydrogen spectrum, or rather the line $H\gamma$, has served as a basis for measurement.

In the autumn of 1888, when the first experiments with the new spectrograph were in progress, an endeavor was made to use another comparison spectrum in addition to the hydrogen spectrum. Magnesium naturally suggested itself, as the Mg line at wave-length 448μμ is very sharp and clearly defined in a great many stellar spectra, and does not fall too far from the center ot the portion of the spectrum given by the spectrograph. No satisfactory results have as yet been obtained in this way, however, as the Mg line artificially produced by the spark discharge in air is broad and diffuse, and is thus not suited for exact measures. The experiments were repeated with various modifications at the beginning of the present year, but with the same negative result. But the iron spectrum has turned out to be very useful for a comparison spectrum. The lines are sharp and not too numerous in the neighborhood of the $H\gamma$ and Mg (448μμ) lines, so that for stars, in whose spectra this magnesium line is the only one visible in addition to the hydrogen line, measures may safely be made by connecting some iron lines with the magnesium line. But for bright stars of the first type, the spectra of which contain, in addition to the hydrogen line, a great number of fine lines mostly belonging to iron, there was reason to believe that a higher degree of accuracy might be reached in the determination of stellar motion in the line of sight by photographing the iron spectrum on the same plate with the spectrum of the star. For this purpose it is necessary that the iron lines do not cross the stellar spectrum, as I have found useful in the case of the hydrogen line, but extend only to its edges on either side. This result may be obtained by covering the part of the slit through which the image of the star passes with a small strip of metal, while the photograph of the iron spectrum is being taken. If this were not done it might happen that on account of their very small displacement, the lines of the artificial spectrum might fall too near the stellar lines, or even overlap them, so as to prevent accurate measures.

In the observations of Sirius recently made here the iron electrodes (piano-wire) were placed at a distance of 35cm from the slit, and were so adjusted that the short spark (2mm to 3mm) was exactly in the optical axis of the collimator. The spark was produced by a large Ruhmkorff coil with 4 Leyden jars. An exposure of 25 seconds was sufficient to give the principal iron lines.

In addition to this, several points essential to accurate measures, to which I have called attention before, have been carefully observed. The comparison spectrum must be taken with the telescope directed to the star, and the middle of the exposures for the stellar and metallic spectra must coincide as closely as possible, in order to do away with the effect on the measures of changes in the flexure of the apparatus and variations in the dispersion due to temperature.

The following wood-cut gives an illustration (negative) of a portion of the spectrum of Sirius with the principal iron lines, as obtained on March 22, 1891. The cut was made from an enlarged copy of the original negative.*



Besides the lines of the iron spectrum, the artificially produced hydrogen line Hγ is seen extending across the spectrum of the star. All of the stellar lines, as compared with the corresponding lines of the artificially produced iron spectrum, show a slight displacement toward the red.

Measures of the plates under the microscope have given the following results:

March 21, 1891. Plate No 246 Exposure for star = 48m. for Fe spectrum = 25s.		March 21, 1891. Plate No. 247. Exposure for star = 15m. between clouds, for Fe spectrum = 60s.		March 22, 1891. Pltae No. 248. Exposure for star = 36m for Fe spectrum = 25s.	
λ	Δ R	λ	Δ R	λ	Δ R
426.1	0.070 (1)	428.3	0.026 (1)	426.1	0.036 (2)
428.3	0.004 (1)	429.5	0.044 (2)	427.2[1]	0.042 :(${}^2{}_3$) 0.036 (1)
429.5	0.044 (2)	430.0	0.037 (2)	428.3	0.047 (1)
430.8	0.056 (2)	430.8[3]	——	429.5	0.036 (2)
432.6	0.049 (2)	431.6	0.044 (2)	430.0	0.026 (1)
435.2[2]	0.039 (0)	436.8	0.035 (1)	430.8	0.019 (2)
438.4	0.044 (2)	437.6	0.045 (1)	431.6	0.033 :(${}^2{}_3$)
440.5	0.033 (1)	438.4[4]	——	432.6	0.024 (2)
		440.5	0.040 (2)	438.4	0.027 (2)
		441.5	0.033 (1)	440.5	0.020 (1)
		442.3[5]	0.044 (1)	441.5	0.024 :(${}^2{}_3$)

[1] Double line, the first component very faint in the star spectrum. [2] As it is doubtful whether the stellar and iron lines correspond the observation is omitted. [3] Lines of the iron spectrum too broad and strong for a good measure. [4] Lines in the iron spectrum too broad and strong, in the star diffuse and not well seen. [5] Iron line very faint.

---

* Much of the perfection of detail in the original has unfortunately been lost in the reproduction. The hydrogen line in the star should be very diffuse at the edges, not sharply defined as shown. [G. E. H.]

The first column gives the wave-lengths in millionths of a millimetre, the second the measured distances between the lines in the stellar spectrum and the corresponding lines of the comparison spectrum in turns of the micrometer screw ($1^R = 0^{mm}.25$). The value of the distance measure obtained as the mean of 4 settings has a weight 1. In the case of particularly well defined lines two sets of independent measures have been made; the mean of these measures is given the weight 2, while the weight ⅔ designates observations of lines which were measured with difficulty.

In the photographs of March 21 the stellar spectra are narrow, and the lines of the iron spectrum do not extend to the edges of the spectrum of the star. In measures of the star spectrum the settings were made tangential to the curved lines, while in the case of the iron spectrum the ends of the arcs above and below the star spectrum were united by the cross-hair, thus rendering necessary a correction to the measures. The mean of several measures in the neighborhood of the $H\gamma$ line gave 266^R as the radius of curvature of the lines in the spectrum, and thus corrections of $0^R.008$ and $0^R.005$ are deduced for the distance of the point of tangency from the middle of chords $4^R.0$ (No. 246) and $3^R.3$ (No. 247) in length respectively. Since the lines are convex toward the red end of the spectrum, and the displacement of the stellar lines as referred to the comparison lines is in the same direction, it follows that all measures will be diminished by this amount. In the photograph of March 22 the iron lines reach to the edges of the star spectrum. In the measures the settings were made on the points of contact, and on the stellar lines also at the edge of the spectrum, so that no correction is necessary.

The amount of the linear displacement in different regions of the prismatic spectrum is different for equal differences of wave-length, or the same displacement corresponds to a different velocity in the line of sight. For the wave-lengths in question the motions in geographical miles may be found in the following table, which has been determined from numerous measures of photographs of the solar spectrum made with the spectrograph.

$\lambda = 426\ \mu\mu$	$1^R = 27.5$ geogr. M.
428	28.1
430	28.7
432	29.4
434	30.2
436	30.9
438	31.7
440	32.5

Applying the correction for the curvature of the lines the motions of Sirius corresponding to the displacements as calculated from the table are as follows:

λ	March 21, No. 246. Δ (geogr. miles.)	March 21, No. 247. Δ (geogr. miles.)	March 22. No. 248. Δ (geogr. miles.)
426.1	1.71 (1)	——	0.99 (2)
427.2	——	——	1.17 (⅔) 1.01 (1)
428.3	1.58 (1)	0.59 (1)	1.33 (1)
429.5	1.03 (2)	1.12 (2)	1.03 (2)
430.0	——	0.92 (3)	0.75 (1)
430.8	1.39 (2)	——	0.55 (2)
431.6	——	1.14 (2)	0.97 (⅔)
432.6	1.21 (2)	——	0.71 (2)
436.8	——	0.94 (1)	——
437.6	——	1.26 (1)	——
438.4	1.15 (2)	——	0.86 (2)
440.5	0.82 (1)	1.14 (2)	0.65 (1)
441.5	——	0.93 (1)	0.79 (⅔)
442.3	——	1.30 (1)	——
Mean:	1.24	1.05	0.87

The mean of the three determinations, considered as of equal weight, is 1.05 geographical miles, which is the amount per second by which the star increases its distance from the Earth, as the displacement of the lines in the spectrum is toward the red. At the time of the observation the component of the Earth's motion in the direction of Sirius was + 3.01 geographical miles. The motion per second of Sirius with respect to the Sun on March 22.0, 1891, was therefore:

— 1.96 geogr. miles.

I give below the observations of the motion of Sirius obtained with the spectrograph, in which the measures of displacement were made with respect to the hydrogen line Hγ.

Date.	Observed Displacement in revolutions of the screw.	Motion of Sirius with respect to Earth. geogr. miles.	Reduction to Sun. geogr. miles.	Motion of Sirius with respect to Sun. geogr. miles.
1888 Dec. 1	−0.110	−3.32	+1.64	−1.68
Dec. 13	−0.103	−3.11	+1.06	−2.05
Dec. 13	−0.101	−3.05		−1.99
1889 Feb. 10	+0.023	+0.69	−1.95	−1.26
1890 Jan. 29	−0.004	−0.12	−1.42	−1.54
Feb. 12	+0.022	+0.66	−2.04	−1.38
Feb. 12	+0.006	+0.18		−1.86
1891 Feb. 7	+0.001	+0.03	−1.81	−1.78
Mar. 21	+0.032	+0.97	−3.00	−2.03
Mar. 22	+0.044	+1.33	−3.01	−1.68
				Mean: −1.73

The agreement of this mean with the value deduced above is certainly very satisfactory, and in this case the use of the iron spectrum is of little advantage, especially if it is considered that much more physical apparatus is needed for the observation. Great accuracy is also required in the adjustment of the electrodes, in order that the spark may be as nearly as possible in the optical axis of the telescope, while the adjustment of the hydrogen Geissler tube at right angles to the optical axis does not require particular care, if the tube is accurately placed at right angles to the direction of the slit. That the advantage of using the iron spectrum is not clearly brought out in the case of Sirius is principally due to the circumstance that the lines in the Sirius spectrum are so very faint and narrow that settings of the micrometer cross-hair cannot be made with as great accuracy as with somewhat broader and stronger lines. The photographs on March 21 and 22 of this year are also not as good with respect to the fine lines as others obtained before. α Cygni would have served better, as the iron lines in its spectrum are stronger.

The principal advantage of the method, which must not be overlooked, lies in the fact that each line, compared with the corresponding line of the artificial spectrum, gives an independent determination of the motion; thus the value of a single plate is much increased, as in the method which I have used for spectra of the second type, for the effect of any irregularities in the photographic film is eliminated by measuring several lines.

The iron spectrum is also recommended as a comparison spectrum for stars of the second type, but in these spectra containing a great number of lines mistakes are more easily made in comparing the stellar lines with the corresponding artificial lines than is the case with stars of the first type, particularly those which show only iron lines, and great care is therefore necessary in the choice of the lines. This caution may even be carried so far as to omit narrow double lines with very unequal components, for I have found that in photographs of emission spectra an unsymmetrical widening occurs in very close double lines, such that after long exposure the centers of the photographed lines are more widely separated, since the deposit of silver is greater on the outer edges than between the lines. When the components are equal this peculiarity of the photographic plates does no harm, if the measures are made on the middle of the double lines. Even in absorption spectra a very similar propensity to that seen in emission spectra is to be expected, though perhaps to a less extent, and in fact it has been found in a great number of measures in the spectra of stars of the second type which contain a great many lines, that large deflections are most frequent in the case of close double lines with unequal components. Single lines have therefore been used as far as possible in the measures.

I may add in conclusion that with the investigations on Sirius here presented my preliminary spectrographic observations for the determination of stellar motions are ended for the present; but I hope that I will be able to resume them shortly with more powerful optical apparatus.

◆

RESEARCHES ON THE RADIAL MOTION OF STARS WITH THE SIDEROSTAT OF THE PARIS OBSERVATORY.[*]

M. H. DESLANDRES.

The investigation of the radial velocity[†] of stars by the displacement of lines in their spectra, according to the method of M. Fizeau, must furnish the solution of new and important questions. But the experiment is a delicate one, and twenty-five years of visual observations of these displacements has given only uncertain or contradictory results; photographic observation, on the contrary, does not seem to be subject to the same sources of error. It is my intention, according to the plan of Admiral Mouchez, to carry on at the Paris Observatory the regular study of stellar motions by spectrum photography.

The first results were obtained with the great telescope of 1.20 metres aperture (see *Comptes rendus*,1891); but the spectroscope employed, which was then the only one which could be adapted to this great instrument, was of small dispersive power (a displacement of $\frac{1}{200}$ millimetre corresponding to a velocity of 11 kilometres per second). I have also used for the same purpose the Foucault siderostat, with which any form of spectroscope may be readily employed.

Method of Experiment.—The beam of light reflected horizontally by the mirror of the siderostat is received by a 12-inch objective (Secrétan),[‡] which gives an image of the star on the slit of the spectroscope. The spectroscope, arranged for photography, has 1 or 2 prisms of light flint, with lenses of 0.65 metre focal length. A displacement of $\frac{1}{200}$ millimetre corresponds, with one prism, to a velocity of 8 kilometres per second; with two prisms, to a velocity of 5 kilometres.

But the siderostat has no finder, and follows the diurnal

---

[*] "Comptes rendus" November 23, 1891.

[†] I call *radial velocity* the velocity projected on the radius which unites the earth to the star. This velocity, as is well known, is not given by ordinary observations, which can only reveal the component perpendicular to the radius.

[‡] This objective was formerly employed on the equatorial of the West tower; I have achromatized it for the chemical rays by a suitable separation of the lenses.

motion very badly. I have had recourse to a special method of directing and maintaining the star on the slit. This slit, which is illuminated by a red light, is formed of two platinum jaws, polished and inclined in such a manner as to reflect to one side the beam of light from the objective. An auxiliary telescope, placed near the right ascension and declination slow motions, receives this light, and gives the image of the star and the slit in the same field of view. It is thus possible to correct the irregular movement of the siderostat.* As a further precaution another auxiliary telescope receives the rays reflected from the first prism, and indicates at any instant the quantity of light which enters the spectroscope.

At the middle of the exposure the comparison spectra are photographed above and below the spectrum of the star, the two sources to be compared being placed in as nearly as possible identical conditions. The sources of comparison are electric sparks from at least three substances, hydrogen, calcium and iron, which are found in most of the heavenly bodies. The electric spectrum of iron, which I was the first to employ and recommend (*Comptes rendus*, 1890 and Feb., 1891), is particularly advantageous on account of the numerous fine lines which it contains; for the investigation of displacement it is much to be preferred to the single line $H\gamma$ of hydrogen, employed by M. Vogel; with white stars of the first type, it assures twice as great precision to the measures. Moreover, in a recent note,† M. Vogel announces that on the 21st of last March he tried the iron spectrum and recognized its superiority.

Results.—These simple arrangements have allowed photographs and measures of displacement to be made of the brighter stars. I have the honor to present to the Academy one of these photographs, which shows the spectrum of Sirius compared March 3, 1891, with the spectra of hydrogen, iron and calcium.

The photograph shows at a glance that 4 lines of hydrogen, 2 of calcium and 11 of iron are present in the star. Moreover, the lines of the star, referred to the comparison lines, are slightly displaced towards the red. This displacement, measured to $\frac{1}{200}$ millimetre on the 10 sharpest lines, corresponds to an apparent receding motion of the star of + 19 kilometres per second. Now the velocity of the earth in its orbit, projected on the direction of

---

* The irregularities are largely due to the nature of the apparatus: four movements of rotation take place around four different axes, and these, with an additional sliding motion, must be simultaneous. Moreover, the correcting movements are insufficient.

† See page 151.

Sirius, is + 20.2 kilometres. Thus on March 3 Sirius was moving towards the Sun with a velocity of — 1.2 kilometres.

These results show the aid that may be derived from the siderostat for the study of the chemical composition and motions of the bright stars; a future note will describe a new arrangement of the great telescope of 1.20 metres aperture for the study of fainter stars with high dispersion.

NOTE ON RECENT SOLAR INVESTIGATIONS.

GEORGE E. HALE.

On December 28, 1891, photographs made at this Observatory showed that the H and K lines are reversed, not only in the vicinity of Sun-spots, but in regions irregularly distributed over the entire disc of the Sun. On January 12, 1892, it was found possible to photograph the *forms* of some of these reversed regions, using a moving slit apparatus just completed for our large diffraction spectroscope by Brashear. The K line in the fourth order spectrum was employed, as is customary in the case of prominences. The reversed regions are of great extent, and in appearance closely resemble faculæ. Several explanations may be suggested to account for them. They may be:

1. Ordinary prominences projected on the disc.
2. Prominences in which H and K are bright, while the hydrogen lines are absent.
3. Faculæ.
4. Phenomena of a new class, similar to faculæ, but showing only H and K bright, and not obtained in eye observations or ordinary photographs because of the brilliant background upon which they are projected.

The investigation will be continued as rapidly as the present unfavorable atmospheric conditions will permit.

KENWOOD ASTRO-PHYSICAL OBSERVATORY,
Chicago, January 18, 1892.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in ASTRO-PHYSICS should be addressed to George E. Hale, Kenwood Astro-Physical Observatory, Chicago, U. S. A. Authors of papers are requested to refer to page 176 for information in regard to reprint copies, etc.

In addition to the letters from well-known astronomers and spectroscopists which were printed in our last number, others expressing interest in ASTRO-PHYSICS, and promising support, have been received from Dr. B. Hasselberg, Stockholm, Professor N. C. Dunér, Upsala, and Dr. Ralph Copeland, Astronomer Royal for Scotland. The latter has been kind enough to make arrangements such that important papers communicated by the staff of the Royal Observatory to the Edinburgh Royal Society, will be found at an early date in these columns. Professor Hasselberg will soon publish a paper in ASTRO-PHYSICS on his recent investigations, and other important articles may be expected from Herr Victor Schumann and Herr J. Plassmann.

Effect of Aberration on Measures of Solar Prominences. On pages 126 and 128 translations are given of the papers on aberration by MM. Fizeau and Mascart, which were referred to by Dr. Crew in the last number of ASTRONOMY AND ASTRO-PHYSICS. Dr. Crew has done a service in pointing out the error in M. Fizeau's paper, for though the question cannot be considered as in any degree difficult, it is at the same time somewhat misleading, as such an error on the part of so distinguished a specialist as M. Fizeau sufficiently testifies. We must ourselves confess to having been deceived on this point, but wickedly find a crumb of comfort in the thought that the editors of the *Observatory* and other well-known publications were equally unfortunate.

Photographs of the Recent Total Eclipse of the Moon. In the *Comptes rendus* for November 23, M. G. Rayet gives the results of observations made at Bordeaux of the total lunar eclipse, which occurred on Nov. 15, 1891. In spite of unfavorable atmospheric conditions it was found possible during totality to photograph a considerable portion of the Moon's disc with an exposure of about two minutes. The instrument employed was the photographic equatorial of 33 centimeters aperture. In his remarks on M. Rayet's communication, M. Janssen suggests that a measure of the photographic value of the light from the totally eclipsed Moon might be obtained by finding the time required to give, on a portion of the plate used in photographing the eclipse, an image of the full Moon of the same intensity. The ratio of the times of exposure would give the inverse ratio of the photographic intensities. As the light reflected from the Moon during eclipse must pass through a great depth of the earth's atmosphere M. Janssen hoped to observe the faint oxygen absorption bands in the green and blue regions of its spectrum, but observations at Meudon were unfortunately prevented by bad weather.

Herr Schumann's Discoveries in the Ultra-Violet Hydrogen Spectrum. In a letter dated Dec. 10, 1891, Herr Schumann sends us a most interesting account of his recent important discoveries in the extreme ultra-violet. During a visit to his laboratory in Leipzig last summer we were greatly struck by the extreme neatness and attention to detail there apparent. Under a microscope the photographs of gaseous and metallic spectra showed a sharpness of definition which has probably never been equalled in work of a similar degree of difficulty. For his extensive investigations of the hydrogen spectrum Herr Schumann has not less than one hundred tubes, most of them fitted with quartz stoppers for end-on illumination, and his collection of quartz and fluor spar prisms and lenses is remarkably large.

In no region of the spectrum does the investigator encounter such great difficulties as in the extreme ultra-violet, for not only do these short waves exercise but little effect upon the most carefully prepared photographic plates, but in addition they are completely absorbed by a layer of air of only a few feet in thickness. For this reason, in passing beyond λ 1800, Herr Schumann finds it necessary to use his spectrograph in a vacuum. After working an entire year he has succeeded in preparing photographic plates by a new formula, which possess an extraordinary degree of sensitiveness. They also have the peculiar property of becoming more sensitive the longer they are kept, without being subject to any of the defects which ordinary bromide of silver plates acquire under the same conditions.

A few weeks preceding the date of his letter, working with his new plates on the spectrum of hydrogen, Herr Schumann succeeded in photographing several centimetres beyond the most advanced ultra-violet boundary line then known. In the most refrangible part of this extremely feeble region, but one plate was sufficiently sensitive to show any trace of action. All other plates, though made by the same formula, were not acted upon in the least, even after very long exposure. With the highly improved apparatus then used the attempt was made to resolve the group of hydrogen lines beyond λ 1820 discovered by the same investigator in the preceding year. The results greatly surpassed his expectations, for the group was not only perfectly resolved, but found to contain many more lines than had been supposed from the photographs of 1890. Beyond λ 1820 fourteen clearly defined groups were found, all of them containing a remarkably large number of lines. The first group, which is only 11^{mm} long on the plate, and was made with a slit 0.004^{mm} wide, contains *over 90* well defined lines. The other groups are hardly so rich in lines, but altogether contain about 600. It is thus evident that the radiation of incandescent hydrogen in the hitherto unknown region beyond λ 1820 is surprisingly great.

It is unfortunate that the nature of the apparatus, supplied as it is with fluor spar prisms and used in a vacuum, will not allow the wave-lengths of the most refrangible lines reached to be determined. For this purpose it is hoped that a Rowland concave grating, which is very brilliant in certain spectra, may be used. With this grating the aluminium lines at λ 1860 and λ 1852 have been photographed through a layer of air two metres thick in 45 minutes, a primary current of only seven amperes being employed, while the plates were prepared after the new formula. It has been found impossible with any other plates to photograph these lines through an equal thickness of air, though with the grating this may be accomplished with ordinary silver bromide plates. The remark is made, in passing, that the line at λ 1929, assigned by Cornu to aluminium, belongs in fact to silicon, as has been found by extensive investigation.

A further peculiarity is recorded in the fact that the lines λ 1860 and λ 1852 show a different relative intensity, according as the grating or prisms, whether quartz or fluor spar, are used. The grating gives the more refrangible line of much less intensity than the other, while with prisms the lines are equal in intensity. As yet a lack of time has prevented an investigation of the cause of this difference. It may be due to atmospheric absorption, but it is also possible that the speculum metal may absorb the short waves more strongly than the long. The general absorption of the speculum metal may change at this point into a selective absorption, such that the more refrangible line would be much weakened.

In the construction of the new spectrograph the camera will be so arranged that it can be set at any desired angle to the optical axis of the lens. In the present instrument the camera is fixed at a constant angle of 26°, which is suitable for the region between λ 1860 and λ 1820. For waves shorter than these, the angle must be very much smaller in order to secure the best definition.

The Chromosphere Line Angstrom 6676.9. In *Nature* for Dec. 31, 1891, Professor Young thus replies to the Rev. Cortie's letter on page 135.

"In response to Father Cortie's implied question as to the identification of this line as belonging to the spectrum of iron, I would refer him to Appendix G of Roscoe's lectures on "Spectrum Analysis" (third edition). It is an extract from a joint paper by Ångstrom and Thalen, giving a list of several hundred (then) new identifications; among them appears K 654.3, ascribed to iron.

"The original memoir was presented to the Stockholm Academy of Sciences in February, 1865, and an English translation appeared the next year. I am unable to assign any reason why many of the identifications given in this memoir fail to appear in the map published three years later; but they do, and K 654.3 is among the missing."

Observations of Sun-spot Spectra. On another page we reprint from the Journal of the British Astronomical Association, a paper by the Director of the Solar Spectroscopic Section, the Rev. Walter Sidgreaves. Those who propose to take up spectroscopic work on the Sun will find in this article many valuable suggestions. Though the fact that the possessors of even very small telescopes can secure valuable results in the study of the Sun has been fully demonstrated by several members of the British Astronomical Association, the impression still seems to be very general that spectroscopic work of any kind cannot be done without the most elaborate and costly apparatus. For this reason many amateur observers with small instruments may be found engaged in planetary, lunar, or stellar observation, while very few ever consider the really important contributions they might easily make to Astro-Physics, without expensive additions to their equipment. At the present time, the spectra of Sun-spots offers a most promising field for investigations with small instruments. Of the two or three engaged in a systematic study of the lines affected in spots, the Rev. Sidgreaves is the most active observer, but the observations at Stonyhurst are necessarily confined to a small portion of the spectrum, and at South Kensington the investigation is even more limited in extent. Many more observers are needed at once for this work, for some of the most important questions in solar physics may find their answers in the statistical study of data thus obtained. A telescope of 4 inches aperture or even less is large enough for the purpose, and, if possible, some sort of driving mechanism should be used, such as a sand-clock, air-bag and weight, water-clock, or similar simple contrivance. As the Rev. Sidgreaves points out, however, observations may be made even without a driving-clock. But we imagine that to many the most serious question will be as to the spectroscope. No difficulty should be anticipated on this point, for a very satisfactory instrument can easily be put together at a very small expense. A suitable frame can be made of wood, and adapted to the telescope. On it two little telescopes of perhaps an inch aperture should be fixed at an angle of 25° or less, and one of them, which is to act as the collimator, must have at its eye-end a simple adjustable brass slit, on which the image of the Sun formed by the large telescope is brought to a focus. The only thing necessary to complete the spectroscope for observing solar prominences or spot spectra is a small reflecting grating, which must be so supported that it can be rotated around an axis through the point of intersection of the optical axes of the collimator and observing telescope, and at right-angles to the plane in which they lie. Such a grating, ruled by Rowland, and therefore of the best quality, can be obtained for about fifteen dollars. It is greatly to be hoped that some amateur observers will take up the study of spot-spectra, and they may be certain of the most fruitful results as the reward of careful investigation.

We heartily recommend to our readers Part XII of Old and New Astronomy, which has recently been brought out by Mr. A. Cowper Ranyard. It will be remembered that at Mr. Proctor's death Mr. Ranyard took up the task of editing "Knowledge," and also that of completing the partly finished volume of Old and New Astronomy. Certainly all astronomers owe a debt of gratitude to Mr. Ranyard for the beautiful reproductions of recent photographs of celestial objects which have been published in "Knowledge." Some of these appear as most fitting illustrations in Old and New Astronomy, and bring out very clearly the prominence-like forms in the Great Orion Nebula, and the remarkable dark structures in the Milky way.

We refer to the book for an interesting discussion of the nature of the Milky Way, where the conclusion is reached that this great structure is much nearer to us than has been supposed. The probability is also pointed out that there is absorption of light in space. In addition to many other interesting points which the author's papers in "Knowledge" have made familiar, the discussion of proper motions is given considerable space, and a reason is offered for the large average proper motions of the smaller stars.

Old and New Astronomy will soon be completed by the publication of Part XIII, which will also contain the index.

CURRENT CELESTIAL PHENOMENA.

THE PLANETS DURING MARCH.

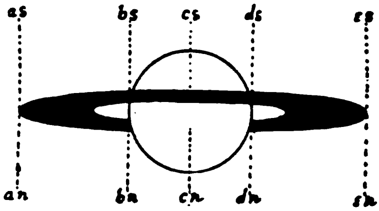
Mercury will be at superior conjunction with the Sun, March 5 at midnight. It will, therefore, for the first half of the month be invisible behind the Sun. Toward the middle of the month it will be far enough east from the Sun for daylight observations with large telescopes, and at the end of the month will be visible to the eye after sunset. Greatest eastern elongation, 19° 03′, occurs March 30, when the planet will set two hours later than the Sun. Mercury and Jupiter will be in conjunction, only 14′ apart in declination, March 12 at 2^h 53^m P. M., central time.

Venus, during March, will be in excellent position for observation. She is moving rapidly northward so that her meridian passage will be at a high altitude, and this, occurring at a little before three o'clock in the afternoon, will give opportunity for both day and evening observations at favorable altitudes. The diameter of the disk of Venus will be 15″ March 1, and 18″ March 31. The illuminated portion of the disk will be 0.760 of the whole on the first and 0.650 on the last day of the month. The brilliancy of this most brilliant of the planets will increase during the month from 81 to 103 on the scale given in the American Ephemeris.

Mars is a morning planet yet, rising in the southeast a little before 3 o'clock. His declination is 23° south, so that he will not be in very good position for observation during March.

Jupiter will be in conjunction with the Sun March 20, so that no observations will be possible during this month.

Saturn will be at opposition March 16, so that his position during this month is the most favorable for observation. This planet is in the constellation Virgo between the stars β and η, being considerably brighter than any of the stars in the vicinity. For chart of path among the stars see page 81 of the January number of this journal.



The rings of Saturn are still very nearly edgewise toward the earth. At present their apparent width is decreasing and will decrease from 1.88″, March 1, to 0.26″ May 25, after which it will increase slowly. Valuable observations upon the relative brightness and thickness of the two *ansæ* of the rings may be made by careful observers during these months. The relative thickness of the *ansæ* and of the shadow of the rings on the face of the planet should also be carefully determined. Sharp lookout should also be kept for the shadows of the satellites and any markings which may be detected upon the face of the planet and which may serve to determine the rotation period. A number of small dark spots were observed last year by Mr. A. S. Williams in England. The accurate determination of the times when the satellites are in conjunction with the ends of the ring, the center and extremities of the planet's equatorial diameter, in the positions indicated by the accompanying diagram, *an*, *as*, *bn*, *bs*, *cn*, *cs*, *dn*, *ds*, *en* and *es*, will be of great value in determining the corrections to the elements of the satellite orbits. The predicted times of these conjunctions are given in Mr. Marth's ephemeris p 166.

Uranus is in the eastern part of Virgo near the star λ, with which it will be in conjunction March 18 at about 7 P. M., central time. Uranus will then be only about 1′ 20″ north of the star. This will be an excellent opportunity for the possessors of small telescopes to identify the planet, for it will be quite near the star λ Virginis for several days. For chart of the constellation Virgo and path of Uranus, see our last number, page 81.

Neptune will be above the western horizon during the evening hours of March, a little north of the V-shaped group of stars, the Hyades, of which the first magnitude red star Aldebaran, is the principal star. For chart of his path, see SIDEREAL MESSENGER, Nov. 1891, p. 463.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Mar. 5	23 8.2	−17 24	6 38 A. M.	12 12.3 P. M.	5 46 P. M.
15	0 18.5	+ 1 34	6 33 "	12 43.0 "	6 53 "
25	1 22.4	+10 23	6 23 "	1 7.6 "	7 53 "
			VENUS.		
Mar. 5	1 31.7	+ 9 59	7 52 A. M.	2 35.5 P. M.	9 19 P. M.
15	2 15.8	+14 41	7 37 "	2 40.1 "	9 43 "
25	3 00.6	+18 49	7 24 "	2 45.4 "	10 07 "
			MARS.		
Mar. 5	17 38.7	−23 16	2 19 P. M.	6 43.8 A. M.	11 09 A. M.
15	18 04.7	−23 32	2 08 "	6 30.5 "	10 52 "
25	18 30.5	−23 35	1 54 "	6 16.7 "	10 39 "
			JUPITER.		
Mar. 5	23 51.8	− 2 04	7 01 A. M.	12 55.9 P. M.	6 51 P. M.
15	0 00.6	− 1 06	6 26 "	12 25.4 "	6 25 "
25	0 08.6	− 0 14	5 52 "	11 54.9 A. M.	5 58 "

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			SATURN.		
Mar. 5	11 55.2	+ 3 14	6 41 P. M.	12 57.3 A. M.	7 13 A. M.
15	11 52.4	+ 3 33	5 58 "	12 15.1 "	6 32 "
25	11 49.5	+ 3 52	5 14 "	11 32.9 P. M.	5 52 "
			URANUS.		
Mar. 5	14 14.6	− 12 58	10 05 P. M.	3 16 3 A. M.	8 28 A. M.
15	14 13.6	− 12 53	9 24 "	2 36.0 "	7 48 "
25	14 12.3	− 12 46	8 43 "	1 55.4 "	7 08 "
			NEPTUNE.		
Mar. 5	4 19.1	+ 19 50	9 56 A. M.	5 22.4 P. M.	12 49 A. M.
15	4 19.6	+ 19 52	9 17 "	4 43.7 "	12 11 "
25	4 20.4	+ 19 54	8 38 "	4 05.1 "	11 32 P. M.
			THE SUN.		
Mar. 5	23 07.1	− 5 39	6 29 A. M.	12 11.5 P. M.	5 54 P. M.
15	23 44.0	− 1 44	6 11 "	12 8.8 "	6 06 "
25	0 20.4	+ 2 13	5 53 "	12 5.8 "	6 19 "

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A................$0^h\ 52^m\ 32^s$
Decl.................+ 81° 17′
Period............2*d* $11^h\ 50^m$

Mar. 2	10 P. M.
7	10 "
12	9 "
17	9 "
22	9 "
27	8 "

ALGOL.

R. A...............$3^h\ 01^m\ 01^s$
Decl...............+ 40° 32′
Period............2*d* $20^h\ 49^m$

Mar. 4	midn.
7	9 P. M.
10	6 "
22	5 A. M.
25	2 "
27	11 P. M.
30	8 "

R CANIS MAJ.

R. A...............$7^h\ 14^m\ 30^s$
Decl................— 16° 11′
Period............1*d* $03^h\ 16^m$

Mar. 3	6 P. M.
4	10 "
11	6 "
12	9 "
13	midn.
19	4 P. M.
20	8 "
21	11 "
28	7 "
29	10 "

S CANCRI.

R. A...............$8^h\ 37^m\ 39^s$
Decl...............+ 19° 26′
Period..........9*d* $11^h\ 38^m$

Mar. 6	6 A. M.
15	6 P. M.
25	5 A. M.

δ LIBRÆ.

R. A...............$14^h\ 55^m\ 06^s$
Decl................— 8° 05′
Period............2*d* $07^h\ 51^m$

Mar. 12	2 A. M.
19	1 "
26	1 "

U CORONÆ.

R. A...............$15^h\ 13^m\ 43^s$
Decl...............+ 32° 03′
Period............3*d* $10^h\ 51^m$

Mar. 2	5 A. M.
9	3 "
15	midn.
22	10 P. M.
29	8 "

U OPHIUCHI.

R. A...............$17^h\ 10^m\ 56^s$
Decl...............+ 1° 20′
Period.......... 0*d* $20^h\ 08^m$

Mar. 3	6 A. M.
4	2 "
9	3 "
9	11 P. M.
14	3 A. M.
14	11 P. M.
19	4 A. M.
19	midn.
24	5 A. M.
25	1 "

U OPHIUCHI, CONT.

Mar. 29	6 A. M.
30	2 "

S ANTLIÆ.

R. A...............$9^h\ 27^m\ 30^s$
Decl................— 28° 09′
Period............0*d* $07^h\ 47^m$

Mar. 2	1 A. M.
2	midn.
3	11 P. M.
4	11 "
5	10 "
6	9 "
7	9 "
8	8 "
9	7 "
10	7 "
11	6 "
12	5 "
13	1 A. M.
13	midn.
14	midn.
15	11 P. M.
16	10 "
17	9 "
18	9 "
19	8 "
20	7 "
21	6 "
22	6 "
23	5 "
24	1 A. M.
25	1 "
25	midn.
26	11 P. M.
27	10 "
28	10 "
29	9 "
30	8 "
31	7 "

Mr. Marth's Ephemerides of the Satellites of Saturn.

[From *Monthly Notices*, Nov. 1891.]

In this table the times have been changed from Greenwich Mean Time to Central Standard Time. The abbreviations *Rh.*, *Te.*, *Di.*, *En.*, and *Mi.*, stand for the names of the satellites Rhea, Tethys, Dione, Enceladus, and Mimas. The letters *a, b, c, d,* and *e*, stand for conjunctions of the satellites in order as follows: With the preceding end of the outer ring; with preceding end of planet's equatorial diameter; with center of planet; with following end of planet's diameter; with following end of ring. The letters *n* and *s* signify that the satellite at the time of conjunction is north or south of the point designated by the preceding letter; *Sh.* means that the shadow of a satellite is near the central meridian of the planet; *Ecl. D.* and *Ecl. R.*, the disappearance and reappearance of a satellite at beginning and end of an eclipse.

Feb. 1892.
15 11.9 pm En as
16 12.1 am Di ds
12.8 Te es
1.3 Di Sh
2.8 Te ds
3.4 Mi an
3.4 Di bs
3.9 Te Sh
5.6 Di as
5.7 Te bs
4.3 pm En en
4.7 Rh es
7.2 Rh ds
8.4 Rh Sh
8.6 Mi as
9.0 Titan an
10.4 Titan Ecl. D
11.1 Rh bs
11.4 Te an
17 1.1 am Te Ecl. D
1.7 Rh as
2.0 Mi an
2.4 En es
3.1 Titan Ecl. R
3.8 Titan c9 .3n
4.3 Te dn
6.3 Te en
6.7 Titan dn
6.7 Di an
2.4 pm Di en
6.8 En an
7.2 Mi as
10.1 Te es
18 12.1 am Te ds
12.6 Mi an
1.2 En en
1 3 Te Sh
3.0 Te bs
5.0 Te as
3.6 pm Di es
5.6 En as
5.8 Di ds
5.8 Mi as
7.0 Di Sh
8.7 Te an
9.1 Di bs
10.4 Te Ecl. D

Feb. 1892.
18 10.8 pm Rh an
11.2 Mi an
11.3 Di as
19 12.7 am Rh Ecl. D
1.6 Te dn
3.6 Te en
3.7 En an
5.1 Mi en
5.3 Rh dn
4.4 pm Mi as
7.4 Te es
8.1 En es
9.4 Te ds
9.8 Mi an
10.6 Te Sh
20 12.3 am Te bs
12.4 Di an
2.2 Di Ecl. D
2.3 Te as
2.5 En as
3.7 Mi en
5.9 Di dn
6.0 pm Te an
6 9 En en
7.7 Te Ecl. D
8.4 Mi an
10.9 Te dn
21 12 9 am Te en
2.3 Mi en
5.0 Rh es
5.0 En es
2 0 pm Rh as
2.7 Di bs
4 7 Te ds
4.9 Di as
6 7 Te ds
7.0 Mi an
7.9 Te Sh
9.5 En an
9.6 Te bs
11 6 Te as
22 12.9 am Mi en
3.8 En cn
3.8 pm Te an
5.0 Te Ecl. D
5.7 Mi an
6.0 Di an

Feb. 1892.
22 7.9 pm Di Ecl. D
8.2 Te un
8.2 En as
10.2 Te en
11.5 Di dn
11.6 Mi en
23 1.7 am Di en
1.2 pm Rh Ecl. D
2.0 Te es
4.0 Te ds
4.3 Mi an
5.2 Te Sh.
5.6 Rh dn
6 9 Te bs
8.2 Rh en
8.9 Te as
10.2 Mi en
10.8 En es
24 2.9 am Di es
3.6 Mi es
5.1 Di ds
5.1 En as
12.9 pm Titan es
2.4 Te Ecl. D
2.9 Mi an
3.2 En an
4.7 Titan es
5.5 Te dn
5.6 Titan Sh.
7.5 Te en
7.7 Titan c 8″ 4s
? Transit
8.8 Mi en
9.5 En en
10.6 Titan bs
25 2.2 am Mi es
2.4 Titan as
1.6 pm Di Ecl. D
2.0 En as
2.5 Te Sh
4.1 Te bs
5.2 Di dn
5.3 Rh es
6.1 Te as
7.4 Di en
7.4 Mi en
7.9 Rh ds

Feb. 1892.
25 9.3 pm Rh Sh
11.8 Rh bs
26 12.1 am En an
12.8 Mi es
2.3 Rh as
2.8 pm Te dn
4 5 En es
4.8 Te en
6.0 Mi en
8.5 Di es
10.7 Di ds
10.9 En as
11.4 Mi es
27 12.1 am Di Sh
2 0 Di bs
4.2 Di as
1.4 pm Te bs
3 3 En en
3.4 Te as
4.6 Mi en
10.0 Mi es
11.5 Rh an
28 1.4 am En es
1.6 Rh Ecl. D
3.9 Mi as
5.4 Di an
5 9 Rh dn
1.0 pm Di en
2.1 Te en
3.2 Mi en
5 8 En an
8.6 Mi es
29 12 2 am En en
2 5 Mi as
5.8 Te es
2 2 pm Di es
4 4 Di ds
4.6 En an
5.8 Di Sh
7.2 Mi es
7.7 Di bs
9.9 Di as
Mar.
1 1.2 am Mi as
2 7 En an
4.5 Te an
5.7 Rh es
12.3 pm Te Ecl. D

Phases and Aspects of the Moon.

			Central Time. h m
First Quarter	Mar.	5	1 14 P. M.
Full Moon	"	13	6 55 A. M.
Apogee	"	15	3 42 P. M.
Last Quarter	"	21	11 16 A. M.
New Moon	"	28	7 18 "
Perigee	"	28	4 00 P. M.

Occultations Visible at Washington.

Date 1892.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean. T. h	m	Angle f'm N. P't. °	EMERSION. Wash. Mean T. h	m	Angle f'm N. P't. °	Duration h	m
March. 4...	ι¹ Tauri	5	11	48	93	12	41	254	0	53
4...	ι² Tauri	6	12	15	59	13	02	288	0	47
8...	λ Cancri	6	12	28	100	13	33	304	1	05
14...	κ Virginis	6	11	06	161	12	16	277	1	10
15...	*m* Virginis	5	9	52	117	11	04	315	1	08
15...	B.A.C. 4591	6	14	34	99	15	50	335	1	16
22...	ω Sagittarii	5	17	03	38	17	58	312	0	55

List of Binary Stars and Test Objects for Small Telescopes for February and March.

No.	Name.	R. A. 1890. h	m	Decl. 1890. °	'	Position Angle. °	Distance. "	Magnitude.
1	OΣ 165, 45 Geminorum	7	02.1	+ 16	07	50	3.5	5 ; 11
2	Σ 1037		06.0	+ 27	25	305	1.3	7 ; 7
3	Σ 170		12.1	+ 9	30	110	1.5	7 ; 7
4	Σ 1066, δ Geminorum		13.6	+ 22	11	205	7.0	3 ; 8
5	Σ 1110, Castor AB		27.6	+ 32	08	230	5.7	3 ; 3.5
	AC					165	73.	; 11
6	OΣ 182		47.2	+ 3	40	30	1.1	7 ; 7.5
7	OΣ 186	7	56.6	+ 26	36	75	0.7	7 ; 8
8	Σ 1186, 11 Cancri	8	02.1	+ 27	48	215	3.2	7 ; 10
9	Σ 1196, ζ Cancri AB		06.0	+ 17	58	30	1.2	5 ; 5.7
	AB-C					120	5.0	; 5.5
10	OΣ 193		22.	+ 33	55	295	14.0	7 ; 11
11	Σ 1273		41.1	+ 6	49	225	3.2	4 ; 8
12	Σ 1291, σ² Cancri		47.7	+ 30	59	330	1.4	6 ; 6.5
13	OΣ 196, ι Urs. Maj	8	51.8	+ 48	28	5	9.5	3 ; 10
14	Σ 1306	9	00.5	+ 67	35	240	3.0	5 ; 8
15	Σ 1334		12.0	+ 37	16	235	2.9	4 ; 7
16	Σ 1356, ω Leonis		22.6	+ 9	32	100	0.7	6 ; 7
17	Σ 1377, 161 Sextantis		37.8	+ 3	08	135	3.3	8 ; 11
18	OΣ 210	9	55.7	+ 46	54	270	0.8	7 ; 8
19	OΣ 215	10	10.3	+ 18	17	215	0.7	7 ; 7
20	OΣ 523, 39 Leonis		11.2	+ 23	39	300	6.7	6 : 11
21	Σ 1424		14.0	+ 20	23	115	3.6	2 ; 4
22	Σ 1457		33.1	+ 6	18	320	1.2	7 ; 8
23	OΣ 224		34.0	+ 9	25	315	0.5	7 ; 9
24	OΣ 228		41.3	+ 23	09	200	0.4	7 ; 8
25	Σ 1504	10	59.8	+ 4	14	285	1.1	7 ; 7
26	Σ 1523	11	12.3	+ 32	10	200	1.7	4 ; 5
27	Σ 1536, ι Leonis		18.3	+ 11	09	60	2.5	4 ; 7
28	OΣ 236		30	+ 66	57	215	2.7	7 , 11
29	OΣ 237	11	33.1	+ 41	45	275	1.0	7 ; 9
30	OΣ 249 AB	12	18.7	+ 54	46	300	0.5	7 ; 8
	AB-C					150	13.0	11

In response to frequent requests of some of our subscribers we give this list of double stars which cross the meridian during the evening hours of February and March. Most of the stars in the list are binaries, which need to be measured frequently, and many of them will afford good tests for the quality of telescopes of 4 inches or more aperture.

Nos. 2, 3, 6, 12, 22, 25, are good tests of the separating power of a 4 or 5-inch objective. Nos. 7, 16, 18, 19, will serve the same purpose for a 6 or 7-inch glass, and Nos. 23, 24, and 30 for larger glasses. As tests of definition Nos. 4, 11, 14, 15 and 21 are good objects. The fainter components of 10, 13, 17, 20, 28 and 30 may be used to test the light-gathering or space-penetrating power of a telescope.

Occultations of Stars by the Planets.

In *Astronomische Nachrichten* No. 3073, Dr. Berberich gives a list of near approaches and possible occultations of stars by the planets during the year 1892. As it is important that these should be observed as generally as possible we will give the list for each month. Most of the stars are so faint as to be beyond the reach of small telescopes when in the vicinity of the planet, yet many may be observed possibly with telescopes of as low as 4 inches aperture. In these observations one should note the exact time, standard or local, corrected for error of time-piece, of the disappearance and reappearance of the star, as well as any change in appearance of the star as it passes behind the planet.

STARS NEAR VENUS.

Date	Central Time of Conjunction. h m	Diff. of Decl. ″	Maximum Duration. m	Magnitude of Star.
Feb. 6	3 56 P. M.	− 58	4.4	7.8
8	12 43 A. M.	− 60	4.5	9.3
10	3 14 A. M.	+ 27	4.5	9.3
18	12 58 A. M.	− 20	4.7	9.0
20	10 47 A. M.	+ 73	4.8	8 9
22	12 04 A. M.	− 56	4.8	7.3
28	5 06 P. M.	+ 49	5.0	9.4
Mar. 7	4 14 A. M.	− 39	5.3	9.0
12	11 51 P. M.	− 79	5.6	9.0
12	11 59 P. M.	+ 87	5.6	9.0
21	11 18 A. M.	+ 57	6.0	8.9
23	5 26 A. M.	− 22	6.1	6.0
28	12 19 P. M.	+ 6	6.5	8.3

Two Minor Planets Discovered by Photography. Two planets were discovered photographically at Heidelberg December 22. They were observed at Vienna, Dec. 31 in the following positions:

Dec. 31.3550 Gr. M. T.; R. A. 6^h 37^m 01.2^s; Decl. + 24° 50′ 22″
Dec. 31.4806 " " " 6 48 48.2^s; " + 18 38 28
Daily motion of the first —1^m 24^s and + 19′
Daily motion of the second —1 00^s and + 2′

The latter of these was found to be Sapientia (275).

New Minor Planet No. (324). A planet of the 11th magnitude was discovered at Heidelberg photographically January 20.2491 in R. A. 3^h 50^m 06.1^s; Decl. + 22° 17′ 34″. Daily motion 12^s eastward and 2′ northward.

Brilliant Meteor. Mr. E. M. Wilson observed a brilliant meteor Dec. 19, 1891, at 8:18 P. M. central time, one mile east of Onslow, Jones county, Iowa. It arose in the northeast, from behind a bank of clouds, near σ or ρ (?) of Ursa Major, crossed a little east of the zenith, between Capella and the Pleiades, toward the southwest, and vanished at an altitude of about 45°, not far from Jupiter. Its motion was slow at first sight, faster as it passed the zenith, and its brightness exceeded that of Jupiter. Its train remaned in view a second or two. No explosions observed, or heard.

Almanaque Nautico Para el Ano 1892 is received. It is a large volume of 591 pages. It is in the usual form and contains about the usual matter of government publications of the kind. It is the first we have seen from Spain.

COMET NOTES.

The Tempel-Swift periodic comet is now too faint for all but the largest telescopes. Mr. Barnard writes that he is still observing it. At Goodsell Observatory we looked for it last on the night of Jan. 13, but the temperature was 13° below zero and seeing poor, so that the comet was not seen. On the same night Wolf's comet was an easy object with the 16-inch and barely visible in the 5-inch finder. With the large telescope Wolf's comet had a sharp stellar nucleus of about the 12 magnitude, dense coma of about 2′ diameter, and short, faint brush of tail directed almost due north. During March this comet will pass through the familiar constellation Orion. March 1 it will be about 4° north and a little west of Rigel, near the star β Eridani. From the 23rd to the 26th it will be passing through the belt of Orion between the stars ε and ζ. There is a nebula near ζ. the lower of the three bright stars in the belt, which must not be mistaken for the comet.

No ephemeris has yet reached us for Tempel's comet which is due at perihelion in the latter part of February. Neither Winnecke's comet nor Brooks' comet (1886 IV) have yet been picked up. We continue below the search ephemeris for the latter from Astr. Nach. No. 3064.

Search Ephemeris for Comet Brooks, 1886 IV.

[See also p. 85].

	Perihelion March 31.			Perihelion April 30.		
1892.	α	δ	Light	α	δ	Light
	h m	° ′		h m	° ′	
Mar. 1	16 52.9	− 14 34	0.32	15 02.1	+ 2 35	0.48
11	17 28.1	− 17 14	0.38	15 24.8	+ 0 32	0.66
21	18 03.8	− 19 44	0.43	15 47.3	− 2 01	0.93
31	18 39.3	− 22 04	0.48	16 09.4	− 5 15	1.37

	Perihelion May 30.			Perihelion June 29.		
	α	δ	Light	α	δ	Light
	h m	° ′		h m	° ′	
Mar. 1	12 45.3	+ 24 48	0.39	10 36.8	+ 39 24	0.20
11	12 43.8	+ 25 29	0.53	10 24.9	+ 39 00	0.22
21	12 38.7	+ 25 58	0.71	10 14.3	+ 37 52	0.25
31	12 31.8	+ 25 45	0.90	10 06.6	+ 36 02	0.28

Next Apparition of Wolf's Comet. In the last number (253) of the *Astronomical Journal* Dr. Berberich gives the elements of Wolf's comet from the observations of its second apparition (the present) as follows:

$$
\begin{array}{l}
\text{Epoch 1891 Sept. 8.0 Berlin M. T.} \\
M = 0^\circ\ 39'\ 12.4'' \\
\left.\begin{array}{l}
\omega = 172\ \ 48\ \ 28.0 \\
\Omega = 206\ \ 21\ \ 27.5 \\
i = 25\ \ 14\ \ 37.6
\end{array}\right\}\ 1890.0 \\
\phi = 33\ \ 51\ \ 25.7 \\
\mu = 520.2536'' \\
\log. a = 0.5558610
\end{array}
$$

These elements represent the observations of 1884 very satisfactorily. The next return will be in 1898, perihelion taking place June 30. The comet will then be observable during many months. The later returns will be unfavorable for observations. In 1922-23 the comet will approach so near to Jupiter as to have its orbit greatly changed and perhaps be lost to sight forever.

Ephemeris of Winnecke's Periodic Comet.

(Continued from page 86.)

	App R. A.			App. Decl.		log r	log Δ	$\frac{1}{r^2\Delta^2}$
	h	m	s	°	′			
March. 1	12	52	36	+ 23	47.8			
2		52	24	24	09.6	0.2689	9.9749	0.325
3		52	10	24	31.8			
4		51	53	24	54.4			
5		51	34	25	17.2			
6		51	12	25	40.4	0.2596	9.9521	0.377
7		50	48	26	03.9			
8		50	21	26	27.7			
9		49	52	26	51.7			
10		49	20	27	16.0	0.2501	9.9298	0.437
11		48	45	27	40.5			
12		48	08	28	05.3			
13		47	28	28	30.2			
14		46	45	28	55.4	0.2403	9.9080	0.505
15		45	60	29	20.7			
16		45	11	29	46.2			
17		44	20	30	11.7			
18		43	26	30	27.4	0.2302	9.8871	0.583
19		42	29	31	03.1			
20		41	30	31	28.8			
21		40	27	31	54.6			
22		39	22	32	20.3	0.2198	9.8670	0.607
23		38	14	32	46.0			
24		37	03	33	11.7			
25		35	49	33	37.2			
26		34	33	34	02.5	0.2092	9.8480	0.769
27		33	14	34	27.7			
28		31	52	34	52.7			
29		30	28	35	17.4			
30		29	01	35	41.9	0.1982	9.8300	0.878
31		27	32	36	06.0			
Apr. 1		26	00	36	29.9			
2		24	27	36	53.3			
3		22	51	37	16.4	0.1870	9.8130	1.000
4		21	13	37	39.0			
5		19	33	38	01.2			
6		17	52	38	23.0			
7		16	09	38	44.2	0.1754	9.7970	1.135
8		14	24	39	05.0			
9		12	38	39	25.2			
10		10	51	39	44.8			
11		09	02	40	03.9	0.1636	9.7819	1.285
12		07	13	40	22.3			
13		05	22	40	40.2			
14		03	31	40	57.4			
15	12	01	40	+ 41	14.0	0.1514	9.7675	1.453

Ephemeris of Comet 1891 (Wolf's Periodic Comet.)

(From Astr. Nachr. No. 3071)

Berlin Midnight.	App. R. A.			App. Decl.		log r	log Δ
	h	m	s	°	′		
Feb. 15	4	42	49	− 7	21.0		
16		43	53	7	10.9	0.3510	0.2705
17		44	58	7	00.9		
18		46	04	6	50.8	0.3533	0.2777
19		47	11	6	40.9		
20		48	18	6	31.0	0.3556	0.2848
21		49	27	6	21.1		
22	4	50	36	− 6	11.3	0.3579	0.2919

Berlin Midnight.	App. R. A.			App. Decl.		log *r*	log Δ
	h	m	s	°	′		
Feb. 23	4	51	45	− 6	01.6		
24		52	56	5	51.9	0.3602	0.2989
25		54	07	5	42.3		
26		55	19	5	32.7	0.3625	0.3058
27		56	32	5	23.2		
28		57	45	5	13.8	0.3648	0.3127
29	4	58	59	5	04.5		
March. 1	5	00	13	4	55.2	0.3670	0.3194
2		01	29	4	46.0		
3		02	45	4	36.9	0.3693	0.3261
4		04	01	4	27.8		
5		05	18	4	18.9	0.3715	0.3328
6		06	36	4	10.0		
7		07	54	4	01.2	0.3737	0.3393
8		09	13	3	52.6		
9		10	32	3	44.0	0.3760	0.3458
10		11	52	3	35.4		
11		13	12	3	27.0	0.3782	0.3521
12		14	33	3	18.7		
13		15	54	3	10.5	0.3804	0.3584
14		17	16	3	02.3		
15		18	38	2	54.3	0.3826	0.3647
16		20	00	2	46.4		
17		21	23	2	38.5	0.3848	0.3708
18		22	47	2	30.8		
19		24	11	2	23.2	0.3869	0.3769
20		25	35	2	15.6		
21		26	60	2	08.2	0.3891	0.3829
22		28	25	2	00.9		
23		29	50	1	53.6	0.3912	0.3888
24		31	16	1	46.5		
25		32	42	1	39.5	0.3934	0.3947
26		34	08	1	32.6		
27		35	35	1	25.8	0.3955	0.4004
28		37	02	1	19.1		
29		38	30	1	12.5	0.3976	0.4061
30		39	57	1	06.0		
31	5	41	25	− 0	59.6	0.3997	0.4117

Comets and Meteors. You recently inserted an extract from a letter of mine to the effect that, judging from their orbits, meteors appeared to belong to the solar system instead of being visitors from external space. May I now add that the comets with which meteor-showers have hitherto been connected are all elliptic or periodical comets. It would thus seem that a parabolic or hyperbolic comet which passes but once through the Solar System, fails to pick up any meteor train worth mentioning, while on the other hand, periodic comets which have circled round the Sun for ages appear to possess these appendages whenever they approach sufficiently near us to afford a test. That comets generally are visitors from outer space is confirmed by some investigations which I lately made as to their aphelia and which I hope to publish shortly. But meteor-comets have at all events been domiciled with us for a considerable time.

W. H. S. MONCK.

A Clark Three-inch Telescope in the possession of one of our subscribers can be purchased at a reasonable price. It is said to be in first-rate condition; eye-pieces are 32, 80, 135 and 220 diameters respectively; ordinary and solar diagonals, plain equatorial mounting, without circles or tripod. The head has been used on a fixed wooden stand. A larger instrument has been procured, and hence this one is offered for sale.

NEWS AND NOTES.

It is gratifying to announce that our subscription list has not fallen off seriously since the advance in price, as we feared it might do, but, on the contrary, it has gained a little during the last month, so that, at present, the number of actual subscribers is a little larger than it has been at any previous time during the ten years of history distinctively belonging to THE MESSENGER.

As usual there is a considerable number of subscribers who are yet delinquent for a portion of 1891. It is respectfully and urgently asked that *every* such one promptly notify the publisher that *continuance* or *discontinuance* is desired, so that the publication under the new form may be sent only to those desiring it. If any names are dropped from our books it will be because subscriptions have not been renewed, or continuance of the same ordered.

If it were our custom to print the good things that our many readers say of us in our new dress and form, we could easily fill considerable space; but it seems best to adhere to our old plan in this particular; so we most heartily and cordially thank our many friends for their well wishes, congratulations, and substantial help, that so many have already rendered us in promptly renewing subscriptions, and offering unexpected aid in other ways.

Light Curve of the Eclipse of Japetus. By referring to the figure on page 120 of Mr. Barnard's article it will readily be understood that the vertical column of figures means the sidereal times of individual estimations, while the horizontal column above gives the difference of light between *Enceladus* and *Tethys* in steps of one-tenth each during the eclipse. Beginning with the emergence from shadow of ball of Saturn the curve indicates the variation of light till the satellite passes into the shadow of the crape ring, and then it falls off rapidly until entering the shadow of the bright ring which was fully as dense as the shadow of the ball itself.

Delicate Refractometer. Mr. J. A. Brashear of Allegheny, Pa., has, very recently, completed the optical surfaces for a new refractometer for Professor A. A. Michelson, who is to determine the value of the standard meter of the International Bureau at Brentueil, in France. These surfaces show work of the most delicately accurate kind. The limiting error is said to be less than one-millionth of an inch. Still Mr. Brashear is conscious of very, very small existing errors, which it seems next to impossible to remove.

Neue Annalen der K. Sternwarte in Bogenhausen bei Munchen. This publication was prepared under the direction of Hugo Seeliger, Director of the Royal Observatory, and contains the results of seven different kinds of work. The first is a catalogue of 13200 stars whose mean places are for the epoch of 1880 and were observed and reduced by Dr. Julius Bauschinger.

2. Neue Beobachtung und Ausmessung des Sternhaufens 38h Persei, von Dr. K. Oertel; mit 2 Taflen.
3. Die Vertheilung der in beiden Durchmusterung enthaltenen Sterne am Himmel von dem Unterzeichnten.
4. Ueber die Biegung von Meridianfernrohren von Dr. J. Bauschinger, mit 1 Taflen.

These and other papers are of special value to the astronomer.

Since our last issue the sad news comes across the water of the death of two of England's great men; Sir George B. Airy, formerly Astronomer Royal, and Professor J. C. Adams of Cambridge Observatory; the former occurring Jan. 2 and the latter Jan. 22. In another issue of this publication will be given brief accounts of the lives of these scholarly men.

A Remarkable Aurora. The Auroral display upon the evening of Tuesday, Jan. 5, as viewed from a suburb of Boston, was one of exceeding beauty, and often of marked brilliancy. At 7:30 P. M., an arched *bank* of auroral light extended from N.E. to N.W., rising at the north point 20° above the horizon. At this time there was no other display except in the N. N.E. at an altitude of 30°; here an isolated bright area, about 15° vertically by 10° horizontally, was fairly permanent, and at times, faintly connected with the underlying bank. The sky was not observed again until about 10 P. M., at which time the aurora had assumed magnificent proportions. At times the sky was almost completely covered from E. S.E. through N. to W. S.W., and when most extended, reached south of the zenith even to the "belt" of *Orion*. A variety of tints was very noticeable both upon the same areas in succession, and upon different areas simultaneously. The colors noted were yellow, pale green, olive green and bluish. At times while one color extended over an area of distinct boundary, another color would completely pervade the adjoining regions. There were comparatively few streamers, the display being mostly in extended sheets and broken waves. There was relatively little smooth upward flow of the waves, but a marked pulsation, the waves rising and falling as they advanced toward the zenith. In one instance a wave seemed to "see-saw" as it ascended; the right and left sides advancing alternately while the general form remained that of a parallelogram hinged at each vertex. One figure which appeared in the zenith was of a character to produce consternation among a superstitious people. At a time when the sky near the zenith was essentially clear, the blue presenting a beautiful contrast with the auroral light to the north, east, and west; there suddenly appeared in the midst of this clear area a form suggesting at once an immense eagle with spread pinions, flying directly southward. The wings were perhaps 15° long, yellow, and exceedingly brilliant.* This form remained approximately permanent for at least three minutes, and soon after its appearance, the general display was extended much farther southward.

There was some haze upon the sky during most of the evening, and there were a few light, high-running clouds. J. B. C.

Measures of the Faint Double Star (H 2948) between β^1 and β^2 Capricorni. The faint pair, H 2948, which lies a little north of the line joining β^1 and β^2 Capricorni, has been often referred to in popular articles as a light-test for moderate apertures. For this reason, and the further reason that it had never been measured, I took occasion to measure it on two nights, after having measured the close pair, β^1 Capricorni, discovered by Barnard in 1883.

As a double star, H 2948 must be regarded a failure. The distance between the stars is much too great to make any physical connection between stars of this magnitude in the least probable. It first appears in Herschel's *Fifth Catalogue* (1830–31) with a single measure of the angle, and the following note:

"A very minute star, forming an obtuse-angled triangle with β^1 and β^2 Capricorni. Pos. from $\beta^1 = 63°.4$; from $\beta^2 = 296.°0$. It is one of the most minute

---

* Being as bright as any area observed that evening, and far surpassing in brilliancy most of the waves and streamers.

and delicate double stars I have seen; and being so easily found, is an excellent test-object."

There is an earlier estimate of the angle, distance and magnitudes in Herschel's *Seventh Catalogue* (observations made 1823 to 1828). Concerning this pair he says in the remarks in the Fifth Catalogue:

"I have sometimes been asked for test-objects to try at once the light and distinctness of a telescope under high powers. In such cases it is desirable to select objects which can be certainly found without the possibility of mistake; and in this view I would point out the small double star accompanying β^1 and β^2 Capricorni, (H 2948), or the small double companion of β Equulei (H 2023) as very well adapted for the purpose. A telescope which will show the former of these objects distinctly double, I have no hesitation in saying, must be competent to the most difficult work which any ordinary observer is likely to task it with. No telescope, I ought to add, can be expected to show the satellites of *Uranus* (at least in the present low situation of the planet in the ecliptic) which will not stand this test."

This little pair is by no means as difficult as one would be led to expect from the foregoing remarks, and from the magnitudes (17 and 18) which Herschel gave to the components. I found it very plain with the 9.4-inch Clark refractor at Hanover in 1874, and as one star it was always easy enough with my 6-inch, but that aperture perhaps could not be said to show it fairly double. But at most it is only a light-test. To form a test for the definition of an objective, the distance would of course have to be reduced to at least one-fifth of that between these stars.

I give in tabulated form the observations of Herschel, and my recent measures with the 36-inch:

1825 ±	120° ±	8″ ±	15......16	H 1*n*
1830 ±	322.2	3 ±	17......18	H 1*n*
1891.66	322.3	6.42	13......13.4	β 2*n*

I measured also the position of this pair from the following of the two bright stars as follows:

β^2 Capricorni and H 2948.

1891.655	294°.1	111″.75
.673	294 .0	111 .66
1891.66	294°.0	111″.70

Obviously there is no evidence of any change either in the components of H 2948, or in their position with reference to β^2 Capricorni. No change could be expected except such as might be the result of some proper motion.

Mt. Hamilton, Dec. 21. S. W. BURNHAM.

Burnham's Measures of Planetary Nebulæ. [During his regular double star work with the 36-inch equatorial of the Lick Observatory, Mr. Burnham has given some attention to the more interesting nebulæ, and incidentally to a few of the Herschel planetary nebulæ. On examining the records of the best observers, he was surprised to find that almost nothing had been done in the way of taking careful micrometrical measures to determine the places even of the brighter of the planetary nebulæ. This seemed to him, very naturally, a most useful field of work, as a means of determining whether or not these bodies have proper motion. There can be no doubt, but that, in time, careful work of this kind would reveal important results. The central star in this class of nebulæ is, of course, used as the point of reference in measurement, and this is so generally found in planetary nebulæ that it is suggested as a criterion for classification of these bodies. Some of these stars are very faint and can only be seen with telescopes of large aperture, and, in a few instances, the large object-glass of the 36-inch equatorial furnishes none too much light for their accurate measurement with the micrometer. Mr. Burnham has used Dreyer's General Catalogue in making up his observing lists, and he says he has examined Nos. 934, 2440, 2452, 4107, 5144 and 6210, and found them more or less lacking in the characteristics of planetary nebulæ. He thinks they properly belong to a much larger and less interesting class of objects which would be briefly described as small circular patches of nebulosity. He also speaks of the so-called "stellar" nebulæ discovered by Pickering, Swift and others. "These are all, so far as I have examined them, very small, bright, round nebulæ, which in a small instrument would resemble stars slightly out of focus, but do not appear to come within the planetary class."

In speaking of the central star in this class of nebulæ, Mr. Burnham says "there can be no doubt that these central stars are, in some way associated with the nebulæ themselves, and that any change in the positions of these stars will be accompanied by a corresponding drift in space of the nebulæ. Of the thousands of nebulae now known, these examples of the planetary class, with a few exceptions possibly among very minute nebulae, are the only ones where any proper motion could be detected within any reasonable time. For this reason there is no reliable evidence yet of the change in position of any nebulae in the heavens."

It is further claimed that there is no apparent reason why the nebulae should not be distributed in space as the stars are, nor why they should not have proper motion like the stars. A few measures during a brief period of years will certainly reveal small changes of place, even if these be in the form of slight annual variation only. The detailed descriptions of thirty or more of these planetary nebulae recently observed by Mr. Burnham add large and new interest to this field of research.

Aurora Observations. We take pleasure in giving the following letter from Mr. M. A. Veeder of Lyons, N. Y., which bore date January 16.

"The note in ASTRONOMY AND ASTRO-PHYSICS in regard to observing auroras is being heard from, and I am much obliged for your inserting it.

"In sending out blanks, etc., during December I generally called attention to the fact that a series of recurrences of the aurora at 27¼-day intervals would probably begin on January 5th. This expectation has been fully realized by the appearance of an unusually brilliant aurora on that date. It would seem from this that the next few months are likely to be especially favorable for observations of this character. Already interesting results are being secured from the plan of observation that has been organized. By noting the time of each observation and recording the absence as well as the presence of the aurora it has become evident that an aurora may be present at southern stations when absent at those directly northward. This is something different from what we would naturally expect, and perhaps its explanation may become apparent in the course of the research."

From Dr. Wilson's notes we give the description of the aurora that was seen at Goodsell Observatory Jan. 5, as follows:

"Remarkable aurora extending from 80° west to 100° east of north point; at times reaching 10° south of the zenith. Noticed first at 6 o'clock P. M., in light of the moon nearly half full. Very few streamers, but large oval, cloud-like masses changing rapidly. Motion from east to west. Dark cloud-like arch about 15° high at 7 o'clock P. M. At 9 P. M. arch 45° high surmounted by fine arch of short, bright streamers changing rapidly, the whole lasting only a few minutes, then changing to the oblong bright clouds."

Variation of Latitude. Recently various scientific journals have been discussing the question of the variation of latitude. The articles that have appeared during the last two months in the *Astronomical Journal* are especially noteworthy. In No. 248, Mr. S. C. Chandler, of Cambridge, calls attention to a series of observations made with the Almucantar, six years ago, which "exhibited a decided and curious progression throughout," the earlier values of the difference between computation and observation being positive while the later ones were negative. These observations extended from November, 1884, to April, 1885, and the range was about four-tenths of a second. The observations were continued to the end of June of the same year, and a negative maximum was found about May 1, while from the previous observations of May to Nov., 1884, a positive maximum appeared about Sept. 1, showing a range of about $0''.7$, "with a half period of about seven months." This discussion was based on the observations of stars between $-5°$ and $+5°$ declination. Another study of stars between $+5°$ and $+50°$ in declination gave an exactly corresponding variation of latitude both in direction and range. In this connection Mr. Chandler mentions the fact, that Dr. Küstner in his determination of aberration from a series of observations made at the same time and published in 1888, noticed similar anomalies, and, tha twork at Berlin, Prague, Potsdam and Pulkowa indicates a change in range and period that surprisingly accords with results already named.

In Nos. 249 and 250 of the *Astronomical Journal*, Mr. Chandler gives a detailed discussion of the observations before referred to, and others similar to them, from which he reaches a general result in this preliminary discussion, showing "a revolution of the Earth's pole, in a period of 427 days, from west to east with a radius of 30 feet measured at the Earth's surface. Assuming provisionally for the purpose of statement, that this is a motion of the north pole of the principal axis of inertia, about the axis of rotation, the direction of the former from the latter lay towards the Greenwich meridian about the beginning of the year 1890. This, with a period of 427 days, will serve to fix approximately the relative positions of the axes at any other time for any given meridian. It is not possible at this stage of the investigation to be more precise, as there are facts which appear to show that the rotation is not a perfectly uniform one, but is subject to secular change, and perhaps irregularities within brief spaces of time."

Readers who wish to make a study of the evidence of these important conclusions should refer to the papers mentioned above.

Periodic and Secular Variations of the Latitude. Professor George C. Comstock, Wasburn Observatory, Madison, Wis., has also published a very suggestive paper, in No. 252 of the *Astronomical Journal*, on the Relation of the Periodic and Secular Variations of the Latitude. In this article he calls attention to a paper which he published in the *American Journal of Science*, December, 1891, and which gives a discussion of the data furnished by observations at Pulkowa, Koenigsberg, Washington and Madison, which appears to show a progressive motion of the terrestrial pole whose effect on the latitudes of these Observatories is represented by the expression

$$\varphi - \varphi_0 + 0''.044 \cos(\lambda - 69^\circ)(t - t_0),$$

in which the longitudes, λ, are reckoned from the meridian of Greenwich, and the unit of t is a year.

Mr. Comstock does not offer any hypothesis for the cause of secular change of latitudes, but prefers to treat it at present as a phenomenon requiring confirmation. Its existence is legitimately assumed, as a working hypothesis, and its relation to other phenomena may be discussed. He thinks that the existence of a secular term in the latitudes will necessarily produce a periodic term also, for by virtue of its progressive motion, the instantaneous axis of rotation of the Earth is moved away from the principal axis of inertia. "The forces developed by the separation of these axes will tend to re-adjust the figure of the Earth so as to bring these axes again into coincidence;" but this can not be done instantly, "and the axis of figure will lag behind the axis of rotation, by an amount depending, in great part, upon the modulus of the Earth's rigidity, thus producing the theoretical periodic motion of the pole associated with Euler's name"

We are sorry we have not before us Professor Newcomb's article on this theme which was published in the *Astronomical Journal*, No. 251, so as to refer to it more fully in this connection. Professor Comstock refers to that paper and says: "Professor Newcomb has indicated that the imperfect rigidity of the Earth may produce a very appreciable lengthening of this period, and he is inclined to attribute to this cause alone the total excess of the period found by Mr. Chandler over the value 306 days which would obtain in a rigid Earth." But Professor Comstock thinks that imperfect rigidity of the Earth would not explain the anomalous variations of amplitude and period of inequality found by Mr. Chandler, chiefly because we are constrained to regard the rigidity of the Earth as practically constant, at least, for short periods of time, but he does think that both can be explained by taking into the account the secular change of the position of the pole. The proofs for this position are given and the results are in striking conformity with the empirical results found by Mr. Chandler. Professor Comstock further says: "That all the characteristic features of the periodic term detected by Mr. Chandler seem to admit of explanation through the assumed nutation and secular variation of the pole. Any secular variation of the position of the pole will produce a periodic variation of latitudes. If the secular variation is a uniform motion along a great circle, the periodic term will be of constant amplitude and length, but, if the secular variation itself contains periodic terms, they will manifest their presence through irregularities in the periodic terms of the latitude." Plans for further study of this question are suggested.

Astronomy and Astro-Physics.

NEW SERIES, No. 3. MARCH, 1892. WHOLE No. 103

GENERAL ASTRONOMY.

TIDAL THEORY OF THE FORMS OF COMETS.*

GEORGE W. COAKLEY.†

In Fig. I let *C* be the center of a comet, Donati's for example, when so far from the Sun, at *S*, on June 2nd, 1858, that it appeared of a spherical form with a diameter of 3′, according to Professor Newcomb's statement, Popular Astronomy, page 380.

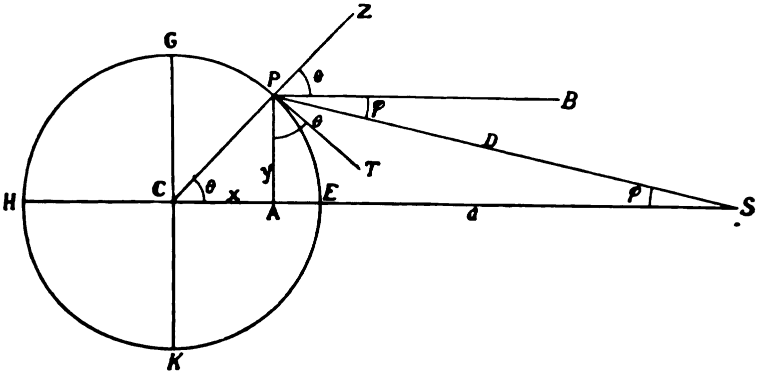


FIG. 1.

Let $CS = a =$ the comet's radius-vector, or distance from the Sun; $CA = x$, $AP = y$, P being any point at the distance $CP = R$ from the comet's center, whether on its surface, or on a concentric circle within it. Let the circle, *EGHK*, represent any section of the comet, in any direction, made by a plane passing through the Sun's center, and that of the comet. Let $PS = D =$ the distance of the particle, *P*, from the Sun, and let *PB* be parallel to *CS*, and *PT* be a tangent to the circle at *P*, and considered as having a positive direction when the particle, *P*, begins to move along it in a right-handed direction counted around the circle, or from *P* towards *E*. In the opposite direction, from *P* towards *G*, or to

---

* Communicated by the author.

† Professor of Mathematics and Astronomy, University of the City of New York.

the left around the circle, it must be counted as negative. *PA* is drawn perpendicular to *CS*, and *CPZ* is the normal to the circle at *P*.

The accelerative attraction of the Sun on *P*, if his mass is *M*, is $\frac{M}{D^2}$, omitting the constant factor *k* used by Professor Watson. The component of this acceleration, in the direction *PB*, is $\frac{M}{D^2}\cos\varphi$. The acceleration of the comet as a whole, at *C*, is $\frac{M}{a^2}$. The disturbing force of the Sun, which tends to draw away the particle, *P*, from the comet in either of the parallel directions, *CS* or *PB*, is the difference of these two accelerations, or

$$\frac{M}{D^2}\cos\varphi-\frac{M}{a^2}.$$

Let this disturbing force be resolved into the two normal and tangential components, acting in the directions *PZ* and *PT* respectively. Denoting them by *N* and *T*, they will evidently be:

$$N=\left\{\frac{M}{D^2}\cos\varphi-\frac{M}{a^2}\right\}.\cos\vartheta,\text{* acting along } PZ, \text{ and}$$

$$T=\left\{\frac{M}{D^2}\cos\varphi-\frac{M}{a^2}\right\}.\sin\vartheta, \text{ acting along } PT.$$

There will also be what may be called a Pressure Component of the Sun's acceleration, $\frac{M}{D^2}$, acting along *PA*, whose value is $\frac{M}{D^2}\sin\varphi$. If this be resolved in the directions *PC* and *PT*, and if they are denoted respectively by *n* and *t*, since they are in the normal and tangential directions, they will be

$$n=-\frac{M}{D^2}\sin\varphi\sin\vartheta, \text{ in the direction } PC,$$

$$t=+\frac{M}{D^2}\sin\varphi\cos\vartheta, \text{ in the direction } PT.$$

The negative sign belongs to the first of these because it tends to diminish the radius, *R*, while the component, *N*, tends to increase it, and is therefore positive.

The component *N*, which tends to remove the particle *P* in the direction *PZ* is resisted, or restrained, by the gravity of the comet or the attraction of its mass, *m*, towards *C*. As this force tends to diminish the radius, *R*, it must be considered as negative, and

---

* $\vartheta=\theta$ of Fig. 1.

may be represented by $-\frac{m}{R^2}$. Hence the particle, P, will be kept in equilibrium, so far as the normal forces are concerned, when

$$-\frac{m}{R^2}+n+N=0, \text{ or}$$

$$-\frac{m}{R^2}-\frac{M}{D^2}\sin\varphi\sin\vartheta+\left\{\frac{M}{D^2}\cos\varphi-\frac{M}{a^2}\right\}\cos\vartheta=0.$$

From Fig. I it is evident that $x = R\cos\vartheta$, $y = R\sin\vartheta$, also $a-x=D\cos\varphi$, $y=D\sin\varphi$.

$$\therefore D^2=(a-x)^2+y^2=a^2-2ax+x^2+y^2$$

$$\therefore D^2=a^2-2aR\cos\vartheta+R^2=a^2\left(1-2\frac{R}{a}\cos\vartheta+\frac{R^2}{a^2}\right),$$

$$\text{Let } \beta=\frac{R}{a}, \therefore D^2=a^2(1-2\beta\cos\vartheta+\beta^2)$$

$$\therefore D=a(1-2\beta\cos\vartheta+\beta^2)^{\frac{1}{2}}$$

$$\cos\varphi=\frac{a-x}{D}=\frac{a-R\cos\vartheta}{a(1-2\beta\cos\vartheta+\beta^2)^{\frac{1}{2}}}=\frac{1-\beta\cos\vartheta}{(1-2\beta\cos\vartheta+\beta^2)^{\frac{1}{2}}}$$

$$\sin\varphi=\frac{y}{D}=\frac{R\sin\vartheta}{a(1-2\beta\cos\vartheta+\beta^2)^{\frac{1}{2}}}=\frac{\beta\sin\vartheta}{(1-2\beta\cos\vartheta+\beta^2)^{\frac{1}{2}}}$$

$$\frac{M}{D^2}\cos\varphi=\frac{M}{a^2}\cdot\frac{1-\beta\cos\vartheta}{(1-2\beta\cos\vartheta+\beta^2)^{\frac{3}{2}}}$$

$$\frac{M}{D^2}\sin\varphi=\frac{M}{a^2}\cdot\frac{\beta\sin\vartheta}{(1-2\beta\cos\vartheta+\beta^2)^{\frac{3}{2}}}$$

$$\therefore \text{(A)}\begin{cases}N=\frac{M}{a^2}\left\{\frac{1-\beta\cos\vartheta}{(1-2\beta\cos\vartheta+\beta^2)^{\frac{3}{2}}}-1\right\}.\cos\vartheta, \text{ in direction } PZ.\\ T=\frac{M}{a^2}\left\{\frac{1-\beta\cos\vartheta}{(1-2\beta\cos\vartheta+\beta^2)^{\frac{3}{2}}}-1\right\}.\sin\vartheta, \text{ in direction } PT.\end{cases}$$

$$\text{(B)}\begin{cases}n=-\frac{M}{a^2}\cdot\frac{\beta\sin^2\vartheta}{(1-2\beta\cos\vartheta+\beta^2)^{\frac{3}{2}}}, \text{ in the direction } PC.\\ t=+\frac{M}{a^2}\cdot\frac{\beta\sin\vartheta\cos\vartheta}{(1-2\beta\cos\vartheta+\beta^2)^{\frac{3}{2}}}=\frac{M}{2a^2}\cdot\frac{\beta\sin 2\vartheta}{(1-2\beta\cos\vartheta+\beta^2)^{\frac{3}{2}}},\end{cases}$$

in the direction PT.

We shall first discuss the Pressure Components, (B). Of these the normal component, n, is evidently zero, both at E and at H, where $\sin\vartheta = 0$; but at G and K, denoting them by n_2 and n_4, they are

$$n_2=n_4=-\frac{M\beta}{a^2}(1+\beta^2)^{-\frac{3}{2}}=-\frac{MR}{a^3}(1-\tfrac{3}{2}\beta^2), \text{ nearly.}$$

Hence the Sun's normal pressure is greatest at right-angles to the line joining the centers of the Sun and comet, and is directed both at G and K towards the comet's center. This force tends to compress the spherical figure of the comet into an ellipsoid of revolution around the greater axis, which is directed towards the Sun.

The tangential component, t, of the Sun's pressure is evidently zero at each of the points E, G, H, K, where $\sin 2\vartheta = 0$. But it will have a maximum value at the middle of each of the quadrants EG, GH, HK, KE, where $\sin 2\vartheta = \pm 1$. Denoting that at the middle of the first quadrant by $t_{\frac{1}{2}}$, it will be

$$t_{\frac{1}{2}} = + \frac{MR}{2a^3} (1 - \beta\sqrt{2} + \beta^2)^{-\frac{3}{2}},$$

$$\text{or nearly } t_{\frac{1}{2}} = + \frac{MR}{2a^3} (1 + \tfrac{3}{2}\, \beta\sqrt{2})\,.$$

It will diminish both towards E and towards G, but will have always the positive sign, and will therefore tend to move the particle, P, along the circle towards the right, or towards E.

The tangential component at the middle of the fourth quadrant, which may be represented by $t_{\frac{7}{2}}$, will be

$$t_{\frac{7}{2}} = - \frac{MR}{2a^3} (1 - \beta\sqrt{2} + \beta^2)^{-\frac{3}{2}} = - \frac{MR}{2a^3} (1 + \tfrac{3}{2}\beta\sqrt{2}), \text{ nearly.}$$

It is negative, as are all the tangential components of the Sun's pressure in this quadrant, and hence they tend to move the particle P in the negative, or left handed direction around the circle, or still towards E.

The tangential component, t, at the middle of the second quadrant, or

$$t_{\frac{3}{2}} = - \frac{MR}{2a^3} (1 + \beta\sqrt{2} + \beta^2)^{-\frac{3}{2}} = - \frac{MR}{2a^3} (1 - \tfrac{3}{2}\beta\sqrt{2}) \text{ nearly.}$$

It is negative like the others in this quadrant, and tends to move P in the left handed direction, or towards H.

In the middle of the third quadrant it is

$$t_{\frac{5}{2}} = + \frac{MR}{2a^3} (1 + \beta\sqrt{2} + \beta^2)^{-\frac{3}{2}} = + \frac{MR}{2a^3} (1 - \tfrac{3}{2}\beta\sqrt{2}) \text{ nearly.}$$

Like the other tangential components of the Sun's pressure in this quadrant, it tends to move P towards the right or back to H.

Hence the tangential components of the Sun's pressure tend always to transfer the comet's materials along the surface, for each value of R, from the positions G and K towards E, nearest the Sun, and towards H, farthest from him. This process will also tend to increase the diameter HE, and to diminish that, GK, at right-angles to the Sun's direction. But it should also be noticed that the maxima and other values in the two quadrants nearest the Sun have the factor $1 + \frac{3}{2}\beta\sqrt{2}$, while those in the two quadrants, or hemisphere, farthest from the Sun have the factor $1 - \frac{3}{2}\beta\sqrt{2}$. Hence more matter is conveyed by these tangential currents into the hemisphere nearest the Sun, than is conveyed by the feebler currents into the hemisphere farthest from him. The consequence of this is, that the effect of the tangential components of pressure is to *transfer the comet's center of gravity away from its center of figure* TOWARDS THE SUN.

Discussion of the Normal and Tangential Components of the Disturbing Force, N and T.

At E, or the beginning of the first quadrant, let these components be denoted respectively by N_1 and T_1.

$$\text{Hence} \quad N_1 = \frac{M}{a^2} \cdot \left\{\frac{1-\beta}{(1-\beta)^3} - 1\right\} = \frac{M}{a^2}\left\{(1-\beta)^{-2} - 1\right\}$$

$$\therefore N_1 = \frac{M}{a^2} \cdot \left\{2\beta + 3\beta^2 + 4\beta^3 + 5\beta^4 + \text{etc.}\right\}$$

$$\therefore N_1 = \frac{M.2R}{a^3}\left(1 + \tfrac{3}{2}\beta + \tfrac{4}{2}\beta^2 + \tfrac{5}{2}\beta^3 + \text{etc.}\right)$$

$$\text{and } T_1 = 0, \text{ since } \sin\vartheta = 0.$$

Denoting these components at G, by N_2 and T_2, they will be found to be

$$N_2 = 0, \text{ since } \cos\vartheta = 0,$$

$$T_2 = \frac{M}{a^2}\left\{(1+\beta^2)^{-\frac{3}{2}} - 1\right\} = -\tfrac{3}{2}\beta^2 \frac{M}{a^2} \text{ nearly}$$

$$\therefore \quad T_2 = -\frac{3}{2}\frac{MR^2}{a^4} \text{ nearly.}$$

Similarly at H and K, will be found for N_3, T_3 and N_4, T_4,

$$N_3 = -\frac{M}{a^2}\left\{(1+\beta)^{-2} - 1\right\} = -\frac{M}{a^2}\left\{-2\beta + 3\beta^2 - 4\beta^3 + 5\beta^4 - \text{etc.}\right\}$$

$$T_3 = 0.$$

$$\therefore \quad N_3 = \frac{M\,.\,2R}{a^3}\left(1 - \tfrac{3}{2}\beta + \tfrac{4}{2}\beta^2 - \tfrac{5}{2}\beta^3 + \text{etc.}\right)$$

$$N_4 = 0,\ T_4 = -\frac{M}{a^2}\left\{(1+\beta^2)^{-\frac{3}{2}} - 1\right\} = -\frac{M}{a^2}\left\{-\tfrac{3}{2}\beta^2\right\}$$

$$\therefore\ \ T_4 = +\tfrac{3}{2}\,\frac{MR^2}{a^4}\text{ nearly.}$$

At E, Fig. I, $T_1 = 0$; at G, $T_2 = -\frac{3}{2}\frac{MR^2}{a^4}$ nearly; and it is easy to see that when $\vartheta > 0$, and $\vartheta < 90°$, T must be positive up to some point on the quadrant EG, where it must again become zero without $\sin\vartheta = 0$, after which it will be negative up to and including G. This point on EG will be determined by the condition

$$\frac{1-\beta\cos\vartheta}{(1-2\beta\cos\vartheta+\beta^2)^{\frac{3}{2}}} - 1 = 0.$$

An approximate solution of this equation gives

$$\cos\vartheta = \tfrac{3}{4}\beta,\text{ nearly.}$$

As β is generally small, hence ϑ will be large, or the required point not far from G. Hence the tangential component of the disturbing force T_1 in the first quadrant, is positive, or right-handed, up to near G. Like the tangential component of the Sun's pressure, it produces a flow of the comet's fluid material from near G towards E. Similarly the flow takes place from near K towards E; and in the second and third quadrants, the flow of material takes place from near G and K towards H. Hence a further increase of the diameter HE, at the expense of the diameter GK.

In addition to the increase of the diameter HE, and the diminution of the diameter GK, by both the normal and tangential components of the Sun's pressure, and also by the tangential components of the Sun's disturbing force proper, or T, there is an increase of the diameter HE by the normal components, N_1 and N_3 and by similar components, which may be called the Solar Tidal Forces. These forces tend to raise tides of unequal magnitude, in the hemisphere GEK, directly towards the Sun, and in the hemisphere GHK, away from him, that towards the Sun being the greater. The type of the tide raised nearest the Sun may be considered as represented approximately by the disturbing force,

$$N_1 = \frac{M}{a^3}\,.\,2R\,.\left\{1 + \tfrac{3}{2}\beta + \tfrac{4}{2}\beta^2 + \tfrac{5}{2}\beta^3 + \text{etc.}\right\}. \qquad \text{(I).}$$

That of the tide in the opposite hemisphere, GHK, by the disturbing force,

$$N_3 = \frac{M}{a^3}\,.\,2R\,.\left\{1 - \tfrac{3}{2}\beta + \tfrac{4}{2}\beta^2 - \tfrac{5}{2}\beta^3 + \text{etc.}\right\}. \qquad \text{(II).}$$

It will be perceived that the maxima disturbing forces, N_1 and N_3, on account of the smallness of β, in general, are nearly in proportion directly to the *mass* of the disturbing body, M, inversely proportional to the *cube* of the disturbed body's distance, a, from the disturbing body, and directly as the diameter, or radius, R, of the disturbed body.

But the effect of these disturbing forces in raising these tides will also depend greatly on the force by which they are resisted, namely the gravitation toward the center of gravity of the disturbed body, principally at its surface, E and H, but more or less also at other distances from the center, C. It will be instructive to compare these forces, and their effects in producing the tides in the waters of the earth, with what they ought to be, when similarly computed, for a given comet, as Donati's.

With the Earth's mean distance from the Sun, considered as constant, its known mass, compared with that of the Sun, $m = \frac{1}{354936}$, according to Professor Watson's tables in his Theoretical Astronomy, that of the Sun being the unit, and its known radius, R, the forces N_1 and N_3, for the Earth's solar tides, are readily computed. But these forces are so resisted by gravity at the Earth's surface, which may be represented by $g = \frac{m}{R^2}$, that the highest tides raised on the Earth, at E and H, by the Sun alone, are about one foot in the open ocean, far away from any land except a small island. According to Professor Newcomb, Donati's comet was first discovered on June 2, 1858, with an apparent diameter of 3′. How large was the comet then, and how far from the Sun was it? From the elements of the comet given by Professor Watson, No. 248 of his Catalogue of Comets, which elements were computed by Professor G. W. Hill, it appears that the comet was then in the part of its orbit 120 days before perihelion passage, which was nearly on Sept. 30. With these data the comet's radius-vector, or distance from the Sun, computed by Watson's formulæ and tables, both as a parabola and as an ellipse, was a little more, especially in the ellipse, than two and a quarter times the Earth's mean distance from the Sun.

Using the solar parallax, 8″.848, and the Earth's equatorial radius given by Professor Chauvenet (Spherical and Practical Astronomy), the Earth's mean distance was found in miles, and thence that of the comet. Then, from the 3′ apparent diameter of the comet, its diameter was found to be, on June 2, 1858, somewhat more than 182,000 miles. Hence the radius of the comet was at least $R = 91{,}000$ miles, or nearly 23 times the

Earth's equatorial radius. Professor Newcomb says, (Popular Astronomy, page 380), "No tail was noticed until the middle of August, and at the end of that month it was only half a degree in length, while the comet itself was barely visible to the naked eye." About the middle of August would bring the comet to within 45 or 46 days of its perihelion passage. At that time, by Watson's formulæ, the comet would be a little more distant from the Sun, than the Earth was. Supposing the comet to have then the same diameter, $HE = 2R = 182{,}000$ miles, or 23 times the Earth's diameter, it is evident from (I) and (II), that the Sun's disturbing forces would tend to raise tides at E and H, 23 times as great as they would on the Earth at the same distance, or nearly 23 feet instead of one foot. But the actual heights of the tides raised by the forces N_1 and N_3 would also depend upon the strength of the forces tending to counteract their effect. On the Earth the counteracting forces are mainly the gravity $g = \frac{m}{R^2}$, acting at E and H toward the centre C. To determine what these counteracting forces are on the comet its mass, m, as well as its radius, R, must be known. La Place's limit of a comet's mass, to produce no perturbation in the solar system, is $\frac{1}{5000}$ of the Earth's mass. It is better perhaps to make the following supposition. Since it is known that the Earth's atmosphere is about $\frac{1}{1000000}$ of the Earth's mass, let it be supposed that the mass of Donati's comet is equal to 400 times that of the Earth's atmosphere. It will then be $m = \frac{400}{1000000} = \frac{1}{2500}$ of the Earth's mass. This is just twice as great as La Place's limit.

As the comet's radius is 23 times that of the Earth, hence the gravity at its surface, at E or H, is $g' = \frac{g}{2500 \times 23^2}$, where g = the gravity at the Earth's surface, and g', that at the comet's. Hence $g' = \frac{g}{1{,}322{,}500}$.

As this restraining force of gravity on the comet's surface is so much smaller than it is on the Earth, the 23 feet elevation of the tides at E and H, in the case of the comet, must be increased 1,322,500 times or 30,417,500 feet, or about 5,760 miles, nearly one-sixteenth the length of its radius.

Without intending this as an absolutely accurate and definite calculation on the subject, in all its complicated details, it is sufficient perhaps to show how enormous the Sun's tidal disturbance of the comet's figure of equilibrium must be, even when it is as far from him as the Earth is, considering how small the comet's mass is, compared with that of the Earth, and how large its diameter is. But when the comet runs down still nearer to the Sun, it gains nothing, as a whole, in its restraining power over the disturbing forces; but these are again enormously increased inversely proportional to the cube of the comet's distance from the Sun.

The difference between the tidal forces towards the Sun, and on the comet's side turned away from him, being greater in the former case, tends still farther to transfer the comet's centre of gravity towards the Sun, in the same direction namely as its transference by the pressure and tangential components.

That this change of the comet's centre of gravity is not a small one may be understood from the following considerations. When Mr. Croll, the English geologist, first published his views with regard to a large ice-cap placed over one of the Earth's polar regions, the north pole for example, and the removal of all ice from the opposite pole, he computed that there would be, in consequence, a considerable displacement of the Earth's centre of gravity towards the pole on which the ice-cap rested. A scientific friend brought these results to my notice; but I was disposed to doubt, or deny, that the effect of such an ice-cap could change the Earth's centre of gravity by any appreciable amount, because the mass of the supposed ice-cap may be regarded as almost infinitesimal compared with the mass of the Earth.

But, said my friend, try the calculation yourself, and tell me how great is the change of the centre of gravity, for an ice-cap at the north pole, say one mile high, and thinning down to zero thickness at 45° north latitude. On making the calculation, by supposing the mass of the Earth, without the cap, with the mean density of 5.6, to have its centre of gravity, or its weight, at the centre of a sphere with the Earth's mean radius, and computing the weight and position of the ice-cap's centre of gravity, with a mean density of 0.92, the place between these two points,—the earth's center, and the ice-cap's center of gravity,—where the two weights, on opposite sides of a fulcrum, would balance each other, was found, to my surprise, at a large fraction of a mile from the Earth's centre. Then it was easy to see that while the ice-cap was really but a small fraction of the Earth's mass, yet its power of changing the centre of gravity really depended upon the *very great leverage* at which it acted; nearly four thousand miles.

In the same manner, although the mass of the comet that is transferred towards the Sun, in excess of that transferred to the opposite side, may be comparatively small, yet the enormous leverage at which it acts, in the case of the comet, 23 times as large as the Earth, and only $\frac{1}{2500}$ of the Earth's mass besides, would necessarily change its centre of gravity towards the Sun by a very large amount.

Again Mr. Croll inferred from the displacement of the Earth's centre of gravity towards that of the ice-cap, that the moveable waters of the Earth would be drawn towards the new centre of gravity, arraying themselves somewhat spherically around this new centre, and thus throwing a still larger mass of water upon the hemisphere containing this centre. The effect of this would be to still farther transfer the centre of gravity in the same direction, until a new equilibrium of all the forces could be established.

Exactly in the same way, the transference of the comet's centre of gravity towards the Sun, by the forces previously discussed, would cause an additional portion of its fluid mass to move towards the Sun, especially at the comet's surface, and thus still farther remove its centre of gravity towards the Sun.

The next important consequence, resulting from this change of the comet's centre of gravity, is that the radius, R, in the two formulæ, (I.), (II.) on page 182, or in the expressions for the Sun's normal disturbing forces at E and H of Fig. I, can not be the same. For the R in (I.), counted from the comet's centre of gravity, is now *diminished*, while that of (II.) is *increased*. Let the smaller R, in N_1 be denoted by R_1, the greater in N_2 by R_2. Then the new values of N_1 and N_2 are, denoting them by an accent placed above them,

$$N_1' = \frac{M}{a^3} \cdot 2R_1 \cdot \left\{1 + \frac{3}{2} \cdot \left(\frac{R_1}{a}\right) + \frac{4}{2} \cdot \left(\frac{R_1}{a}\right)^2 + \frac{5}{2} \cdot \left(\frac{R_1}{a}\right)^3 + \&c.\right\}. \quad \text{(I'.)}$$

$$N_2' = \frac{M}{a^3} \cdot 2R_2 \cdot \left\{1 - \frac{3}{2} \cdot \left(\frac{R_2}{a}\right) + \frac{4}{2} \cdot \left(\frac{R_2}{a}\right)^2 - \frac{5}{2} \cdot \left(\frac{R_2}{a}\right)^3 + \&c.\right\}. \quad \text{(II'.)}$$

At the same time the restraining force of the comet's gravity at its surface, at E and H respectively, will be $g_1' = \frac{m}{R_1^2}$, and $g_2' = \frac{m}{R_2^2}$.

Thus it is evident that the normal disturbing force, N_1' for raising the tide at E, nearest the Sun, is now, in consequence of the displacement of the comet's centre of gravity, less than the opposite normal disturbing force, N_2', at H. At the same time, the comet's restraining force, at E, g_1' is now greater than that, g_2', at H. In other words, the comet, by the change of its centre of gravity, has *gained control* over its surface *towards the Sun*, and it has *lost control* over that part of its surface turned away from him.

For a distance, R_1, from the new center of gravity, in the direction towards *H*, away from the Sun, the gravity $g_1' = \frac{m}{R_1^2}$ will be the same as that towards the Sun. Hence the mass of the comet, at the new center of gravity, will tend to collect a spherical portion of its fluid materials around this center, in every direction at the distance R_1; but the more distant portions, out to the limit R_3, will be less attracted, and rarer or less dense, as long as the attraction $\frac{m}{R_3^2}$ is greater than N_3'.

The tendency will evidently be to form a dense nucleus at, and very near the comet's center of gravity, and a less dense spherical *head* or *coma* around the nucleus, or radius R_1. The comet's figure will be more or less that of an elongated ellipsoid, with the longest axis directed towards the Sun, the nucleus and head being nearest to him.

With the decrease of the comet's distance from the Sun, the disturbing forces will increase inversely as the cube of the radius-vector, the two radii, R_1 and R_3, will become more and more unequal, and the control of the comet's attraction on its materials turned away from the Sun, less and less, until finally the Sun's disturbing force in this direction becomes too great for the comet's attraction to control its figure of equilibrium in the direction away from the Sun. The figure will, therefore, be *ruptured*, and the tail of the comet will be formed of a somewhat paraboloidal form, rather than the previous ellipsoid.

The nucleus and head of the comet will now journey down towards the perihelion, with accelerated velocity; the more distant tail following more slowly along nearly the same orbit.

When the nucleus and head of the comet shall have approached very near the perihelion, their velocity will be exceedingly great, since it is nearly inversely as the square-root of the distance from the Sun. But the greater part of the tail will be spread out backwards along the orbit to such great distances, and will be moving so much more slowly in consequence, that the nucleus and head will be forced to break away from all connection with these portions of the tail. The nucleus and head, containing the greater part of the comet's mass, having passed the perihelion, and now receding from the Sun, his action on them will be exactly the same as before they passed the perihelion. That is, he will still draw the center of gravity nearest to him, and the action on the more remote parts will as closely *resemble* a repulsive force by which he will *seem* to drive them away from him, as was the case *before perihelion passage.* But, in neither case is there any *real repulsion*; only the same *difference of attraction* by which the tides in the Earth's waters are produced.

The portions of the tail, separated from the head and nucleus at perihelion passage, will subsequently, at their proper times, according to their distance from perihelion, pass around that point, and move in a somewhat wide track along nearly the same orbit, spread over a considerable arc of the orbit. Having reached the perihelion later than the comet's head, they will never be able to overtake it, as both are retarded alike in their journey towards aphelion, if the orbit be a long ellipse. When the head arrives at aphelion it begins to be accelerated again towards perihelion, while the separated portions of the tail are yet climbing with retarded velocity towards the aphelion. Of course their chance of overtaking the head is diminished still more.

At the next and at each return of the comet to perihelion, a like separation takes place, and thus the materials of the comet become gradually strewn around the orbit, in their patches, forming those nebulous bodies that produce the meteor-swarms whenever the orbit of the comet happens to nearly intersect the orbit of the Earth.

This tidal theory of the forms of comets, and of their disruptions without scattering the fragments into outer space, beyond the Solar System, as the repulsion theory requires, is the only one, so far presented, that accounts for the Leonid, the Perseid, and other swarms of shooting stars, with a recognized comet pursuing the same general orbit as the meteoric bodies themselves.

No claim is hereby made to any originality in this tidal theory of comets. For it seems obvious that it ought to present itself naturally to anyone, as it did to me, who should reject, as I always did, the repulsion theory, on account of its inconsistency with the abundantly verified Newtonian Law of Gravity.

On speaking to a mathematical friend, more than thirty years ago, of this tidal theory of comets, he informed me that he had heard that such a theory had been maintained by one of the Professors at Hamilton College, New York. Professor Newcomb mentions that Professor B. Peirce of Harvard maintained that the nucleus of a comet must possess metallic density to prevent its being torn to fragments by the Sun's tidal forces at perihelion.

Somewhere about 1860 or 1861, I found a statement by M. Faye, the discoverer of the comet that bears his name, to the effect that on seeing the great comet of 1843, he said to Arago, "There is a magnificent tide produced by the Sun on the comet." "No," said Arago, "it cannot be a tide, because, if it were, there should be a tail of equal length pointing *towards the Sun.*"

Thereupon M. Faye gave up the idea of the tide, and fell back upon the repulsion theory. But Arago was not warranted in pushing so closely the analogy of the *small tides* on so *small a body*, and so *great a mass*, as the Earth, at a great and constant distance moreover from the disturbing body, to the extreme case of the *large bodies*, *small masses*, and *greatly varying distances* of the comets from the Sun.

OBSERVATIONS OF JUPITER MADE WITH THE 16-INCH EQUATORIAL OF GOODSELL OBSERVATORY.*

H. C. WILSON.

During the fall and winter of 1891, I have observed the planet Jupiter on quite a number of nights, with the 16-inch equatorial of Goodsell Observatory. On several nights sketches were made of the detail which could be seen. Four of these sketches are given with this paper (Plate VII.). As some of the notes made may be of interest to amateur astronomers, I give the substance of them here.

Aug. 31, 1891, $12^h\ 30^m$ central time.—A sketch (No. 1) shows eight belts, one of them exceedingly narrow and lying almost exactly on the planet's equator. On the northern edge of the first northern belt near the meridian are two small dark spots with a white spot between them. On the southern edge of the next northern belt are two more small dark spots. All of these dark spots are slightly elongated parallel to the equator.

Sept. 3, $12^h\ 10^m$, $12^h\ 20^m$ central time.—Sketch (No. 2) shows eight belts, one very narrow one lying close to the planet's equator. The great red spot has its preceding end on the meridian. Just south of this on the meridian is a small white spot. Another white spot is on the same parallel nearly half way to the preceding limb of the planet. Beyond this the belt in which the white spots lie is very dark. The belt where it passes the great red spot seems to be pushed aside, not resuming its orginal

---

*Communicated by the author.

latitude until it is some distance past the spot. There are three small dark spots in the second northern belt and two in the third northern belt. All five are past the meridian.

Sept. 25, 11^h central time.—Partial sketch shows the great red spot on the meridian. The spot encroaches upon the belt just south, apparently pushing it aside and making it denser, as a stream of water is made deeper by being forced through a narrow channel. Five small white spots are seen in this belt, one in conjunction with the preceding end of the great red spot, another near the following end of the red spot. The great southern belt is very much darkened in the portion opposite the preceding end of the great red spot. There are two small dark spots in the north edge of the first northern belt near the following limb of the planet. The center of the great red spot was not quite up to the central meridian at 10:50; on meridian at 10:54; certainly past meridian at 10:58 central time.

Oct 8.—Long red spot in second southern belt had its center on the central meridian of Jupiter at 10^h 12^m ± 2^m central time. This spot is very prominent, bright crimson in color, almost a parallelogram in shape.

Oct. 15, 8^h 30^m.—A white spot south following the great red spot was on meridian at 8^h 30^m. The sketch (No. 3) shows the great red spot half way from the meridian to the left limb of the planet. The central portions are covered with a white cloud. The great southern belt is very intense especially near the great spot, and is curiously narrowed, like a pencil point, toward the left. On the northern edge of this belt about half way from the center to the east limb is a curious projection curved to the left with a white indentation preceding it. The second southern belt is strangely curved to the south connecting with the next belt. The narrow belt on the equator is distinctly shown.

Oct. 27.—A round white spot preceded by a very dark shading, on the lower edge of the great southern belt, was at the central meridian at 8^h 20^m. Great red spot a little more than half way from meridian to left edge of disk.

Oct. 30.—Shadow of Satellite III was noticed beginning transit at 6^h 18^m. Satellite I reappearing from eclipse was first noticed at 7^h 08^m 35^s; very faint; it had regained its normal brightness at 7^h 11^m 35^s.

Nov. 9.—While showing Jupiter to visitors I noticed the three satellites (I, III and IV) in the form of a small triangle to the left of (preceding) the planet. The upper one of the three is much fainter and bluer in color than the other two. [The upper one was IV. The transit of its shadow had occurred two or three hours earlier. A rough sketch indicates that III was about twice as bright as I and the latter twice as bright as IV].

Nov. 16, 7^h central time.—Satellite IV is much fainter than any of the others and of a darker color. Air hazy. [IV was on left side of planet. Occultation occurred 13 hours later].

Nov. 17, 7^h-8^h.—Satellite III reappeared from eclipse just above (south of) IV, while I was examining the latter. I first noticed it at 7^h 28^m 50^s, when the appearance of the two satellites was that of a very unequal double star. At 7^h 29^m 40^s, the two were equal in brightness and a minute later III was at least twice as bright as IV. III was perceptibly elongated while coming out of eclipse, but round afterward. [IV was then on the right side of the planet, about to be eclipsed an hour later. No note is made of color and, as I now recollect, it did not differ much from that of the other satellites].

Nov. 19.—The long red patch in the second belt south of Jupiter's equator was on the central meridian at 8^h 18^m.

Nov. 23.—Sky hazy and image fuzzy except at moments. I was surprised, as I have been several times lately, by the faintness and bluish color of satellite IV. This satellite was on the left of the planet, about ⅔ diameter distant, and approaching. The satellites on the left of the planet form a descending series as to their apparent diameters. The one farthest out has double the diameter of the next and that double the diameter of the one nearest the planet. These are not the real disks of the satellites but are enlarged by poor definition. [I find on comparison with the American Ephemeris that the satellite supposed to be IV in the above observation was really II. IV was on the right of the planet and according to the sketch was about equal to I in brightness. The satellites on the left were in order III, I, II.]

Dec. 12, 7^h.—While showing Jupiter to visitors I was surprised by the faintness and purple color of satellite IV, which had only a couple hours before passed off from the face of the planet. The contrast between its light and that of III, which was very near it, was very striking. IV was very much fainter than I and II.

Dec. 17, 4^h 30^m.—Sketch (No. 4) shows great red spot east of central meridian. White spot exactly over its center surrounded by dark shading. Both spots on meridian at 4^h 44^m. The great southern belt seems narrower than usual and on its northern edge is a series of five projections all curving backward toward the east limb. The white equatorial belt is far from white, being filled with dusky details which are seen indistinctly and cannot be sketched. The narrow dark belt on the equator is not seen.

Dec. 18, 7^h.—The three visible satellites (IV, I and III) all had a a reddish yellow tint, darker than the planet, which was very white between the dark belts. Definition poor.

Jan. 2, 1892, 5^h and 7^h 30^m.—The satellites were all of the same color, yellowish white, and nearly the same brightness. The three on the right, III, I and II, were almost exactly equal in brightness and color. Magnifying power 200 and 300.

Jan. 4, 5^h 45^m.—Definition fair. White spot on central meridian in middle of first dark belt south of equator. A small dark spot immediately follows and another precedes it by one-fifth diameter of Jupiter's disk on the same parallel of latitude. The satellites are all of nearly the same color, yellowish white, but differ greatly in brightness. In order of brightness they are IV, I, II, III.

Jan. 23, 4^h 30^m.—Satellites of Jupiter were all of the same color, yellowish white. Satellite IV was the faintest and possibly a little darker in color than the others. This satellite was on the right side of the planet, having just reappeared from eclipse.

On every occasion when the great red spot was seen it was conspicuous, having a light red or pink color, quite different from that of the belts on either side. It gave me the impression always of being at a higher level than the other dark markings. The permanence of outline of this spot and of the great belt on its north and the clear white channel between them would suggest a surface of a comparatively solid nature rather than that of cloud formation. Yet a comparison of the drawings accompanying this paper will reveal many marked changes in other portions of the planet's surface.

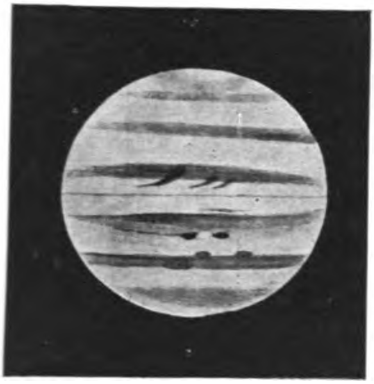
It has been a disputed question whether the portions of the belt next south of the great red spot, which have the same latitude and a shorter period of rotation than the latter, passed over or around it. It has seemed to me at each observation that the dark belt on coming up to the spot was forced aside, there being nearly always a very narrow line of white between the belt and spot. Only on one occasion did the belt seem to encroach upon the spot and that was when the seeing was poor.

The few notes which I have upon the brightness of the satellites go to confirm the view which has been expressed by several, that the variations of brightness always occur in the same parts of the orbits about Jupiter. In each case when IV was noted as especially faint, it was but a short distance to the left (west) of the planet having just passed off from the planet's disk.

I have not, in any case, been able to see any markings upon the

PLATE VII.

1.



Aug. 31, 1891, $12^h\ 30^m$.

2.

Sept. 3, 1891, $12^h\ 15^m$.

3.

Oct. 15, 1891, $8^h\ 30^m$.

4.

Dec. 17, 1891, $4^h\ 30^m$.

Sketches of Jupiter made with the 16-inch equatorial of Goodsell Observatory by H. C. Wilson.

ASTRONOMY AND ASTRO-PHYSICS,
Vol. XI, No. 103, March, 1892.

satellites. In the best seeing, the disks have always seemed perfectly round except in one instance when satellite III was plainly elongated, the position angle of the elongation being about 30° less than that of the belts of the planet. The satellite was on the preceding side of the planet about to disappear by occultation. Unfortunately no memorandum was made at the time of this observation so that I cannot now tell the date.

THE OBSERVATION OF SPOTS AND MARKINGS OF THE PLANET JUPITER,*

G. W. HOUGH.†

In the publications of the Astronomical Society of the Pacific, No. 5, and more recently in the *Monthly Notices* of the Royal Astronomical Society, November, 1891, Professor Barnard of the Lick Observatory, has called attention to a statement I made some years ago in relation to the value of micrometer measments for fixing the longitude of spots on the planet Jupiter.

Professor Barnard from eleven observations of the Great Red Spot, made at Lick Observatory in 1891, with a 12-inch object-glass, as well as from observations made at Nashville in 1880-82 with a 5-inch object-glass, has attempted to prove that eye-estimates are as exact as micrometer measurements, for determining the time of passage of the Red Spot over the central meridian of Jupiter.

From what has already been published by others, regarding the various sources of error incident to the method of eye-estimates, I imagined that the subject was no longer open for serious discussion.

It seems to me that an eye estimate for longitude on Jupiter, in point of accuracy, holds about the same relation to micrometer work, as the estimation of the position angle and distance of the components of a double star does, to direct micrometrical measurement.

In the *Monthly Notices* of the Royal Astronomical Society for May, 1880, Professor Marth, who for so many years has given us his invaluable ephemerides, has compared with an ephemeris the observations made by thirteen different observers, on the Great Red Spot in 1879.

---

* Communicated by the author.

† Director of Dearborn Observatory, Northwestern University.

He says: "The discrepancies between the observations of different observers and on different days point to the existence of some grave source of error."

A comparison of these observations shows that on some days, the observers differed as much as eleven minutes in the time of passage of the center of the Red Spot over the central meridian.

The average "mean" error may be placed at about ± 2.5^m.

The observations also indicate a personal equation, for each observer; the constant difference between two well-known astronomers amounting to 6.5^m.

In the *Astronomische Nachrichten*, No, 2342, Dr. Schmidt, of Athens, from the reduction of 180 observations, found a "mean" error of ± 2.57^m for the time of passage of the center of the Red Spot over the central meridian. For good definition he gives the average error $\pm 2^m$ and for poor definition $\pm 5^m$.

In the *Astr. Nach.* No. 2410, Dr. Schmidt has determined the personal equation error for a large number of observers. As compared with his own observations, the personal equation of different observers varies between $+ 3.6^m$ and $- 5.8^m$.

He also found a systematic error depending on the hour-angle of the planet, due to the position of the equator of the planet to the line of sight. The maximum correction for this error was 7^m.

With these facts before us, regarding the gross possible errors incident to the method of eye estimates, it seems to me rather late to claim for it any great degree of precision.

Professor Barnard's excellent observations of the passage of the Red Spot over the central meridian in 1891, are certainly as good as the best micrometer work, but I think these particular observations should be regarded as a happy accident rather than a demonstration of the value of the method of observation.

Professor Barnard is a very careful observer, and the Nashville observations are excellent for the size of the instrument used, but when he claims a "mean" error of ± 0.7^m for observations made with a 5-inch object-glass and a power 137, I think he has been too hasty in his conclusions.

He says: "In twenty-three of these transits *three* estimates were made of each phase (the ends and middle of the spot) from these I get for the transit of the middle of the mean of the *nine* observations, the error of the transit = ± 0.7^m."

I do not quite understand what he means by "three estimates of each phase." There is only *one* instant for the time of transit and assuming a great number of different times certainly will not improve its value. A comparison of the observations made during any opposition with an ephemeris which will best satisfy them all will indicate the average accidental error on each day, but may not show the personal equation or other constant errors.

In order to get a "mean" error of ± 0.7^m on the time of transit of the Red Spot over the central meridian, one must be able to bisect the disk of the planet as well as the Red Spot, each within $0''.10$ of arc at mean distance; and this degree of accuracy must be accomplished by a single estimation.

The error in astronomical observations of all kinds greatly exceeds this limit. The method of transits, owing to the apparent slow motion of the spots and the absence of a visible meridian, is not susceptible of great precision. A very good illustration of the conditions involved is to imagine a clock dial without any minute hand and all the divisions erased except III and IX. Under these circumstances the problem is to determine when the hour hand is midway between III and IX, or when it is 12 o'clock.

It appears probable that the determination of noon from a clock dial arranged in this way would be affected by all the various sources of error found by Dr. Schmidt for Jupiter observations. On the other hand if one should make repeated measurements of the position of the hand with reference to III and IX, the time of noon could be ascertained with any required degree of precision.

The micrometer method offers the following advantages in the determination of longitudes on Jupiter:

1st. A great saving of time.

2d. The measures are referred to a visible meridian, viz.: the limbs of the planet.

3rd. The ability to make numerous repetitions of the same quantity.

The longitude of a spot, or the time of passage over the central meridian of the disk, can be determined with the micrometer at any distance from the central meridian, provided it is wholly on the disk. I have occasionally observed spots at 1^h 20^m before or after their passage over the central meridian. Owing, however, to greater difficulty in seeing objects so far from the center of the disk as well as to possible errors in the adopted constants for reduction, viz.: size of the disk, length and latitude of the object observed, such measures are liable to greater error than when made nearer the central meridian.

The following example of the observations of the Great Red Spot on Nov. 1st, 1880, will illustrate the micrometer method:

Two sets of measures were made when the spot was on the following side, one set near the middle of the disk, and two more sets when on the preceding side.

t = mean of the times when the measures were made.
m = distance from the central meridian, reduced to mean distance.
Δt = reduction in time.
T = time of transit over the central meridian.

t		m	Δt	T		*Diff.*
h	m	″	m	h	m	m
8	23.6	+ 3.99	+ 22.5	8	46.1	+ 0.8
	28.8	+ 2.99	+ 16.8		45.6	+ 0.3
	42.1	+ 0.28	+ 1.5		43.6	− 1.7
9	19.8	− 5.89	− 33.6		45.2	− 0.1
	23.7	− 6.59	− 37.8		45.9	+ 0.6
			Mean,	8	45.3	± 0.7

In 1880–82 I made a number of sets of measures on each night to ascertain what degree of precision could be reached, but usually the observation consists of a single set of three or four bisections for each limb. The latitudes are determined in precisely the same way.

To sum up the whole matter, it seems to be proved from the observations which have been made by well-known astronomers, as well as from the theoretical consideration of the problem, based on our knowledge regarding astronomical observations in general, that the method of transits for ascertaining the time of passage of the Red Spot over the central meridian of Jupiter is necessarily subject to a mean error of at least ± 2.5^{m}, and a possible error three or four times as great. Aside from the accidental error the personal equation of an observer may amount to a number of minutes.

From what I have said on this subject it is not to be inferred that I consider eye estimates of no value. All observations of planetary phenomena are valuable and during the past twelve years many important contributions in regard to physical phenomena on Jupiter have been made by amateurs and others.

I wish, however, to state emphatically that when it is necessary to get precise measures either of longitude, latitude or magnitude of objects on the disk of Jupiter, the micrometer is vastly superior to any system of estimation.

DISCOVERY OF NEBULÆ.*

LEWIS SWIFT.†

The success of the past year in the discovery of nebulæ has not equalled that of the few years previous, or since the assumption of the directorship of the Warner Observatory, for two reasons, viz.: first, from the presence of haze, clouds, and moonlight, the season has been exceptionally unfavorable; and second, from the sky illumination from the increased number of electric street lights now in nearly every part of the city. And as this method of street lighting has come to stay, at least until some indiscreet individual shall invent one still more damaging to delicate astronomical observation, I thought that perhaps some time might elapse ere my tenth catalogue of 100 nebulæ could be attained, so I have just sent to the *Astronomische Nachrichten* a list of 60 nebulæ discovered since the publication of my ninth regular catalogue, a little more than one and a half years ago.

So detrimental has this sky illumination become that I am seriously questioning whether I shall not be obliged to altogether abandon the search for nebulæ and take up some other branch of work. Though, like the stars, the nebulæ are, doubtless, endless in number, yet there is probably not a single undiscovered bright one in the heavens, so thoroughly has the sky been searched by such persistent gleaners as Sirs William and John Herschel, D'Arrest, Lord Rosse, Stephan, Marsh, Tempel, Stone, Messier and many others. The entire sky does not, probably, hold a dozen so bright as Herschel's Class II, and very few as bright as his Class III yet remain undiscovered between the pole and 25° south of the equator. A very large proportion of the nebulæ in my several lists are very much fainter than the faintest of Sir Wm. Herschel's Class III, his faintest.

To prosper in their finding henceforth the observer must be the possessor of a large telescope with a suitable eye-piece made especially for this work, which quest he should be enthusiastically in love with, and he must have a keenness of vision not vouchsafed to everyone, which he has still farther improved and intensified by long practice in observing what Sir John Herschel declared to be so faint as to be almost spiritual.

I have been led to these remarks by an exceeding effort of vision of a few nights since in endeavoring to re-find a nebula discovered on Dec. 23, 1889, but which I could not subsequently re-

---

* Contributed by the author.

† Director of Warner Observatory, Rochester, N. Y.

cover, and, therefore, concluded it must have been a comet. It is No. 13 of my ninth catalogue where it stands described as "Exceedingly, exceedingly faint, pretty large, round, first of three. In line with N. G. C. 1417-18. Cometary. Unable to re-find it. Seeing good. Failed also at Harvard College Observatory."

In *Monthly Notices* of December, 1891, Dr. Dreyer, Compiler of the N. G. C. and Director of Armagh Observatory, Ireland, says he several times at Lord Rosse's Observatory saw all three of these nebulæ, and, again, on several occasions could not find them though looked for. Connecting his own observations with those of Sir John Herschel's and with mine, and with D'Arrest's failure to find it, he suggests that it is, possibly, a variable. Fortified with these facts, I, on Jan. 31st ult., essayed to find the missing nebula. The two with which it was in line, were easily seen, but not even a glimpse of the other, using a power of 132. Changing the eye-piece to one giving a power of 195, I, after a prolonged endeavor, gained two glimpses of the object but they almost instantly vanished.

The suspect was not exactly in line with the other two but a little north, agreeing with Sir John Herschel's observation. Sir William Herschel never saw this nebula, as has long been supposed.

I have given some thought to the unraveling of the mystery hanging over this object, and the following solution is satisfactory to myself, at least; viz.: that its first discovery was by Sir John Herschel, who recorded it as No. 305 of his own Catalogue, erroneously considering it as identical with Sir William's III 569 (New General Catalogue, 1397). In trying to reconcile this discrepancy, D'Arrest was unable to find it. Subsequently, it was seen, on several occasions, as I have said, by Dr. Dreyer, but was not again found until picked up by myself as above stated. Sir John Herschel does not describe it; he only says, "First of three; one observation."

If it be not variable, which I can hardly believe it to be, it seems strange that, on one occasion, I should have so easily observed it in sweeping, while, ever afterward, I have not been able to find it even with the most persistent effort, and, with the knowledge of its exact position relative to the other two in the same field. That Dr. Dreyer, too, failed, on several occasions, to find it while well knowing its place, seems unaccountable, if it maintain a uniform degree of brightness.

WARNER OBSERVATORY,
Rochester, N. Y., Feb. 11, 1892.

ASTRO-PHYSICS.

THE OBJECTIVE PRISM.*

Two methods have been used for photographing the spectra of the stars. The first of these methods, placing a large prism over the objective of a telescope, was that employed by Fraunhofer in observing stellar spectra visually. It was also used by Secchi for the same purpose. The second method consists in receiving on the slit of a spectroscope the image of a star formed at the focus of a telescope. This method was used by Dr. Draper and Dr. Huggins, and is that now employed at the Potsdam Observatory. The first of these methods has been used at the Harvard College Observatory during the last seven years. It possesses the advantages that the loss of light is very small, the spectra of all stars contained in the field of the instrument are photographed and slight errors in the clock driving the telescope are unimportant. In fact the clock is made to run a little faster or slower than sidereal time, since otherwise the image of each star would be spread into a narrow line in which the spectral lines could not readily be distinguished. By the change in rate this line moves over the plate at right angles to its length, forming a band whose width depends on the rate of the clock and the duration of the exposure. If the deviation from sidereal time is small, the image moves slowly over the plate, and a photograph will be obtained even if the star is very faint. In this case a long exposure should be used, otherwise the band will be too narrow. A variation in the rate of the clock, or other change affecting the right ascension, will only alter the density and breadth of the spectra. A variation in the differential refraction or other change affecting the declination will alter the direction of the spectral lines, rendering them oblique or curved instead of perpendicular to the direction of the spectrum. This will not affect the intensity of the image. With a slit spectroscope, the image of the star must be kept exactly on the slit, the least deviation causing all the light to be lost. It has, however, the great advantage that a comparison spectrum may be photographed by the side of the stellar spectrum, and the true wave-lengths thus determined directly. This advantage is, however, apparent rather than real, since the hydrogen and other solar lines are present in nearly all the stars, and the wave-lengths of any additional lines may be determined

---

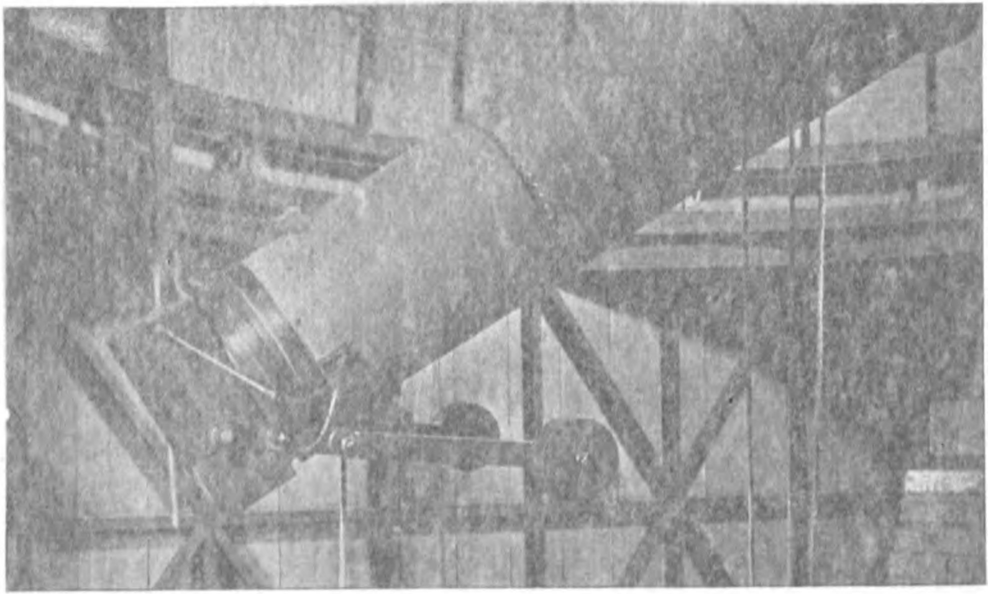
* Communicated by Professor Edward C. Pickering.

differentially from them. When, however, we wish to obtain the absolute wave-lengths of these lines in order to measure the approach or recession of the stars, the slit spectroscope has hitherto alone been used. This seems to be the only portion of this work for which the objective prism cannot be employed. Experiments are still in progress (see H. C. O. Annals, Vol. XXVI, Part I, page xx,) by which it is hoped this difficulty may be overcome. The success of these experiments would permit a fixed reference line to be photographed upon the spectrum always having the same position with regard to it. The precision with which measures of the spectral lines can be made is sufficient to determine the approach or recession with great accuracy, if only the reference line can be measured equally well. If this can be done the slit spectroscope will possess but few advantages over the objective prism. By the latter method equally good definition may be obtained, since, as the loss of light is smaller, greater dispersion may be used. With the brightest stars, however, it is difficult to obtain a dispersion sufficient to utilize the full advantages of this method. With a large telescope the prism would, of course, be heavy, expensive, and from its thickness, would cause considerable loss of light. The objective prism has special advantages in studying the spectra of the fainter stars, since all in the field of the telescope may be photographed simultaneously. If a photographic doublet is used for an objective all stars of sufficient brightness in a region ten degrees square may be photographed at once. In some cases several hundred spectra appear upon a single 8 × 10 plate.

With means furnished by Mrs. Draper the spectra of the stars have been photographed at the Harvard College Observatory as a memorial to her husband, the late Dr. Henry Draper. For the brighter stars a telescope having an aperture of eleven inches, and corrected for the photographic rays, has been employed. Four large prisms were placed over the objective and gave spectra about six inches in length. By staining the plate with erythrosin, the sodium line D was photographed in the brighter stars, both components being readily shown.

For the fainter stars one or two prisms only were employed. When the prisms were first attached to the end of the telescope, as their entire weight was about one hundred pounds, heavy weights were fastened to the other end of the tube of the telescope, and also to the end of the declination axis. It was, consequently, a laborious and perhaps dangerous operation to remove and replace the prisms. Therefore spectra and chart

PLATE VIII.

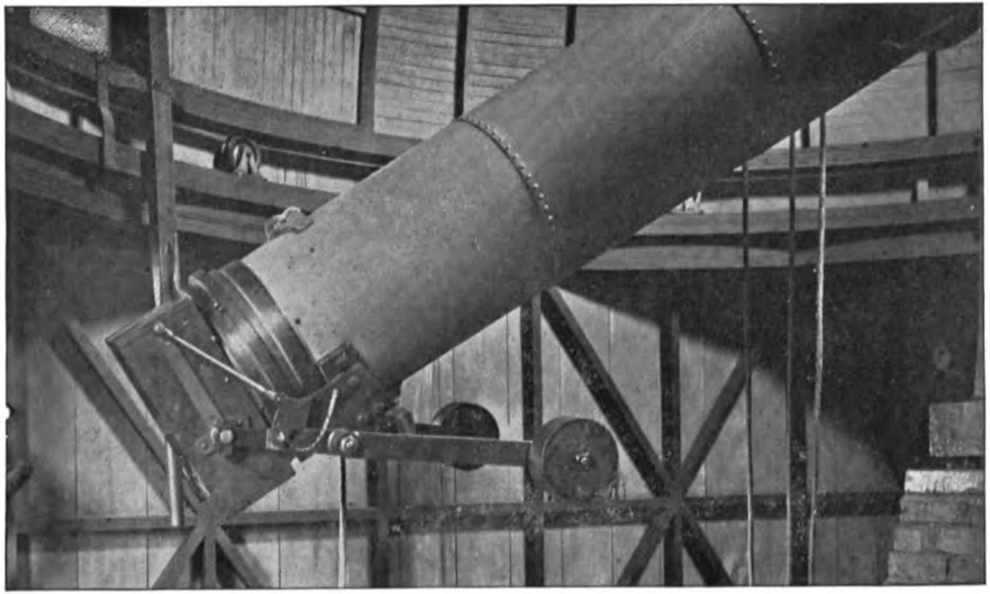


Objective Prism at the Harvard College Observatory

to obtain the
to measure the ap-
troscope has hitherto
portion of this work
Experiments
XXVI, Part I, page
may be overcome. The
a fixed reference line to
having the same posi-
with which measures of
to determine the ap-
only the reference line
can be done the slit spec-
over the objective
good definition may be ob-
smaller, greater dispersion
stars, however, it is difficult to
the full advantages of this
prism would, of course, be
ness, would cause consider-
has special advantages in
stars, since all in the field of
simultaneously. If a photo-
objective all stars of sufficient
square may be photographed
hundred spectra appear upon a

Mrs. Draper the spectra of the
the Harvard College Observa-
the late Dr. Henry Draper.
having an aperture of eleven
rays, has been em-
placed over the objective and
length. By staining the plate
D was photographed in
being readily shown.
or two prisms only were
were first attached to the end of
weight was about one hun-
fastened to the other end of the
to the end of the declination axis
ious and perhaps dangerous oper-
the prisms. Therefore spectra and

PLATE VIII.



Objective Prism at the Harvard College Observatory.

photographs could not readily be taken on the same night. A great improvement on this process was to remount the prisms in square boxes, which could be slid, like the drawers in a bureau, into a large box permanently attached to the cell of the objective. A series of cast iron rings could be bolted to the tube of the telescope, the weight of each ring being such that it would compensate for the weight of the corresponding prism. As each prism was removed a ring was attached, and it thus became unnecessary to change the counterpoise at the further end of the telescope and declination axis. It was still difficult for one person to make the change and much time was lost if frequent changes were required. The method now employed of attaching the large prisms to the telescope is shown in the accompanying engraving (Plate VIII). Two of the prisms only are now used and they are mounted in a square brass box. This is attached to the end of the telescope by a form of link motion. A cast iron bar is fastened to a pivot on each side of the cell, the line connecting the pivots passing through the centre of gravity of the prisms and box. The bars are also free to turn around pivots attached near the end of the tube of the telescope. At the further end of each bar is placed a counterpoise exactly balancing the prism and box, so that the latter will remain in equilibrium in any position. Two links, one on each side of the square box, connect its end with pivots attached to the tube of the telescope. The dimensions are such that in one position the box containing the prisms lies flat against the end of the cell and in another against the side of the tube. The first of these positions is shown in the photograph. Accidental movements of the prism are prevented by small pins attached to the bars by chains. The prisms can thus be removed and replaced in a few seconds without disturbing the balance of the telescope. About 4,400 photographs have been obtained with this instrument since January, 1886. They include the spectra of all stars north of — 30° and sufficiently bright to be photographed in this way. Among other interesting results this has led to the discovery that ζ Ursæ Majoris, β Aurigæ, and probably β Lyræ are close binaries. An expedition has been sent to Peru and similar photographs of the southern stars are now being taken with a telescope having an aperture of thirteen inches.

In a second investigation the Bache telescope is used, which has a photographic doublet for an objective having an aperture of eight inches. The advantages of this form of instrument for photographing very faint celestial objects were first recognized by the writer in 1869, when preparing to observe the total eclipse of the Sun of that year in Mt. Pleasant, Iowa. As the usual methods were inadequate to photograph the faint exterior portions of the solar corona, a local photographer, Mr. Hoover, was requested to take a photograph with a large portrait lens. The result was very satisfactory (Journal Franklin Institute, Vol. LXII, p. 54) and apparently gave the best picture of the outer corona obtained up to that time. The advantages of the doublet are first the large angular aperture which permits very faint stars to be photographed, and secondly, the extent of the field by which the stars in a large part of the sky can be taken upon a single plate. Good definition is obtained over a region five degrees square, while over a region ten degrees square the definition is sufficiently good for many purposes, such as the classification of spectra, variability in light, etc.

A prism having a refracting angle of thirteen degrees was placed over the objective of the Bache telescope and the entire sky north of — 20° was photographed with this apparatus using exposures of about ten minutes. About twenty-seven thousand spectra of more than ten thousand stars were obtained and are published under the name of The Draper Catalogue (H. C. O. Annals, Vol. XXVI, Part 1, and Vol. XXVII). Similar photographs, with exposures of sixty minutes, cover nearly all the northern sky and serve to classify the spectra of the fainter stars. By using a prism of five degrees, of which the dispersion is less, the spectra of still fainter stars are photographed. This dispersion is sufficient to show any marked peculiarities. Since July, 1885, 3,300 plates were obtained with this instrument at Cambridge and in California. It was sent to Peru in the spring of 1889 where it is now in use, and over 3,200 photographs taken there have already been received. When this instrument was removed from Cambridge, the want of it was so great that Mrs. Draper had another instrument constructed to replace it. This is known as the 8-inch Draper telescope, and with it over 5,300 photographs have been taken since August, 1889.

It is expected that a still further advance will be made with the great photographic telescope, the gift of Miss C. W. Bruce. This instrument will be three times the size of the Bache telescope which it will resemble in form. Its aperture will be twenty-four inches and it should, therefore, photograph stars one or two magnitudes fainter than those obtained with the Bache telescope. It is hoped that with the Bruce telescope satisfactory photographs of the spectra of stars of the tenth and eleventh magnitude may be obtained. The four glass disks required for the lenses have been cast and are now ready for grinding. The prism, which has an aperture of twenty-four inches, is completed.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., Jan. 23, 1892.

ON THE SPECTROGRAPHIC METHOD OF DETERMINING THE VELOCITY OF STARS IN THE LINE OF SIGHT.*

PROFESSOR H. C. VOGEL.

The experiments made at Potsdam in 1887 showed that, as a result of the extremely sensitive photographic methods employed, a sufficiently great dispersion could be made use of to readily detect and measure the displacement of the spectral lines produced by the motion of the stars in the line of sight. It very soon became clear that the measurement of the stellar spectra admitted of a far greater exactness than the direct observations, and that the disturbances of the atmosphere—the chief cause of the difficulties of the direct method—exert their influence in a lesser degree on the photograph. The very numerous measurements on more than two hundred negatives of forty-seven stars, which are now available, have confirmed this result, and show further that the exactness of the measurements far surpasses the expectations based on the first plates taken with a provisional apparatus, and that the definitive observations have reached a degree of accuracy which in some cases is surprising.

This great accuracy has been secured by an advantageous construction of the apparatus, by its very exact adjustment, and especially by the peculiar methods adopted in measuring the photographs. I have already published several communications on this spectrographic method, viz. one in *Astr. Nach.* No. 2896, a further one announcing the discovery of the motion of α Virginis (*Astr. Nach.* No. 2995), and more recently an article on the employment of iron as a comparison spectrum in spectrographic researches (*Sitzungsberichte der Akademie zu Berlin*, June 4, 1891).†

The reductions of the observations and measurements are at present nearly completed, but the passing through the press will still require several months, and therefore I now take the liberty of presenting a short review of the investigation and its chief

---

* *Monthly Notices*, Dec. 1891.

† ASTRONOMY AND ASTRO-PHYSICS, Feb. 1892.

results, in the hope that this summary, and more especially the explanation of the method of measuring the plates, may be of value and interest to many who are employed in similar lines of work.

In the construction of the apparatus the following points were taken into consideration: great stability for the smallest possible weight; suitable dimensions of prisms, collimator, and camera objectives, in order to preserve sufficient brightness with the greatest possible dispersion; accurate adjustment of the photographic plate in the focal plane of the camera objective; and exact keeping of the star on the slit of the spectrograph. I have endeavored to satisfy the first two conditions by having the frame made of cast steel, and by giving it a form which offered the greatest possible resistance to flexure. The most suitable dimensions for collimator and camera objective, for the 12-inch refractor to which the spectrograph was to be applied, were found to be 408^{mm} focal length for 34^{mm} aperture.

The two Rutherfurd compound prisms have the following dimensions: Height (length of the refracting edge) 35^{mm}; breadth (perpendicular distance from the refracting edge of the flint-glass prism) 45^{mm}. They are of the most colorless glass obtainable, and the dispersion from F to H amounts for each to about 5°. The camera is constructed of sheet steel; the plate-holders are of brass and can be rigidly connected with the camera. The adjustment of the photographic film in the focal plane of the camera objective is accomplished by a motion of the latter, and can be effected with an accuracy of a fraction of a millimetre. In order to facilitate keeping the image of the star exactly on the slit, a small telescope is so connected with the apparatus that it receives the light which is reflected from the front side of the first prism.

The slit, illuminated by the Geissler tube, which furnishes the comparison spectrum, appears in this telescope as a narrow line of light with the star in the middle, and may be readily so held by means of the slow motions of the refractor. A cylindrical lens is not employed, since, with the slit set parallel to the line of the diurnal motion, a slight widening of the linear stellar spectrum can be readily effected by changing the rate of the driving clock. A very important point in the adjustment of this apparatus is that the optical axis of the collimator shall fall in the prolongation of that of the refractor; this is easily and accurately effected by three screws.

By means of a table giving the proper setting for various degrees of temperature the plane of the slit is, before each observation, adjusted to lie in the focus for the rays of the wave-length of Hγ, for which the prisms are set at the angle of minimum deviation, and which appear on the middle of the negative. It is of great importance that the latter be precisely adjusted in the focus of the camera objective. This is likewise effected before each observation according to a table with the argument of the thermometer attached to the instrument. This table has been determined by many experiments, as well as by artificial warming of the apparatus. A false adjustment, which exerts a great influence on the sharpness of the images, and hence on the subsequent measurements, can be at once detected by the lack of distinctness of the image of the artifical hydrogen line, and, similarly, changes of the apparatus which occur during the exposure reveal themselves in the altered appearance of the comparison line.

In nearly all the observations hydrogen has been chosen for the comparison spectrum. The Geissler tube was placed directly in the cone of rays of the refractor, at a distance of 40cm. from the slit, and was set at right angles to the optical axis of the refractor as well as to the slit, aud therefore its light is to be regarded as dispersed on reaching the slit. The tubes used were very thin, so that only a comparatively small amount of light (17 per cent) was lost in passing through them.

A further advantage of this arrangement of the Geissler tube lies in the fact that an exact adjustment of its position is not necessary, and any slight changes in its place during the exposure, due to an altered position of the instrument, can exert no injurious influence; for one can readily see that with an adjustment even several degrees false, the slit would still appear fully illuminated.

At first the time of exposure was regulated according to the brightness of the star and to the chosen width of slit, but later it appeared advantageous to leave the width unchanged at 0.02^{mm} and to give a uniform exposure of one hour. The observer then, however, varied the width of the spectrum to correspond with the brightness of the star. The performance of the apparatus has been tested on the Sun by direct observations and by photographs. In the vicinity of Hγ, where the spectrum is sharpest, nearly all the lines are visible which are contained in Rowland's large photograph of the solar spectrum, in spite of the comparatively small dimensions of the apparatus. Of course very close double lines cannot be separated if the width of the slit be greater than that corresponding to the distance between the lines.

One perceives less detail on the photograph than by direct observation, since, on account of the extraordinary delicacy of the lines, some details are lost through the coarseness of the silver grains. The excellent prisms would admit of a much greater magnification of the spectrum by the use of a camera objective of longer focus, and thus make possible the production of still sharper photographs, if the light power of the refractor were not too small and the observations therefore necessarily limited to the brightest stars. I have given in *Astr. Nach.*, No. 2896, a collection of about fifty lines on one of the solar negatives which lie between 431.4 and 436.8$\mu\mu$, and may remark further that my assistant, Dr. Scheiner, has been able to measure 290 lines in the spectrum of α Aurigæ between 412.4 and 466.8$\mu\mu$.

In order to decide further as to the correct adjustment of the apparatus, numerous photographs of the Moon's spectrum, with that of hydrogen for comparison, have been made, and show an absolute coincidence of the corresponding lines. Two photographs of Venus are not without interest as showing the accuracy of the measures as well as the correctness of the adjustment:

	Observed Velocity.	Calculated Velocity.
1889 Jan. 2	— 7.8	— 7.4 English miles.
Feb. 10	— 7.4	— 7.8

The measurement of the spectra is accomplished with the aid of a microscope under the employment of magnifying powers from 7 to 35.

The table of the microscope carries a sliding apparatus, movable by a fine micrometer screw of 0.25$^{\text{mm}}$ pitch, to which the negative is firmly clamped. The periodic and progressive errors of this screw have been accurately determined. By means of a large number of measurements in the solar spectrum it has been found that one revolution of the screw corresponds to a difference in wave-length of 0.324$\mu\mu$. With this value can now be computed g, the value in miles per second of velocity of one revolution of the screw, from the formula $g = \frac{\Delta\lambda}{\lambda}\mathrm{V}$, where V is the velocity of light and λ the wave-length of Hγ, 434.07$\mu\mu$. The result is $g = 139.13$ miles. This value, strictly speaking, holds good only for the temperature at which this standard photograph of the solar spectrum was taken, since the dispersion varies with the temperature. A small correction has, therefore, been applied to all the photographs made at a different temperature. For stars of the second type, however, a method of measurement has been chosen which takes for a basis this standard solar negative, as I shall presently show.

In the case of the spectra of Classes II. and III., containing numerous lines, it suggested itself, in determining the displacement between the artificial Hγ and the star line, to connect the former by differential measurements with the other neighboring lines, not only in order to obtain an increased degree of accuracy, but also indeed from necessity, since, in the generally very small displacements, it wholly or partly concealed the star line. All the difficulties which at first arose in the way of direct measurement of the plates, into the details of which I cannot here enter, were thereby overcome in that I simultaneously with the star spectrum also measured a standard solar spectrum taken with the spectrograph. The plate with the solar spectrum is cut off lengthwise, and so laid upon the star spectrum that the two appear in the microscope one above the other, and separated only by a small space.

The solar negative is observed through the glass, since, in order to avoid parallax, it must be inverted so that the two gelatine films are in contact. It is therefore cut off in order to obviate the effect of the unavoidable impurities in its gelatine film, through which otherwise the star spectrum would have to be observed. It can then be readily brought about that the lines of the one spectrum form the prolongation of those of the other.

The setting upon one of the threads of the system in the eyepiece of the microscope is effected solely by the motion of the above-mentioned sliding apparatus, to which both negatives are firmly attached. In the measurements four settings were usually made on a Sun line, then an equal number on the corresponding star line, those lines being sought out which, generally three on each side, lie nearest Hγ. The Hγ line in the star has only been measured when it was fully separated from the artificial line; but generally, instead of upon it, settings were made six or eight times on the solar Hγ, and an equal number on the artificial Hγ on the star plate.

The difference of the readings on the two spectra gives, in the mean, their displacement as compared with each other as they were brought together under the microscope; this mean, being applied to the difference of the settings on Hγ in the solar negative and the artificial Hγ due to the Geissler tube, gives the actual displacement of the star lines referred to the artificial line.

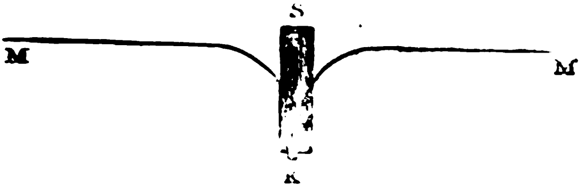
In most cases the star spectra have been photographed at other temperatures than the Sun, and the differences Sun — star are unequal and show a rate of progression. Under the assumption of a simple proportional change, which is fully admissible for the small distances which alone come into question, a reduction to the dispersion of the solar negative must first be made, which has been done by the method of least squares.

The great advantage of this method of measurement lies in the fact that the unavoidable distortions in the sensitive film, which, owing to the smallness of the quantities to be measured, might easily come into consideration, are as much as possible eliminated, and also, further, that every prejudice of the observer is entirely eliminated, since the amount of the displacement is not directly obtained, but only after computation.

Most stars of the first spectral class show, in addition to the broad and strongly marked hydrogen lines, a great number of other lines, so fine, however, that they can be distinctly recognized only in the case of the brighter stars. The majority of these lines belong to the iron spectrum, and can be readily identified with solar lines; the measurement of the displacement can therefore either be made by reference to the solar negative, or, under the precautions which I have already stated in the article quoted, the iron spectrum may be used for comparison.

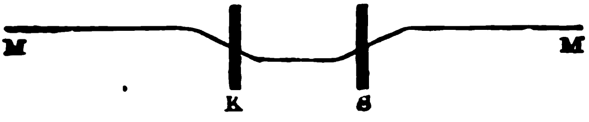
In the case of fainter stars of this class, however, one is restricted to the hydrogen lines, and if the more or less distinctly pronounced maximum of intensity lies outside of the artificial line, then the measurement presents no difficulty; but this is seldom the case, since the breadth of the maximum intensity corresponds to a difference in wave-length of about $0.03\mu\mu$, and a displacement of the artificial line only enough to bring its edge into coincidence with the position of maximum intensity would presuppose a velocity of fourteen miles. This maximum of intensity is generally not very sharply bounded, and, with this gradual decrease of the blackening on the negative, it could be accurately observed only in cases of a much greater displacement. The difficulties of this case were therefore insurmountable until a special procedure was thought out, which consisted in covering the Hγ star line, along with the artificial line, by a comparatively broad strip which was brought exactly over the middle of the Hγ line in the star. If, then, the thread of the micrometer be set on the middle of this strip, and the latter be then removed and the thread set on the artificial line, the difference in the readings will give the displacement.

The accompanying figure will make the procedure clearer. M M is the intensity curve of the star spectrum in the vicinity of Hγ, K is the artificial Hγ, displaced from the middle by the star's motion, and S is the strip covering the middle of the position of maximum intensity and the line K.



With a magnification such that the silver grains are readily perceptible, the setting of the strip over the middle of the broad Hγ line can, after some practice, be accurately accomplished by fastening the attention upon the density of the silver precipitate on the plate to right and left of the strip. From a series of small glass plates, upon each of which had been photographically produced a dark strip of differing width (from 0.05 to 0.20$^{\mathrm{mm}}$), the suitable one was chosen and laid directly upon the star negative, and fastened by a simple mechanical contrivance which allowed of its being moved backwards and forwards by a fine screw.

When the line in the star spectrum has been very broad and without a distinct position of maximum intensity, I have employed still another method in the measurement of stars with large velocities. A number of lines of varying breadth and blackness, but narrower than the strips just mentioned, were photographed upon small glass plates, and that one was then selected which most nearly equalled in breadth and blackness the artificial Hγ on the negative to be measured. The plate was then laid upon the star negative, and by the fine screw set upon the broad star line, so as to be symmetrical with the artificial Hγ. In the figure the star line is represented by the dipping of the curve MM, K is the line from the Geissler tube, to which is symmetrically set the line S on the glass plate. The micrometric measurement of the distance KS gives the double value of the displacement. By practice much can here be gained in accuracy;



attention to the silver grains is in this case also important. It has shown itself to be of advantage to repeat the measurements on different days, since very soon a certain habit of perception sets in which gives the measurements on a single day the appearance of an accuracy which is somewhat illusory.

The first result of any importance which the spectrographic method furnished was the proof of the influence of the Earth's motion on the displacement, which the earlier direct observations had failed to show with certainty. I append here a few examples:—

α Aurigæ.

Date.	Obs. Vel.	Earth's Vel.	Vel. of Star red. to Sun.
1888 Oct. 6	− 3.5	− 15.4	+ 11.9
22	+ 2.9	− 13.0	+ 15.9
24	+ 3.8	− 12.6	+ 16.4
25	+ 3.5	− 12.4	+ 15.9
28	+ 3.8	− 11.8	+ 15.6
Nov. 9	+ 9.2	− 8.9	+ 18.1
Dec. 1	+ 10.8	− 2.9	+ 13.7
13	+ 15.6	+ 0.7	+ 14.9
1889 Jan. 2	+ 20.2	+ 6.6	+ 13.6
Feb. 5	+ 30.8	+ 14.3	+ 16.5
May 6	+ 33.2	+ 17.0	+ 16.2
Sept. 15	− 3.6	− 16.8	+ 13.2

α Tauri.

Date.	Obs. Vel.	Earth's Vel.	Vel. of Star red. to Sun.
1888 Oct. 28	+ 18.1	− 9.5	+ 27.6
Nov. 10	+ 24.9	− 5.9	+ 30.8
Dec. 4	+ 30.6	+ 1.8	+ 28.8
1890 Jan. 9	+ 43.7	+ 12.3	+ 31.4
α Ophiuchi.			
1888 Sept. 30	+ 27.6	+ 14.1	+ 13.5
1889 June 7	+ 9.7	− 1.0	+ 10.7
α Ursæ Majoris.			
1888 Nov. 7	− 17.0	− 11.9	− 5.1
9	− 18.1	− 11.9	− 6.2
1889 May 4	+ 5.2	+ 11.8	− 6.6
22	+ 3.4	+ 11.2	− 7.8

A further result of the new method was the discovery of the changes in the motion of Algol, and thereby the proof of the existence of a dark satellite, for the determination of which the most delicate measurements were necessary. The discovery of the periodic motion of α Virginis then followed.

As an example of the accuracy of the method of symmetrical setting, which has been applied for stars with broad and ill-defined lines, and generally in the case of α Virginis, I give here the results of the measurements, with the period which I have deduced from them:—

α Virginis. Velocity in the line of sight — velocity of system

$$= 56.7 \sin\left(\frac{t-t_0}{p}\right)360°, \text{ in miles.}$$

Velocity of system $= -9.2$ miles. Period, p, $= 4.0134$ days.

Epoch, t_0, $=$ 1890 May 4, $10^h.50$ Potsdam M. T.

Date.	Obs. Vel. less Vel. of Translation	Calc. Vel.	O—C.
1889 April 21	− 48.4	− 53.5	+ 5.1
29	− 54.3	− 52.1	− 2.2
May 1	+ 50.7	+ 52.6	− 1.9
1890 April 4	− 6.5	− 12.4	+ 5.9
9	− 55.3	− 56.2	+ 0.9
1890 April 10	+ 6.0	+ 10.6	− 4.6
11	+ 50.7	+ 56.2	− 5.5
13	− 57.6	− 56.2	− 1.4
15	+ 62.7	+ 56.2	+ 6.5
May 1	+ 53.5	+ 56.7	− 3.2

Date.	Obs. Vel. less Vel. of Translation	Calc. Vel.	O.—C.
1890 May 4	− 3.7	− 1.8	− 1.9
7	− 61.3	− 56.7	− 4.6
8	− 0.5	− 1.4	+ 0.9
9	+ 63.2	+ 56.7	+ 6.5
17	+ 61.8	+ 56.7	+ 5.1
18	+ 6.0	+ 5.5	+ 0.5
23	− 65.5	− 56.2	− 9.3
24	− 1.4	− 5.5	+ 4.1
25	+ 53.0	+ 56.2	− 3.2
May 26	+ 5.1	+ 5.5	− 0.4
27	− 52.6	− 56.2	+ 3.6
28	− 12.9	− 8.8	− 4.1
31	− 56.2	− 56.2	0.0
June 4	− 49.8	− 55.8	+ 6.0
1891 April 24	+ 3.2	+ 4.6	− 1.4
27	+ 47.9	+ 45.2	+ 2.7
May 3	− 58.1	− 63.2	+ 5.1

As an example of the delicacy of the spectrographic negatives, I remark that in those of β Aurigæ not only has the periodic doubling of the lines been perceptible and well measurable in the magnesium line $\lambda = 448\mu\mu$, but also on some plates in other very fine lines in its vicinity. These observations may be found in *Ast. Nach.*, No. 3017.

In order now to give an illustration of the accuracy which is attainable by the method of covering Hγ by a strip, I add my observations on α Lyræ and α Canis Majoris:—

α Lyræ.

	Obs. Vel.	Earth's Vel.	Star's Vel. red. to Sun.
1888 Sept. 28	− 2.6	+ 8.6	− 11.2
Nov. 11	− 1.7	+ 7.0	− 8.7
13	− 1.5	+ 6.8	− 8.3
1889 May 31	− 10.7	− 4.8	− 5.9
June 6	− 9.9	− 4.0	− 5.9
Sept. 15	− 1.8	+ 8.1	− 9.9
Nov. 24	− 4.2	+ 5.7	− 9.9
25	− 6.7	+ 5.6	− 12.3
26	− 7.2	+ 5.4	− 12.6

α Canis Majoris.

	Obs. Vel.	Earth's Vel.	Star's Vel. red. to Sun
1888 Dec. 13	− 14.1	− 4.9	− 9.2
1890 Feb. 12	+ 0.8	+ 9.4	− 8.6
1891 Feb. 7	+ 0.1	+ 8.3	− 8.2
Mar. 21	+ 4.4	+ 13.8	− 9.4
22	+ 6.1	+ 13.9	− 7.8

I remark, further, that the observations of Sirius by the method for stars of the second class give 7.3 miles, and with the aid of the iron comparison spectrum 9.0 miles as the rate of approach towards the Sun.

In regard to the exactness of the measurements in general I will state that out of the average of all the observations the resulting probable error of a single negative for stars of Class II. is ± 1.34 mile; for the stars of Class I. ± 2.31.

Each star has on the average been observed 3.3 times, and the measurements have been made independently by myself and by Dr. Scheiner. It may, therefore, be concluded that the probable error of the definitive values for both spectral classes will amount to less than one mile.

I intend after the definite completion of the measurements to communicate to the Society a list of the observed velocities, and will remark in conclusion that the velocities of the stars have proved to be much smaller than was to be expected from the direct observations. The mean result for forty-seven stars is 10.6 English miles.

Among them six have a velocity less than 2, and five greater than 20 miles; the greatest is that of α Tauri, about 30 miles. Fifteen of the stars have a positive and thirty-two a negative motion.

POTSDAM, ROYAL OBSERVATORY,
1891 December.

NOTE ON THE STONYHURST DRAWINGS OF THE SOLAR SPOTS AND FACULÆ.*

REV. WALTER SIDGREAVES.

At the commencement of the series of Sun-spot drawings, instituted by the late Fr. Perry in November 1880, it was decided to fill in the faculæ, so far as this could be done with certainty. No small difficulty was experienced in the attempt, for it seemed impossible to produce a faithful representation of them, and both the director and the observer were forced to be content with a skeleton tracing of the brighter parts which could be differentiated from the rest of the photosphere without chance of error. Experience, however, in the course of time, taught the observer the magic effect of motion imparted to a faint image; and as he slowly travelled the image of the Sun across the drawing-sheet, the patches stood out with a clearness of definition that excluded all doubt of the border-line between faculæ and photospheric glare. The method then adopted, and followed ever since, was first to outline the brighter parts upon the stationary image, and then to fill in the picture by sketching the fainter details taken from the image while moving it slowly to and fro across the paper. By this means a very trustworthy record was obtained; and it was much improved by adopting the suggestion, made by Sir G. Stokes in 1883, that the contrast of a red-lead tracing of the faculæ would greatly help the eye in its search through the drawings for the true relation between the dark spots and their glowing attendants. This is apparent in following the disturbances through all their changes, and in sifting their evidences for an answer to the query, Which is the forerunner of the other?

During the entire period of Fr. Perry's direction of this

---

* Monthly Notices, December, 1891.

Observatory no clear instance of faculæ preceding the birth of a spot had been detected in the drawings. Faculæ were always most abundant after the birth of a spot, and always outlived it, lingering for weeks and sometimes for months before expiring. But, on the other hand, the drawings afford no positive evidence of the birth of a spot before the appearance of faculæ; while every spot of importance appears to have been attended from the beginning with at least a small surrounding of faculæ. So that, although it remains true that faculæ in no extensive form precede the birth of a spot, but develop and grow to maturity either along with the spot or after its decline, we must guard our conclusions against their extension to the absolute priority of the spot.

The chances of gaining the positive evidence about the priority are not favorable. The greater part of the Sun's surface, on which a spot may spring into life, offers no possibility of seeing the faculæ. And during the years of greater activity our chances are greatly reduced by the interlacing of old and new faculæ. It is only during the minimum period of spot-life, when the intervals are greater and old *debris* get cleared away before new storms begin, that we can well hope for the evidence we want.

The drawings of the recent minimum period of 1889 have been under careful study during the past twelve months, and we find amongst them two cases in which the evidence of first appearance is unquestionable. And both of these show faculæ before any trace of a spot appears.

On June 29, a small patch of faculæ was sketched near the eastern limb, in latitude — 40°.5 and in longitude 252°. There was no trace of a spot in the neighborhood, and neither spot nor faculæ had been seen near the position for years. On the following day a small round spot appeared in latitude — 40°.3 and longitude 252°.2—*i. e.*, in the midst of the faculæ, the faculæ on this day being visible only just close round the spot. Again, on July 31, another small patch of faculæ appeared in latitude — 22°, longitude 155°, without any spot near it. It was seen again on the following day, and still without a spot. But on the third day, August 2, a spot was sketched in latitude — 21°.9, longitude 155°.4.

In both cases the faculæ were of small area, but bright. And there can be no doubt either of the faculæ or of the spots. Both were new. The faculæ were not remnants, and the spots were not revivals of old disturbances. We may not be able yet to conclude that faculæ are really forerunners of spots. The two spots referred to may have been for the time hidden from our view by the faculæ. But this has no appearance of probability, the faculæ being seen at a distance from the limb of quite one-tenth of the solar diameter. So far, therefore, as our drawings at these dates are witnesses to priority, their evidence stands for some faculæ preceding the birth of a spot. And more of the same class of evidence may be found even in the years of greater spot frequency, when the records of their spots and faculæ have been more fully examined and the history of each group is more accurately written.

STONYHURST OBSERVATORY,
Lancashire.

RESUME OF SOLAR OBSERVATIONS MADE AT THE ROYAL OBSERVATORY OF THE ROMAN COLLEGE DURING THE FOURTH QUARTER OF 1891.*

M. P. TACCHINI, DIRECTOR.

	RELATIVE FREQUENCY		RELATIVE SIZE		
No. of days.	of spots.	of days without spots.	of spots.	of faculæ.	No. of groups per day.
October......26	15.54	0.00	54.69	85.77	4.96
November...22	12.50	0.00	61.38	51.50	3.41
December....28	8.57	0.00	42.18	35.36	2.68

By comparing these data with the results of the preceding quarter, it is seen that the phenomena of solar spots and faculæ have decreased somewhat during the last quarter of the year. It must be remarked, however, that in the new series of observations there is not a single day without spots, and that the frequency of the groups is the same as for the preceding quarter; it may thus be concluded that we are now in a maximum spot period.

The season has been less favorable for prominences, especially in November. The following are the results obtained:

			PROMINENCES.	
	No. of days.	Mean number.	Mean height.	Mean extent.
October..........................	22	9.82	43″.6	1°.7
November.......................	15	5.73	35 .4	1 .6
December.......................	21	6.48	40 .2	2 .2

The marked frequency in the month of September continued into October; since then the number of prominences has somewhat diminished, so that for this quarter the phenomena of solar prominences may be considered as stationary relatively to the preceding quarter.

---

* Communicated by the author.

ON THE INFLUENCE OF PRESSURE ON THE SPECTRA OF FLAMES.*

G. D. LIVEING AND J. DEWAR.

We have already described (*Phil. Trans.*, A, 1888) the remarkable spectrum of the oxy-hydrogen flame burning at the ordinary atmospheric pressure. Recently we have examined the spectrum of the same flame at various pressures: hydrogen burning in excess of oxygen up to a pressure of 40 atmospheres, and oxygen in excess of hydrogen up to a pressure of 25 atmospheres, also that of the mixed gases burning in carbonic acid gas.

The apparatus employed was an adaptation of one of the tubes used in our experiments on the absorption spectra of compressed gases (*Phil. Mag.*, September, 1888, and *Roy. Soc. Proc.*, vol. 46, p. 222). It consisted of a steel cylinder, about 50^{mm} in internal diameter and 225^{mm} long, fitted at one end with a quartz stopper, *a* in the annexed figure, and with a jet, *b*, for burning the gas, adapted by a properly fitting union joint to the opposite end. There were two tubes, *c* and *d*, connected to the cylinder at the sides, of which one, *c*, served for the introduction of gas, while the other, *d*, was fitted with a stopcock, and was used to draw off the water formed, or to reduce the pressure of the gas in the cylinder if that was desired. The flame was observed, nearly end on, through the quartz stopper. The whole apparatus was kept cool by a stream of cold water running on to a sponge cloth wrapped around the cylinder. In the course of the tube conveying gas to the jet *b* was interposed a small cylinder, *e*, in which sodium was placed, and by heating this the gas entering could be charged with sodium vapor.

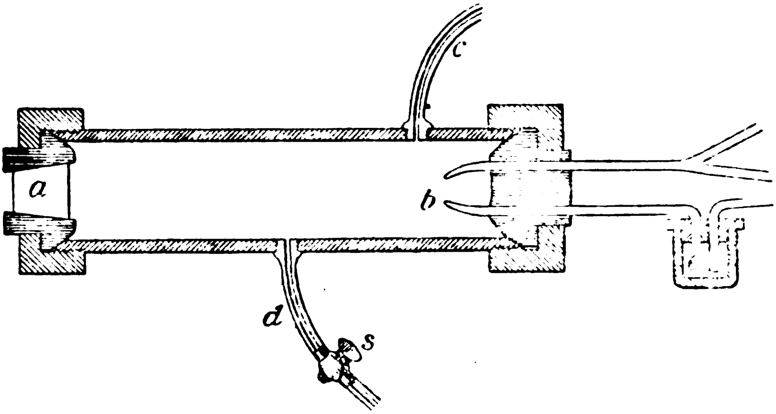
The gases were supplied from steel cylinders into which they had been compressed, and the pressure was registered by a gauge attached to the tube by which the gas entered the experimental cylinder. Commercial compressed gases were used, containing a sensible percentage of air.

When hydrogen was the gas forming the burning jet, it was lighted at the end of the tube *b* before introducing it into the experimental cylinder. When it was desired to have a jet of oxygen burning in hydrogen, this could be managed by introducing oxygen through the second tube and increasing the supply of hydrogen until the flame passed over to the oxygen jet. The same result was sometimes attained by first filling the experi-

---

* Proceedings Royal Society, No. 298

mental cylinder by a gentle stream of hydrogen through the side tube *c* before the end with the tube *b* was screwed on; the hydrogen as it issued was then lighted, and the jet, with a gentle stream of oxygen issuing, inserted and screwed down. The stopcock *s* was kept open until this was done, and then by closing *s*, and admitting more gas from the reservoirs, the pressure in the experimental cylinder could be increased at pleasure.



Hydrogen Burning in Oxygen.

The first observations were made with a jet of hydrogen burning in oxygen. As the pressure rose, the luminosity of the flame increased, as long ago described by Frankland ('Experimental Researches,' p. 905). The color of the flame, viewed end on, was yellow, as if it contained sodium; but, on examining it with a spectroscope, it was found to give a continuous spectrum intersected by many shaded bands, and the D lines of sodium were only faintly present. The shaded bands were faint at a pressure of 5 atmospheres, but at pressures of 20 atmospheres and upwards they came out strongly. They were evidently the absorption bands of NO_2, derived from the residue of atmospheric air mixed with the condensed gases. We took a photograph of them, and on comparing this with a photograph of the NO_2 bands, we found the two to be identical. Except for the bands, and the bright lines of sodium, the spectrum appeared to be continuous, and to extend from about λ 6200 to λ 4150, with the brightest part about λ 5150. It increased in brilliance as the pressure increased, as well as in extent, being visible at 3 atmospheres pressure from about λ 6720 to λ 4040. The greater distinctness of the NO_2 bands at the higher pressures was due both to the greater brightness of the continuous spectrum and to the greater quantity of NO_2 formed. A large quantity of water accumulated in the experimental tube, and when this was drawn off by the stop-cock *s* it effervesced with escape of NO, and was found to be strongly acid. A specimen titrated was found to contain very nearly 3 per cent of nitric acid. The observations were continued up to a pressure of forty atmospheres. There was no indication that the continuous spectrum had any connection with the line spectrum of hydrogen. There was no increase of brilliance in the neighborhood of the C, F, or G lines of hydrogen. The characters of the spectrum were, however, better seen in the absence of NO_2, and will be described in the next section.

Oxygen Burning in Hydrogen.

In this case the color of the flame was very different from that of hydrogen burning in oxygen. Instead of being yellow, it appeared, to the unaided eye, to have a lavender hue. In the spectroscope it showed a perfectly continuous spectrum, brightest in the green, about the region of the Fraunhofer line *b*, and very gradually fading away on either side. On the red side it could be just traced up to about λ 6150, and on the violet side to about λ 4285, at ordinary pressures. The sodium lines were absent. With increase of pressure it increased very much in brightness, and at 8 atmospheres pressure it could be traced as low as λ 6630 and as high as λ 3990.

The dispersion used was that of a direct-vison spectroscope (such as was described by us, *Roy. Soc. Proc.*, vol. 41, p. 449), equivalent to three prisms of white flint glass, but the collimator and telescope very short, so as to obtain plenty of light. With less dispersion, perhaps, the continuous spectrum might have been traced further. Photographs, however, showed that it scarcely extended into the ultra-violet. There was no indication that this spectrum was due to an expansion of the lines of either the first, or second, spectrum of hydrogen. It is true that the maximum brightness (which could not be determined with any great accuracy) was not very far from F, but no indication of any second maximum in the neighborhood of either C or G, or anywhere else, could be detected. The pressure was carried up to 12 atmospheres, and at this pressure the visible spectrum was brilliant, but, in the ultra-violet, photographs showed that the spectrum consisted only of what we have called the "water-spectrum," very strong and sharp. The lines of this spectrum showed no signs of expansion even at a pressure of 12 atmospheres, and, though much more intense than at ordinary pressures, remained clearly defined

Observations were continued with the eye up to 25 atmospheres pressure, but no trace of emission, or absorption, corresponding to either spectrum of hydrogen could be detected, and it is doubtful if either spectrum can be produced in such a flame. Since the formation of steam from its component gases is attended with a diminution of volume, increased pressure will increase the stability of the compound, and the flame will contain a larger proportion of steam, as well as have a higher temperature, than at ordinary pressures.

The water formed when the flame was a jet of oxygen burning in hydrogen was found to be alkaline, and to contain ammonia. But the proportion of ammonia was much less than the proportion of nitric acid formed when the jet was hydrogen burning in oxygen; a specimen titrated contained 0.004 per cent of ammonia.

Effects of Pressure on the Sodium Spectrum.

In order to see what effect would be produced by increased pressure on the spectrum of other substances in the flame, we charged the hydrogen with sodium vapor by making it pass, before entering the experimental cylinder, through a small iron cylinder, *e* in the figure, containing metallic sodium, heated by a lamp. As the D lines of sodium are very easily expanded and self-reversed in a flame at ordinary pressure, some care was needed to discriminate the effects, which were really to be ascribed to pressure. The gas was easily charged with sodium vapor, and when burning in oxygen, not only the D lines, but the citron and green pairs, and sometimes the blue pair (λ 467), and the orange pair (λ 616), were well seen; but we could not find that they were expanded by increase of pressure. A sudden change of pressure generally produced an expansion, but it did not last; the lines fined down again when the pressure was steady, whether that pressure was high or low. These experi-continued up to a pressure of forty atmospheres without any definite effect on the width of the lines which could be ascribed to the pressure.

It may be said that at the higher pressure the evaporation of the sodium would be slower, and so the proportion of sodium vapor to hydrogen be diminished; also when the lines are diffuse at the edges to begin with, it is extremely difficult to judge whether there is any expansion. At all events, we may say that there is no expansion produced by pressure at all comparable with that produced in a flame at ordinary pressure by increasing the quantity of sodium in the flame. We noticed, however, that the presence of sodium, which produces a feeble continuous spectrum in a flame at an ordinary pressure, seemed to increase the continuous spectrum of the flame under pressure, especially in the orange and green.

Oxy-Hydrogen Jet in Carbonic Acid Gas.

For this experiment a two-branched tube (the upper one in the figure) was used. The jet of mixed oxygen and hydrogen was first lighted and introduced into the experimental cylinder, while the latter was full of air and the stop-cock *s* open. The air was then replaced by CO_2 entering by the tube *c*. The effect of this was at once to brighten the flame and change its color from yellow to blue. Seen in the spectroscope, the change consisted in an increase of continuous spectrum, especially towards the more refrangible end. When the stop-cock, s, was closed so that the pressure rose in the experimental cylinder, the flame increased in brightness, but there was no other change in the spectrum. It remained continuous with no bright or dark lines, or bands, except the D lines of sodium. It resembled an ordinary flame of CO. The jet would not burn in CO_2 unless there was some excess of oxygen, and even with an excess of oxygen we could not get it to continue to burn in CO_2 at a pressure higher than two atmospheres.

Ethylene in Oxygen.

A jet of ethylene burning in oxygen gave, when the flame was small, the usual candle flame spectrum, together with a band in the indigo (λ 431) shading towards the violet; but as the pressure was increased the continuous spectrum brightened and completely overpowered the bands, and at the same time the absorption spectrum of NO_2 appeared. We carried the pressure up to 33 atmospheres, and at that pressure the flame seemed to give nothing but a continuous spectrum, intersected by the absorption bands of NO_2. In our tube, the flame was viewed almost directly end on, and it is possible that if we had seen the flame sideways, we might have detected the hydro-carbon flame spectrum near the nozzle. At the high pressure much soot separated. We tried burning a mixture of ethylene and oxygen. The mixed jet burnt well in air and, when the supply of oxygen was sufficient, gave the hydro-carbon flame spectrum. In the experimental tube in oxygen the jet burnt well at the atmospheric pressure, but we failed to get it to continue burning when the pressure was increased. The shaded band, commencing with a sharply defined edge about λ 431, seems to be independent of the pressure, and has been before observed in a gas flame (Huggins, *Roy. Soc. Proc.*, vol. 30, p. 580). In fact the only effect of pressure in this, as in the former cases, seemed to be the increase of the continuous spectrum.

Cyanogen and Oxygen.

As we could not obtain cyanogen at such pressure as we had used in the case of the other gases, we were obliged to content ourselves with exploding mixtures of cyanogen and oxygen in an iron bottle, fitted with a quartz stopper like that of the experimental tube above described. The bottle, having been exhausted by an air pump, was filled with the mixture of gases, and exploded by an electric spark. With less than 3 vols. of oxygen to 1 vol. of cyanogen, there was always a considerable deposit of carbon, which covered the quartz and impeded vision; but with 3 vols. of oxygen to 1 of cyanogen the carbon was all burnt. Notwithstanding the brilliant banded spectrum of a flame of cyanogen in oxygen at ordinary pressure, nothing but a continuous spectrum could be seen in the flash of the exploded gases, except the ubiquitous D lines of sodium. The continuous spectrum was bright. Photographs showed a continuous spectrum with lines of iron, calcium, potassium, and sodium, but no cyanogen or carbon bands, or carbon lines. When a little hydrogen was added to the mixture of gases, no trace of the hydrogen red or green line could be detected in the spectrum of the exploding gas.

In every case, the prominent feature of the light emitted by flames at high pressure appears to be a strong continuous spectrum. There is not the slightest indication that this continuous spectrum is produced by the widening of the lines, or obliteration of the inequalities, of the discontinuous spectra produced by the same gases at lower pressures. On the contrary, it seems to be developed independently. This is, on the whole, quite in accordance with what would be expected, considering that under pressure the molecules of the gases have much less freedom, encounters amongst them are much more frequent, and they have much less chance of vibrating independently, and of taking up exclusively, or chiefly, the fundamental rates of vibration which are natural to them when free. Their condition, during a large part of any given time, approximates to that of the molecules of a liquid, and their spectra approximate to that of a liquid to at least a like extent. On the other hand, the higher temperature which, in many flames, attends an increased pressure, ought to give some intensity to the special radiation which the molecules emit during their time of free motion; and this we have noticed to occur in the principal sections of the discontinuous spectrum of the oxy-hydrogen flame. Whether the continuous spectrum is due to the mutual action of the molecules of the compressed gases may perhaps be best determined by some photometric measures of the rate at which the brilliance increases with the pressure. Frankland (‘*Exp. Researches,*’ pp. 892 *et seq.*) has made some such measures, but not sufficient to solve the question. We have made an attempt to measure, not the total intensity of the light, but that of rays of definite refrangibility.

Photometry of Oxy-Hydrogen Flame under Pressure.

The apparatus used for these measures was a spectro-photometer of the pattern employed by Crova (*Annales de Chimie,* ser. 5, vol. 29, p. 556). In this, the rays of one of the sources of light to be compared are passed through two Nicol's prisms, and then reflected into one-half of the slit of the spectroscope, while the light from the other source passes directly into the other half of the slit. By turning one of the Nicol prisms, the light from the first source can be reduced at pleasure, and any small section of the spectrum can be separately observed by cutting off the rest by means of a shutter in the eye-piece. We found it by no means easy to get good concordant observations. A much larger vessel was used than for the earlier experiments, one which contained several litres, and so we may presume a more uniform pressure was maintained within it. The results of the best series of observations on the photometric intensity of the jet of oxygen burning in hydrogen are given in the following table. The comparison light was a petroleum lamp.

1.	2.	3.	4.
15 lbs.	3°	274	$30 \times 3^2 = 270$
35	7	1485	$30 \times 7^2 = 1470$
55	11	3641	$30 \times 11^2 = 3630$
75	14	5853	$26 \times 15^2 = 5850$
95	19	10600	$29 \times 19^2 = 10469$

The first column gives the pressure of the gas, the second the mean of four to six observations of the angular deviation of the Nicol's prisms from the position of complete extinction, for each pressure. The third column gives the squares of the sines of the angles in the second column multiplied by 100,000.

It will be seen from the last column that the numbers in the third column, which should be proportional to the photometric intensities at the respective pressures, are approximately proportional to the squares of the pressures.

This may be taken to indicate that the brightness of the continuous spectrum depends mainly on the mutual action of the molecules of gas.

A series of similar observations on hydrogen burning in oxygen gave somewhat different results, tabulated below:

1.	2.	3.
15 lbs.	6°	1093
35	13	5060
55	18	9549
75	22	14033
95	28	17861

The flame was brighter than that of oxygen burning in hydrogen at ordinary pressure, but the rate of increase with increased pressure was not so rapid as in the former case. It seems as if the continuous spectrum were made up of two parts, one varying as the square of the pressure, and another according to some other law. The flame is evidently not the same in the two cases. The products of combustion derived from the small quantity of air are different, and also the hydrogen jet always showed the presence of sodium, sometimes calcium. The appearance of the flame was also different; the hydrogen jet being faintly visible and yellowish in the elongated part, whereas the light from the oxygen jet was concentrated near the base, the point being invisible. The measures of which the means are tabulated above were also less concordant than the corresponding measures for the oxygen jet. We were unable to carry our measures beyond a pressure of 95 pounds, because at higher pressures a cloud was formed in the apparatus which prevented our seeing the flame directly. We hope to prosecute these measures with flames of other gases, and, if possible, at higher pressures.

The conclusions to which our experiments have led seem inconsistent with those which have been drawn from Plücker and Hittorf's well-known observations on the widening of the hydrogen lines in vacuous tubes with a residue of hydrogen when that residue increases. That the widening of the lines in a Plücker's tube results from increasing the density of the residue of hydrogen in the tube cannot be gainsaid, but we are wholly ignorant of the mechanism by which the gas is lighted up by the electric discharge. It is sometimes assumed, but without any sufficient reason, that the energy of the electric current is first converted into heat, and then in turn into radiation; but the electric energy may equally well be directly converted into the motion of radiation. As a fact, we have never yet been able to obtain either the emission or the absorption spectrum of hydrogen without the aid of an electric current, so that, in reasoning on this spectrum, we are much more in a region of speculation than when treating of flames. Whether the hydrogen lines, bright or dark, in the solar spectrum are produced directly by the high temperature of the Sun, may even be called in question. And though we may admit that the density of the hydrogen in the Sun's atmosphere, outside the photosphere, is but slight, it does not follow that the total pressure of all the gases forming that atmosphere is so very small as Messrs. Franklin and Lockyer ('*Roy. Soc. Proc.*,' vol. 17, p. 288) have, from the width of the lines, concluded it to be. After all, it is not so easy to connect the temperature, even of a flame, with its radiation, for it is only when the condition of a gas is steady that we can assume that there is a definite relation between the motion of agitation, on which temperature depends, and the vibratory motions on which radiation depends. In speculating on such questions, chemical, as well as electrical, changes must not be lost sight of although the latter may be more directly concerned in radiation.

Experiments which we have commenced upon the arc in an atmosphere of compressed gas tend to the same conclusion. It does not appear that the metallic lines in the arc are sensibly affected by a steady pressure up to 15 atmospheres. The details of these observations, which are complicated by the variation of resistance with change of pressure, we defer until the experiments are finished.

ON THE PHYSICAL CHARACTERS OF THE LINES IN THE SPARK SPECTRA OF THE ELEMENTS.*

PROFESSOR W. N. HARTLEY, F. R. S.

The properties of the atoms are a periodic function of their masses, and the physical characteristics of the spectra of the elements appear to be an expression of the properties of the atoms; for there is undoubtedly an intimate connection between the rays emitted by the self-luminous vapors of the elements and their chemical and physical properties.

If we photograph the spark spectra of thirty or forty of the elements and arrange the spectra in groups following the periodic law, the arrangement will be seen to be a perfectly nat-

---

* Proceedings Royal Society, No. 300.

ural one. This observation applies not only to the groupings of the lines, but also to the physical characteristics of the individual lines. In spark spectra the three most striking characteristics are (1) an extension of certain lines above and below that part of the spectrum bounded by the points of the two electrodes; (2) the nimbus which surrounds the extremities of the lines, even to some extent those portions which form an extension; and (3) the continuous spectrum which forms the background to the lines.

(1.) *On the Extension of the Lines.*—The spark discharge, as shown by Perrot, is composed of two parts, of which the fiery track, or central portion, is a statical discharge, and the aureole, or flame, is dynamical, and capable of electrolytic action.

From careful observation of the sparks, and photographs of spectra, I have come to regard all those spectra with lines extended as spectra of different discharges taken simultaneously. The principal lines lying between point and point of the electrodes are spectra of the fiery path of the spark; the extension of the principal lines above and below the points of the electrode appear to be spectra of the aureole. The principal observation which leads to this conclusion is that the electrodes are seen to glow silently and continuously above and below the points of the upper and lower electrodes, and frequently slight roughnesses present the appearance of brightly but steadily shining dots; particularly is this the case with those metals which exhibit the most extended lines, as, for instance, cadmium, thallium, and indium. The lines in many spectra are free from this extension, and no glow is observed on the electrodes. A study of about thirty different spectra of the metals and semi-metallic substances has led to the following observation.

Elements which are difficult to volatilise, and those which are bad conductors of electricity, do not exhibit spectra with extended lines; and, conversely, metals which are the best conductors and the most volatile exhibit spectra with their principal lines largely extended.

The following metals are good conductors, that is to say, sufficiently good not to impede the spark when broad electrodes are used, and they are more or less volatile. They show a large extension of their principal lines:

	Boiling point.	Atomic mass.		Volatility.	Atomic mass.
Magnesium	1100° C.	24.4	Aluminium	Not volatilised by ordinary means.	27.08
Zinc	924° to 954° C.	65.3	Indium	Volatilised at a red heat.	113.7
Cadmium	763° to 722° C.	112.1	Thallium	Easily Volatilised at a red heat.	204.2

		Atomic mass.
Copper	Not volatilised by ordinary means	63.33
Silver	Boils about 1570° C.	107.93
Mercury	Boils about 357° C.	200.1

In these examples the extension of lines is least in the case of the least volatile metals, which are also those of least atomic mass, and it is greatest with those which are most volatile and of greatest atomic mass.

The continuous spectrum in these examples is very weak, and the air lines are almost absent from the thallium and mercury spectra, the air spectra being suppressed by the excess of dense vapor in the track of the spark. The lines most extended are the following: In the cadmium spectrum, those with wave-lengths $\overbrace{3611.8, 3609.6}$ (*a pair*), $\overbrace{3466.8, 3465.4}$ (*a pair*). These pairs appear as single lines if the dispersion is insufficient and the definition imperfect.

The most refrangible line of each pair is the more extended. The other lines in this spectrum are 3402.9, 2747.7, 2572.2, 2313.6, and 2265.9, all with fine extensions. In the spectrum of thallium, wave-lengths 3775.6, 3528.8, 3518.6, and 2917.7.

In the spectrum of mercury, the lines with wave-lengths 4358, 4046.5, and 3984 are well extended, but the most important extensions in this spectrum are the lines with wave-lengths 3662.9, 3654.4, 3632.9; the last of these, which form a well-marked triplet, is by far the most extended. The pair of lines 3130.4 and 3124.5 are greatly extended, and the same remark applies to 2966.4 and 2946.6.

The dimensions of the principal lines in the cadmium, thallium, and mercury spectra were measured on my enlargements. The principal portion of the lines lying between point and point of the electrode was 42 mm. in all spectra. The extension of the lines *below* was 22 mm. to 25 mm., extension *above*, 9 mm. to 10 mm. As the extension is always sharp and well-defined, it is an important feature in these spectra. Even concentrated solutions of the metals, when photographed with graphite electrodes, exhibit this extension in their principal lines. For instance a solution of beryllium chloride shows a very remarkable extension above and below the points of the upper and lower electrodes; the dimensions of the principal line, wave-length 3130.2, are as follows: between the points, 42 mm., *below*, 10.5 mm.; *above*, 17.5 mm. It is at the upper or positive electrode that the longest extension is observed, but at the lower or negative electrode that it is strongest. In the case of the cadmium lines, the extension is smaller, but strong at the side of the negative electrode, and very fine and long at that of the positive.[*] The appearance of lines due to impurities or traces of metals in the spectrum of the negative electrode only, I have attributed to the oscillation of the spark discharge, and the fact that the negative electrode is the hotter.[†]

(2.) *The Nimbus.*—The nimbus is not apparently dependent on the volatility or the oxidisability of the vapor of the elements, though these properties are connected therewith.

By far the largest nimbus is that of magnesium; those of cadmium and mercury stand next in order; the smallest are those of platinum, gold, copper, and silver. It is thus evident that neither conductivity nor vapor density controls it, for there is very little nimbus on the lines of the thallium and iridium spectra; but volatility certainly increases it. There is a considerable nimbus on some of the lines in the spectra of arsenic, antimony, and bismuth; also on a few lines of tin and of lead. In the case of magnesium, the cause of the dense and large nimbus is probably the intensity of the chemical action of which the rays of the incandescent vapor are capable, together with the large quantity of metal in the track of the spark, owing to its volatility.

The chemical activity of the zinc rays is less than that of the rays of magnesium, but the effect of this is overbalanced by the density of the vapor and the volatility of the metal being both greater; accordingly the lines of zinc have a large nimbus. The nimbus is somewhat larger on the lines of cadmium than on those of zinc, the volatility and the density of the vapor are both greater.

The nimbus is evidently an expression of the quantity of matter in the spark, and the intensity of the chemical action which the rays emitted by its ignited vapor are capable of exerting.

---

[*] In a paper published in the 'Scientific Proceedings of the Royal Dublin Society,' on the constitution of electric sparks, this does not appear in the lithographed illustration, but I have carefully verified the fact by referring to the original photographs.

[†] *Loc. cit.*, p. 373.

(3.) *On the Continuous Spectrum which forms the Background to the Lines of certain Spectra.*—This must be caused by the ignition either of some solid substance or of a vapor which is not that of an element but an oxide. An examination of the spectra in which the continuous background of rays is a conspicuous feature discloses the fact that the metals which are not oxidisable do not possess it, for instance, gold, silver, and platinum. Metals of the iron group show it near the points of the electrodes when the non-volatile oxides are formed. The very volatile metals with volatile oxides, such as mercury, iridium, thallium, zinc, and cadmium, do not show it.

Spectra of the metalloids, such as tellurium, arsenic, antimony, and bismuth, which are not only volatile but which form volatile oxides, show it very strongly. Ordinarily, magnesium does not show it, because the exposure necessary for photographing the spectrum of that element is less by one-half the period of the others, and by one-quarter that of tellurium. When a plate is long exposed to the rays of magnesium, the continuous spectrum appears at the points of the electrodes where the non-volatile oxide would be formed. It may be considered that in the passage of the spark, the vapor of the element fills the track, and this vapor, on cooling, forms, for a minute period of time, an incandescent oxide, and, the spectrum of this being a continuous spectrum, its photograph appears as a background to the rays emitted by the element.

But it is nevertheless the fact that the continuous background is a very characteristic feature of the metalloids, though why the vapors of these oxides should produce this action more conspicuously than those of the oxides of the volatile metals, there seems to be no sufficient or well-understood reason to be advanced at present. It may be that the vapors of the metalloids in cooling emit a continuous spectrum for a short period prior to oxidation.

On the Breadth of Lines.—It is well known that under identical conditions, the principal lines in the spectrum of an element become stronger and broader as the rays forming the spectrum proceed from a larger quantity of material, that is to say, form a denser radiating layer. It is evident, then, that in any series of three or more elements of similar character, the intensity and the breadth of the lines in their spectra will depend upon (1) intensity of chemical energy, (2) volatility and vapor density, and (3) electric conductivity of the metal. In accordance with these conditions, the lines of cadmium are broader than those of zinc, and the lines of zinc broader than those of magnesium.

THE NEW STAR IN AURIGA.*

EDWARD C. PICKERING.

The photographs of the Henry Draper Memorial afford a means of studying the past condition of the portion of the sky in which the new star in Auriga has recently been discovered. Eighteen photographs of this region were taken with the 8-inch photographic telescopes from November 3, 1885 to November 2, 1891.

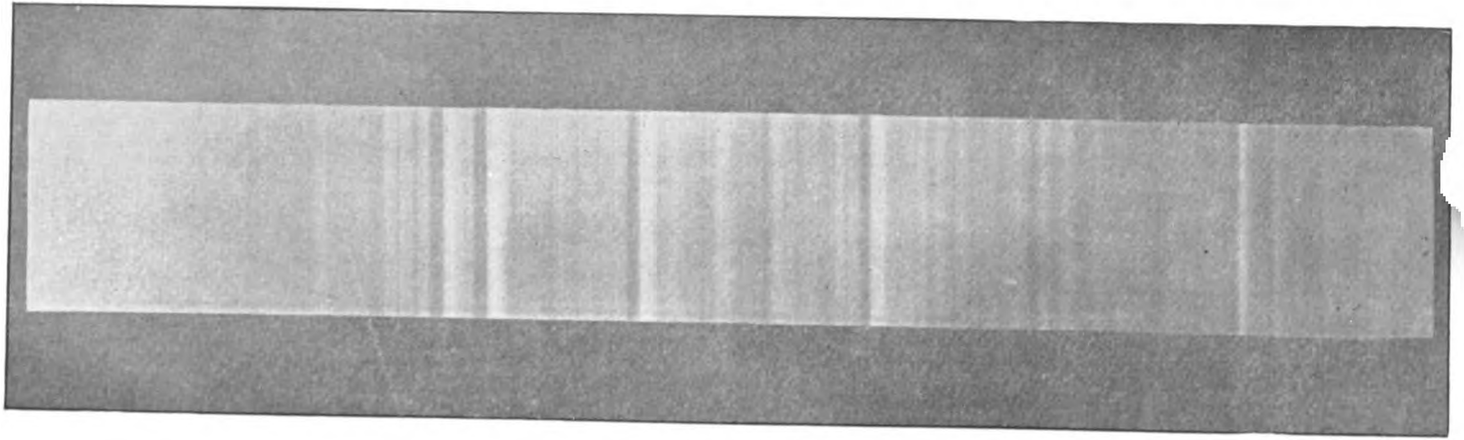
On none of them was the star visible, although on all but five, stars of the eleventh magnitude were shown, and on some of them stars of the thirteenth magnitude were visible. On the plate taken November 2 spectra of stars of the eleventh magnitude were shown. It is probable that the star was not visible during these six years. Five plates, on the other hand, taken from December 16, 1891, to January 31, 1892, show stars of the twelfth magnitude and the Nova appears as a bright star of the fifth magnitude. A still closer watch of the sky has been kept for the past year with an instrument intended to furnish the scale of stellar magnitudes of the brighter stars to which the stars photographed with the Bruce 24-inch photographic telescope will be referred. This instrument is called the transit photometer. It consists of a telescope having a Voightländer doublet of five inches aperture as an objective mounted like a transit instrument and driven automatically by clockwork in such a way that a region extending from 30° below the north pole to 30° in declination and in right ascension over three hours will be photographed on one plate.

The exposure given to each portion of this region is two seconds, and in this time stars of the sixth magnitude and brighter are distinctly shown. Plates were thus obtained on thirteen nights from October 21 to December 1, 1891. On none of these was the star visible, although χ Aurigæ, magnitude 5.00, was always clearly shown. On twelve nights beginning December 10, 1891, and ending on January 20, 1892, similar plates were obtained, on all of which the new star was clearly seen. Measurements of these images were made by Mrs. M. Fleming who also made the examination of the photographs described above. The Nova was compared directly with χ Aurigæ, and the difference in brightness estimated in grades as in Argelander's method of observing variable stars.

---

[*] Communicated by the author.

PLATE IX.



The Spectrum of Nova Aurigæ. Photographed at Harvard College Observatory. Feb. 5, 1892, with the 11-inch Draper Telescope. (Exposure = 123 minutes).

To secure independence in the measurements an assistant recorded the numbers of the plates and the measures, rearranged their order according to chance, and returned them to Mrs. Fleming to be measured again. A third measure was made in the same way. On December 10, 11, 18, 28, and 30, 1891, and on January 5, 8, 9, and 16, two photographic images of the star were obtained. On December 17 and 18 the first measures were repeated. The corresponding dates, magnitudes and residuals expressed in tenths of a magnitude are given in the following table:

Date	Magn.	Residuals.					
1891 December 10	5.37	0	−1	−1	0	0	0
“ 11	5.33	0	0	0	+1	+1	0
“ 13	5.22	0	0	0	+1	0	0
“ 17	4.67	0	0	−1	−1	0	0
“ 18	4.46	−1	−1	−1	+1	0	+1
“ “		−2	−2	−2	−1	+1	+2
“ 28	4.55	0	−1	−1	0	0	−1
“ 30	4.60	−1	+1	0	−1	+1	0
1892 January 5	4.58	−1	0	+1	−1	−1	+1
“ 8	4.72	0	0	0	+1	0	0
“ 9	4.67	0	+1	−1	−1	0	−1
“ 16	4.96	0	0	0	0	0	0
“ 20	5.23	+1	0	0			

The accordance of the measures is shown by the average residual which equals ± .05. From this it appears that the star was fainter than the eleventh magnitude on November 2, 1891, than the sixth magnitude on December 1, and that it was increasing rapidly on December 10. A graphical construction indicates that it had probably attained the seventh magnitude within a day or two of December 2, and the sixth magnitude December 7. The brightness increased rapidly until December 18, attaining its maximum about December 20 when its magnitude was 4.4. It then began to decrease slowly with slight fluctuations until January 20 when it was somewhat below the fifth magnitude. All of those changes took place before its discovery, so that it escaped observation nearly two months. During half of this time it was probably brighter than the fifth magnitude.

Since the announcement on February 2 of its discovery it has been closely followed at this Observatory both visually and photographically. Comparisons by Argelander's method visually are made every clear night by Mr. O. C. Wendell and Mr. W. M. Reed. Comparison stars have been selected so as to form a sequence having intervals of three or four tenths of a magnitude. Their numbers, positions for 1855.0 and magnitudes according to the Durchmusterung are given below when they occur in that catalogue. In other cases the positions have been determined directly. The first of these stars is 16 Aurigæ, the second χ Aurigæ. The faintest star *w* is of the twelfth magnitude.

Design.	D. M.	No.	R. A.	Dec.	Magn.
			h m s	° ′	
a	+ 33°	1000	5 8 39.8	+ 33 13.1	5.1
b	+ 32°	1024	5 23 18.4	+ 32 4.8	4.8
c	+ 33°	1013	5 10 28.7	+ 33 48.1	5.9
d	+ 29°	869	5 11 59.6	+ 29 25.4	6.0
e	+ 30°	898	5 17 51.4	+ 30 4.2	6.2
f	+ 29°	947	5 30 5.9	+ 29 7.6	6.2
g	+ 29°	909	5 20 27.9	+ 29 3.9	7.0
h	+ 27°	806	5 26 50.0	+ 27 33.7	7.1
k	+ 32°	1003	5 19 52.8	+ 32 4.8	7.4
l	+ 31°	1001	5 23 20.4	+ 31 55.0	7.6
m	+ 31°	989	5 20 56.5	+ 31 40.8	7.7
n	+ 30°	912	5 20 27.2	+ 30 28.4	8.5
o	+ 30°	913	5 20 48.6	+ 30 19.8	8.7
p	+ 30°	918	5 21 55.6	+ 30 3.9	9.3
q	+ 30°	914	5 20 48.8	+ 30 28.0	9.4
r			5 22 36.8	+ 30 27.5	
s			5 22 43.6	+ 30 21.2	
t			5 22 45.3	+ 30 26.2	
u			5 22 54.7	+ 30 18.3	
w			5 22 43.6	+ 30 29.4	
Nova			5 22 40.3	+ 30 19.9	

The magnitudes of all these stars will be determined photometrically for use in the final reduction. On every clear night Mr. Wendell also compares the Nova with the star *s* in the list given above. These observations are made with the 15-inch equatorial by means of a polarization photometer (H. C. O. Annals XI, Part I). Measures of the Nova and of the brighter comparison stars are made by Mr. S. I. Bailey and the writer with the meridian photometer. Five independent series of visual observations will thus be obtained which will test the reality of any apparent fluctuation. The position of the Nova with regard to Weisse 5^h 709 which is DM. + 30° 912. has been determined by Mr. Wendell with the 15 inch equatorial. The dates, the resulting differences in right ascension and declination, and the position for 1900.0 are given below.

Date	$\Delta\alpha$	$\Delta\delta$	α 1900.0	δ 1900.0
1892	m s	′ ″	h m s	° ′ ″
Feb. 4	— 1 48.20	— 6 21.2	5 25 33.40	+ 30 22 13.2
Feb 6	— 1 48.29	— 6 19.9	5 25 33.31	+ 30 22 14.5
Feb. 9	— 1 48.33	— 6 20.3	5 25 33.27	+ 30 22 14.1
All	— 1 48.27	— 6 20.5	5 25 33.33	+ 30 22 13.9

Photographic charts are made every clear evening with the 8-inch Draper telescope, and photographs are also taken with the transit photometer.

An important series of photographs of the spectrum is being obtained with the 11-inch Draper telescope, and since the star will probably soon be too faint to photograph in this way, spectra are also taken with the 8-inch telescope using a small dispersion. The spectrum can thus be photographed until the star is as faint as the eleventh magnitude. With these last photographs several lines, including F, G, h, K, and α, appear to be bright. But on closer examination they are shown to be really dark with the edge of greater wave-length bright. This is confirmed with the greater dispersion, the bright lines really consisting of broad bands sharply defined on the edge of smaller wave-length. The breadth of the bands is not due to poor definition since numerous fine lines are also visible. Many of the lines, including the K line and those due to hydrogen are double. The evidence that this doubling is due to the different velocities of different portions of this object is not conclusive owing to the breadth of the bands. The difference in velocity indicated by the separation of the lines is about 370 kilometers per second. The apparent separation of the different lines in the photograph increases as the wave-length diminishes, as it should according to this theory owing to the increasing dispersion of the violet rays. Two explanations have been offered of the sudden increase in light of stars of this class—the mechanical theory that it is caused by approach or collision, and the chemical theory that it is due to volcanic action. The doubling of the lines strengthens the first of the above theories rather than the second.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., February 15, 1892.

ON THE VISIBLE SPECTRUM OF THE NEW STAR IN AURIGA.[*]

HENRY CREW.

The following is only a *preliminary* general description of the spectrum of Nova Aurigæ, whose appearance was announced at this Observatory on the 6th of February, 1892. The observations cover two evenings, Feb. 10th and 11th, and were made with the spectrometer attached to the 36-inch.

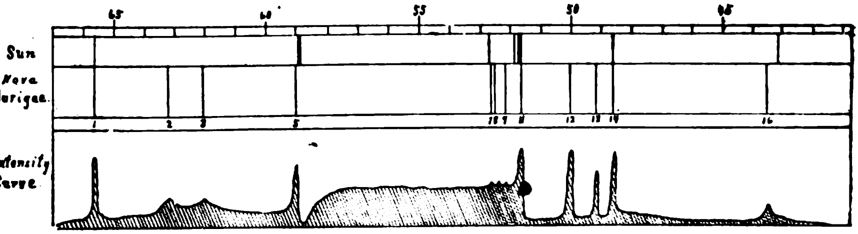
The wave-lengths, while in no sense final, will be found much more accurate than necessary to identify the lines, and will furnish a hint as to the identity of some of them with known lines. The positions were determined by comparison with the lunar and spark spectra. The wave-lengths of the principal lines are given

---

[*] Communicated by the author.

in the following table. The values for lines 11 and 14 are more accurate than the others, these having been measured with a 14,438-line grating in the third order: line No. 11 was compared with b_4 of the magnesium spark, and line No. 14 with F of the hydrogen tube.

The remaining lines were determined by the use of a compound prism. The numbers of the lines correspond with those in the accompanying diagram, which, taken with the light curve underneath, will give some idea of what can be seen with the eye.



Line.	Wave-length.	Description.
1	6565.8	Probably C: very broad and bright in prism: not seen in grating: more brilliant than C line in Phi Persei, but not so bright or sharp as C in Gamma Cassiopeiæ, when this last star is at its brightest
2	6321.	Faint, broad, diffuse.
3	6209.	Not quite so bright as 2: but broader: both 2 and 3 may be bright only in comparison with neighboring absorption bands.
5	5898.	Yellow line, just below D_1: intensity diminishes very rapidly on the side towards the violet: at times this edge appears very sharp: just above this line there is a rather narrow, dark, absorption band, suspiciously near D.
7	5265.	Three very faint lines: difficult to say whether they are really bright lines or simply bright regions bounded by dark spaces.
8	5254.	
9	5216.	
11	5167.1	Much more brilliant than any of the preceding: quite broad: much sharper on the upper side than the lower: nearly coincides with b_4. The most brilliant part of the continuous spectrum is terminated abruptly by this line.
12	5009.	Of about the same brilliancy as 11: and, like it, sharper on the upper side. Nebular?
13	4920.	Much fainter than either of its neighbors: perhaps half as bright as 12.
14	4861.6	Probably F: very wide: not less than 6 tenth-metres in width: measures made on center.
16	4352.	Hγ? Wide, and difficult to see: but not doubtful.

It is not an easy matter to describe the intensities of these lines except by comparison with their immediate neighbors. As seen with a single prism attached to the 12-inch, the lines 11, 12, and 14 appear intermediate in brilliancy between the two green lines in the Wolf-Rayet star, Lalande 13412: the continuous part of the spectrum is, however, much brighter than that of the Lalande star.

The ordinates of the light curve, given above, are for the prism, although plotted to a normal scale: that is, the relative values of the *ordinates* are approximately correct, but the relative *areas* of different portions do not represent the relative amounts of light which these portions give. The curve was drawn at the eye end of the telescope.

The new star thus falls, apparently, into Vogel's class, II. *b*, bright lines being superposed upon an absorption spectrum.

It might be called a typical specimen but for the fact that the absorption appears to take the form of bands rather than lines.

Photographs may show, however, that these bands, such as those indicated in the curve between lines 11, 12, 13, and 14, are really made up of lines which have not been seen, by the writer at least, on account of the faintness (fifth magnitude) of the star.

Perhaps the general appearance of the spectrum cannot be better described than by saying that it has "a ragged look."

LICK OBSERVATORY,
18th of February, 1892.

ATTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in ASTRO-PHYSICS should be addressed to George E. Hale, Kenwood Astro-Physical Observatory, Chicago, U. S. A. Authors of papers are requested to refer to page 256 for information in regard to illustrations, reprint copies, etc.

A New Star in Auriga.—A telegram received from Professor E. C. Pickering of the Harvard College Observatory gives the following position for a new star in Auriga: R. A. $5^h 25^m 33^s$, Decl. 30° 22′ 14″. On Feb. 15 the star was of the fifth magnitude. We learn from Professor Holden that all the resources of the Lick Observatory have been brought into play in a study of the Nova. Photographs are being taken with the 36-inch telescope for position, and with the Crocker telescope (several times each night) for magnitude; Polaris is used as a standard on the plates for photometric determinations. The spectrum is also being observed for relative brightness of lines, and measures of their position will follow. At the Kenwood Observatory cloudy weather has up to the present time prevented any observation.

The note below from *Nature* February 4, tells of the first observations of the *Nova:* The following circular was issued from the Royal Observatory, Edinburgh, 1892, February 2:

Yesterday an anonymous post-card was received here bearing the following communication:

"*Nova* in Auriga. In Milky Way, about two degrees south of χ Aurigæ, preceding 26 Aurigæ. Fifth magnitude, slightly brighter than χ."

At $6^h 8^m$ G. M. T. the star was easily found with an opera glass. It was of a yellow tint, and of the sixth magnitude, being equal to 26 Aurigæ. Examined with a prism between the eye and the eye-piece of the 24-inch reflector, it was immediately seen to possess a spectrum very like that of the Nova of 1866. The C line was intensely bright, a yellow line about D fairly visible; four bright lines or bands were conspicuous in the green; and lastly a bright line in the violet (probably $H\gamma$) was easily seen.

A telegraphic notice was sent to Greenwich in the afternoon, and later on, when the true nature of the object was recognized, to Kiel, for general distribution. The star was photographed last night at Greenwich.

Its place for 1892.0 is $5^h 25^m 3^s + 30° 21'$. It does not occur in the Bonn map. RALPH COPELAND.

Dr. Huggins has sent us the following note on his observations of the spectrum of the Nova; it was first printed in the *London Times*, Feb. 8, 1892:

"Our observations began on the evening of the 2nd inst., when the star was not much brighter than the 5th magnitude, less bright than the star of 1866, which was about the 2nd magnitude, and that of 1876, which was about 3½ magnitude when first observed.

"The most noticeable feature in the new star's spectrum—common also to the stars of 1866 and 1876—and which Dr. Copeland had already seen, was the very great brilliancy of the red, green, and blue lines of hydrogen.' The reality of these lines was made certain by comparison with the corresponding lines of terrestrial hydrogen. The bright double line of sodium was conspicuous and its nature confirmed by a comparison with a flame containing sodium. Very striking were three brilliant lines in the green on the red side of F, and making with it a remarkably splendid quartet of bright lines. The first line is distant from F about one-third of the interval separating it from the second line. The next line falls, as was shown by the method of direct comparison, very near the position of the chief nebular line. But it is not possible to say certainly yet whether it is the nebular line or a line of some other substance accidentally close to it. It is desirable that the motion in the line of sight of the star should be known, in consequence of which the whole spectrum might be shifted a little towards the red or the blue. The cloudy state of the sky on Friday night prevented us from attempting the determination of the star's motion. The probability of the presence of the chief nebular line would be much greater if the second nebular line were found in the star, and there are, indeed, three lines, but much fainter relatively, not far from the position of the second line. At present we reserve our opinion, though we incline to consider no one of them to be the second nebular line. The third brilliant line from F appears in a small spectroscope to fall near the beginning of the brightest of the hydro-carbon flutings, but greater resolving power shows the line or band not to be coincident with this fluting.

"The spectrum of the star is superb, glittering with lines throughout. There are bright lines in the red near C; a brilliant line about one third of the distance from C to D; and there is a bright line on each side of D.

"If only the weather be propitious, we hope to clear up the points I have mentioned, as well as many others, and to supplement our eye observations by photographs of the invisible region of the spectrum."

We learn from *Nature* of Feb. 11 that the spectrum of the Nova was photographed at South Kensington by Mr. Norman Lockyer on the night of Feb. 3, employing a 6-inch objective with a prism before it. The approximate positions of 13 lines were obtained from two photographs, and *G*, h, H, and K were present. No mention is made, however, of the remarkable characteristics of the spectrum which are so well brought out in Professor Pickering's photograph. The visual spectrum was examined with a 3-foot reflector, and of it Mr. Lockyer remarks: "C was the brightest line observed. In the green there were several lines, the brightest of which was in all probability F, the position being estimated by comparison with the flame of a wax taper. Another line was coincident—with the dispersion employed—with the radiation at wave-length 500 from burning magnesium wire. A fainter line between the two last named was probably near λ 495, thus completing the trio of lines which is characteristic of the spectra of nebulae. There was also a fairly bright line or band coincident with the edge of the carbon fluting at λ 517 given by the flame of the taper. A feeble line in the yellow was coincident under the conditions employed with the sodium line at D. The hydrogen line at *G* was distinctly seen, as well as a band, or group of lines, between G and F."

Nova Aurigæ.—Letter from Professor Holden.

LICK OBSERVATORY, February 18, 1892.

MY DEAR MR. HALE:

Dr. Crew will send you to-day or to-morrow a short note on the visible spectrum of Nova Aurigæ. Besides the observations which he gives, others have been made here, which will be published in due time. They are

(*a*). A series of visual comparisons of the magnitude of the new star with the magnitudes of H. P. 1001 and 1033 by Professors Schæberle and Campbell.

(*b*). A series of photographs of the neighborhood of Nova and of Polaris (with the Crocker portrait-lens on the same plates) for the purpose of determining the photographic magnitude of the new star. At least one such plate has been taken by Professor Schæberle, and at once developed, on every clear night since the afternoon of February 6 (when we first heard of the star's appearance). Whenever desirable (and possible) other plates have been taken on the same nights. A considerable range of variation in magnitude has been manifested in the observations already made, and they appear to fall into a short period. Further good weather is required to decide this point.

(*c*). Visual spectroscopic observations have been made by Professor Campbell on several nights. The places of some 25 bands and lines have been fixed by measurements. Comparisons show that the hydrogen lines are bright and that D (not D^3) is also bright.

(*d*) The spectrum has also been photographed by Professor Campbell with the 36-inch and the 12-inch equatorials. The photographs fix the place of some 25 other bands and lines in the spectrum; and they confirm his visual observations with regard to the nature of the hydrogen lines of the star. Attempts to photograph the D's were not successful, as our plates were not suitable.

Other series of observations are planned and will be carried out if the weather permits.

I am, my dear Mr. Hale,

Very sincerely yours,

EDWARD S. HOLDEN.

Progress in Solar Photography at the Kenwood Observatory.—In the last number of ASTRONOMY AND ASTRO-PHYSICS it was stated in a "Note on Recent Solar Investigations" that photographs had been obtained at the Kenwood Observatory of the regions on the Sun in which the H and K lines are reversed. Since that time the work has been continued, and it has been found that the reversals take place in the faculæ, so that we are now in possession of a new method of photographing the faculæ. The great advantage which this method offers lies in the fact that the faculæ are as well shown at the center of the Sun's disc as at the limb. We shall thus be able to study them more thoroughly than has before been possible. The spots are shown on the same plates with the faculae, and with a somewhat slower speed of the clepsydra the prominences are obtained by the same method. Since the great spot entered the disc on Feb. 4 we have obtained 45 photographs showing the spot and surrounding faculae, and a large number of its spectrum.

The first photographs showing all the prominences around the Sun's limb with a single exposure were made here early in February.

Group of Stars of the Fifth Type in Cepheus.—Professor E. C. Pickering communicates to *A. N.* 3070 the following note on this subject: "The photographic spectra of the stars DM. + 55°.2721, magn. 8.9, and DM. + 56°.2818, magn. 8.9, whose approximate positions for 1900 are in R.A. $22^h\ 15^m$; Dec. + 55° 37′, and R.A. $22^h\ 32^m.9$; Dec. + 56° 23′, are well shown in a photograph taken at the Harvard College Observatory on October 10, 1891. They prove to be of the fifth type, their spectrum being similar to that of the stars discovered by Wolf and Rayet. On November 2, 1891, a photograph of the same region was taken for confirmation of this peculiarity, and from this plate another star having a spectrum of the fifth type was discovered. The approximate position of this star for 1900 is in R.A. $22^h 23^m.7$; Dec. + 55° 46′. The presence of bright lines in the spectrum of the last named star was confirmed from a plate taken on November 3, 1891. This increases the number of known fifth type stars to 38. These three stars, like all the others of the same class, fall near the central line of the Milky Way, their galactic latitudes being — 0° 50′, — 1° 25′ and — 1° 20′ respectively. Their galactic longitudes are 70° 29′, 73° 3′ and 71° 38′ respectively."

Nebulosity about the Wolf-Rayet Stars.—In the January number of *Knowledge* there is an interesting letter from Rev. T. E. Espin in regard to Dr. Max Wolf's photographs of Cygnus. In spite of the bright illumination of the sky by a moon only three days past the full, the Rev. Espin was able to see every star shown in Dr. Wolf's beautiful photograph (reproduced in *Knowledge*, December 1891), in the three zones which he examined. It is thus regarded as probable that all the stars on the photograph, which was given an exposure of thirteen hours, are within the 14.5 magnitude on Argelander's scale.

But another fact is brought out which is very significant. It will be remembered that in Dr. Huggins' paper on the spectrum of the Wolf-Rayet stars in Cygnus (Proceedings Royal Society, No. 296) an account is given of some photographs taken by Mr. Isaac Roberts to ascertain whether any nebulosity were present in connection with these peculiar bright line stars. With an exposure of $3^h 15^m$ Mr. Roberts found no traces of nebulosity. But recent results show that this negative conclusion was probably due to the too great focal length of the telescope employed. At the request of the Rev. Espin, Dr. Wolf has photographed the same region with his short focus portrait lens, and although the exposure was too short to bring out any definite form, there seems to be no doubt that the Wolf-Rayet stars, and also the bright line star P Cygni, are directly connected with nebulous matter. Considering the peculiar type of spectrum which these stars possess, and the fact that they tend to group themselves in the plane of the Milky Way, this discovery of nebulous appendages must be regarded as of considerable importance.

Photographic Halation and Its Remedy.—The reflection of light from the back of the plate during exposure is often very troublesome in astronomical photography, and many methods of obviating the difficulty have been proposed. In the *Photographic Times* for Feb. 5, 1892, a method which was devised by the well-known spectroscopist, M. A. Cornu, is described as follows: "If we make a mixture of *six volumes of essence of clove and one volume of turpentine oil* we find that it possesses the same index of refraction as glass by immersing in it a strip of glass plate from which the emulsion has been scraped off. In the liquid the plate is almost entirely invisible, the edges only being apparent by a slight red or bluish green coloration. The mixture is thickened with lampblack to form a paste, which is applied on the back of the plate with a brush or a tuft of cotton. The photo film is exposed in the camera, and, before developing, one wipes off the black paste, and then develops as usual. These manipulations are not very agreeable, but it gives one the absolute certainty that the halo will be entirely avoided."

In the *Year Book of Photography* for 1886, Mr. Edgar Clifton recommends a mixture of burnt sienna ground in water with dextrine and water until the consistency of thick cream is reached. This is applied to the back of the plates with a soft sponge, and will be dry and ready for use in from fifteen to twenty minutes.

A dyed collodion film in contact with the back surface of the plate has also been proposed, but one of the above methods would probably prove more satisfactory.

Herr Schumann's New Vacuum-Spectrograph.—In a letter dated Jan. 15 Herr Schumann writes us from Leipzig that by diligent work during the holidays he has been able to practically complete his new spectrograph, which is to be used in a vacuum for photographing the extreme ultra-violet of the hydrogen spectrum. Reference was made to this instrument in our note in the February number on Herr Schumann's discoveries, where it was pointed out that the shortest light-waves are absorbed by air, and must therefore be investigated in a vacuum.

The spectrograph is furnished with a 70° prism and two lenses of 120^{mm} focal length (for λ 5890). The material of which they are made is white fluor-spar, obtained for Herr Schumann in a remarkably pure state by the well-known optical house of Carl Zeiss. Quartz cannot be used in this research, as it exercises considerable absorption above λ 1820. In its present improved form the spectrograph is so constructed that all of the following adjustments can be made when the instrument is in a vacuum, or filled with any gas at a pressure up to one atmosphere:

1. The width and length of the slit may be changed and measured micrometrically.
2. A diaphram of adjustable length may be moved by a micrometer screw over the slit, so as to allow a large number of spectra to be taken on a single plate for comparison.
3. The lenses of collimator and camera may be moved in either direction for focusing.
4. The tubes of both collimator and camera may be turned in such a way that the angle between their optical axes varies about 30°.
5. The prism may be set for minimum deviation.
6. The sensitive plate may be turned about its central line so as to make any angle from 0° to 90° with the optical axis of the camera lens.
7. The photographic plate may also be moved in its own plane in a direction parallel to the slit, so as to give space for several series of exposures.

The spectrograph is exhausted by a Geissler mercury-pump. It has already been tested satisfactorily, and we may shortly expect to hear of important results obtained by its means.

The Aurora of Feb. 13, 1892.—Auroras can rarely be seen from the Kenwood Observatory, owing to the illumination of the northern sky by the lights of Chicago, but the magnificent display of February 13 was easily observed. At about 6^h 25^m P. M. (Chicago M. T.) the brilliant red auroral light was first seen here, extending more than two-thirds the distance from the horizon to the zenith, and reaching about 45° east and west of north. Local changes in brilliancy and depth of color were very rapid, and straight, white streamers partook of the general motion from east to west. At about 6^h 55^m the aurora disappeared.

The spectrum was well seen here with a small direct-vision spectroscope, using a rather wide slit. Four bands were made out, and their positions were estimated as follows:

1. Bright; probably same width as slit; in red near C.
2. Bright; probably same width as slit; yellowish green ("aurora line?")
3. Very faint; broad and hazy; in green, near *b*.
4. Faint; probably same width as slit; near F.

The appearance of the electric storm which accompanied the aurora was first noticed on Feb. 13, about 1 P. M. Between 5 P. M. and 7 P. M. the storm was at its height, and interfered with the working of the telegraph system over a considerable section of the country. At intervals during the auroral display it was found possible to send messages between Albany and New York without the aid of the regular batteries. (*Chicago Tribune*).

The question naturally arises whether these phenomena were in any way connected with solar disturbances. The regular observations of the Sun were in progress during the greater part of the day at the Kenwood Observatory, but no very remarkable outbreaks were observed. At noon, there were evidences of activity in the region of the great spot group, and the distortions of the hydrogen C line indicated a greater velocity (downrush) than has been noticed before in this group. A bright prominence on the N. E. limb, following the small spots which were already well advanced on to the disc, showed in the C line a marked distortion toward the violet, and at 4^h 10^m this had considerably increased in amount. 14 photographs of prominences, spots and faculae, and 11 of spot and prominence spectra, were made here between 10^h 30^m A. M. and 4^h 15^m P. M.

We wish to call attention, in this connection, to the work of Dr. M. A. Veeder, of Lyons, N. Y., on the relation between auroras and solar phenomena. As has been mentioned before in ASTRONOMY AND ASTRO-PHYSICS, Dr. Veeder has prepared blank forms to be filled out with notes on auroras, and these he is glad to furnish to anyone who is willing to spend a few minutes each evening on the work. In another Note we print a report we have received from him on the auroras of January. It is to be hoped that many will be ready to offer their assistance in this interesting investigation.

Newspaper dispatches received later show that the aurora was very widely seen. In Sweden and Russia, earth currents seriously affected the operation of the telegraph lines.

The following is Dr. Veeder's report of the aurora of Feb. 13, as observed at Lyons, N. Y.

Description, Strong scarlet red streamers marking the central portion of the region in which this feature was prominent and persistent throughout the continuance of the display, or in other words, from 6.45 P. M. until 8.06. (Eastern Standard Time).

Time, Special observations were made at 6.59, 7.03, 7.07, and 7.09 P. M.

Azimuth at point of origin, 50° W. of N.

Inclination, Westward at an angle with the horizon of 80°.

Altitude, Varied from 45° to 50°.

Description, Bright red streamers forming the detachment from the preceding which extended farthest south of any seen during the evening.

Time, 7.55 P. M.

Azimuth of origin on horizon, 65° W. of N.

Inclination, Westward at an angle of 78°.

Altitude, 35°.

Description, Faint yellowish green streamers which varied in brightness in sympathy with those described in the following section, but which had the peculiarity of not conforming to the usual lines of magnetic force.

Time, 11.58 P. M.

Azimuth of point of origin on the horizon, 12° E. of N.

Inclination, Westward at an angle of 55°.

Altitude, 35°.

Description, Yellowish green streamers entirely similar to the preceding, but conforming to the more usual direction.

Time, 11.59 P. M.

Azimuth of origin, 19° E. of N.

Inclination, Eastward at an angle with the horizon of 87°.

Altitude, 40°.

Prominent features were noted during the evening as follows:
The time of beginning was almost precisely 6.40 P. M. At that moment a small patch of greenish streamers was seen about 15° above the horizon at a point due N. E. At 6.45 a rosy blush was observed in the N. W. in the location of the prominent and persistent streamers above described. At 6.52 a curtain having a sinuous lower margin from which short green streamers arose vertically formed just below the North Star. At 6.56 a faint and irregular streak of luminous haze extended E. and W. through the zenith. At 6.59 red streamers began to form in the N. W. and continued to brighten at 7.03, becoming very strong at 7.07. At this moment faint red patches began for the first to appear in the N. E., in which location greenish patches and streamers only had appeared hitherto. Generally the display was less bright east of the meridian, and the colors were mostly of some hue of green or light yellow, but west of the meridian red was the predomi nating color throughout, and the streamers were much stronger and more persistent. At 7.08 an irregular band made up of patches and streamers extended E. and W. across the sky about 20° N. of the zenith. The color of this band was generally red, but nearer the horizon, particularly toward the N. E., the colors were at this moment greenish. At this moment also the maximum extent of sky covered was attained, the display extending very nearly to the zenith. Generally throughout the evening the southern margin of the luminous mass did not extend further S. than the North Star, but remained persistently at about that point. At 8.05 the aurora was fading rapidly, and at 8.06 had disappeared entirely. At 8.15 a faint red glow appeared for a few minutes about 20° above the northern horizon. At intervals later in the evening very faint haze was seen overspreading the sky, from the zenith northward, which might have been auroral in character. At 11.45 a small patch of bright green streamers was seen in the N. E., at almost the precise location where the display began at 6.40. At 11.58 and 11.59 the streamers above described as being seen at that hour were first noticed, but faded out in about three minutes.

The Auroras of January, 1892. The following results appear to be justified by the reports of observations thus far received. As was anticipated and announced in advance to many of those receiving blanks for recording observations, the finest display of the month, and an aurora of the first magnitude, appeared on January 5th. Sporadic, and for the most part very faint displays were reported on January 15th, 20th, 21st, 25th, 26th, 27th, 28th and 29th, those on the last three dates named being the best defined.

The reports from stations along the base line adopted, extending from Washington northward into Canada, show that the aurora of January 5th had a probable altitude of 175 miles and perhaps upwards. The amount of sky covered at different stations shows that the plane of the southern margin of the chief portion of the luminous mass reached the earth at a point on the 77th meridian not far from 45° north latitude. Comparison with observations on other meridians shows that the aurora tended to reach its maximum brightness at the same hours of local time, rather than at the same hours of absolute time. A study of the arrangement of the arches and patches of light reported from different stations reveals the fact that they are very largely of the nature of halos, their position depending as much upon the position of the observer as upon the general source of illumination in the auroral mass. As in the case of a rainbow, each observer sees his own arch and consequently the elevation will be approximately the same at stations not too far apart to prevent the arch from being seen at all. In this way, also, the differences in the prismatic colors displayed, even at stations quite close together, may be accounted for. Hence the difficulty of employing arches or colors for the estimation of altitude. It is suspected that this may be true of streamers also.

The method of recording the absence as well as the presence of the aurora at each observation has made it apparent, especially in connection with the lesser displays of the month, that even well defined auroras may be confined within quite narrow limits, appearing, for example, at southern stations when absent at those directly northward. The aurora thus exhibits a tendency to frequent certain localities, presumably because of some peculiarity of the soil or topography of the country; but further observations in regard to this point are desirable.

Disturbed areas upon the Sun, containing both spots and faculae, appeared by rotation on January 5th, 6th, 15th, 21st, 28th, 29th and 30th. Thus the dates of auroral display during the month, and the extent of the displays reported, has been in exact conformity with the relations to solar and associated conditions described in the paper upon the Zodiacal Light, copies of which have been distributed generally to observers co-operating, and which may be obtained from the undersigned, from whom, also, blanks and circulars for auroral observations may be had. M. A. VEEDER,

LYONS, NEW YORK, U. S. A.,
February 8, 1892.

The Eruptive Prominence of July 9, 1891.—In the January number of ASTRONOMY AND ASTRO-PHYSICS an account was given in an article on "Recent Results in Solar Prominence Photography" of a prominence observed simultaneously at the Haynald Observatory, Kalocsa, Hungary, and at the Kenwood Observatory, Chicago. We have recently received a letter from Mr. J. Evershed, Jr., of Kenley, Surrey, England, in which he writes as follows:

"I take the liberty of writing you, thinking you may be interested to learn that the prominence of July 9th last, photographed by you and observed at the same time at Kalocsa, was also, by an extraordinary chance, well seen by me here. I am very rarely at liberty to observe in the afternoon, but happened to be so on the above date; furthermore, the Sun is hidden in trees from about 4 P. M. to sunset, but there is a gap in the foliage which allows it to be seen for about 20 minutes between 5:30 and 6 P. M., and it was during this time my observation was made. I enclose copies of my drawings made at the time. My observation of the form of this prominence differs somewhat from M. Fényi's drawing in that the main stem seemed to me much narrower, and not so inclined. I first observed the N. F. limb at 5.30 ± 2^m G. M. T., at which time the brilliant column had a 'stranded' appearance like a partly unravelled rope. Near the highest part a number of bright filaments like descending rockets gave the impression of matter falling back on the Sun, but these faded very rapidly, and before any actual motion could be detected. With a narrow slit C was much distended on each side of its normal position near the base of the column.

"I may mention in connection with photographic work that I have been lately experimenting on the F hydrogen line with a view to photographing the prominences. I find with an exposure of a little over 1 second with rapid isochromatic plates a very distinct impression can be obtained of the ordinary quiet prominences, but of course less detail is visible than in visual observation with C. I therefore conclude that for simply registering the forms F is a more promising line than K, which I understand requires a more prolonged exposure in spite of the dark background due to the broad absorption shade."

We were much interested to learn of Mr. Evershed's observation; there certainly was a remarkable series of coincidences connected with the eruption referred to. It lasted but 20 minutes, and was seen in Hungary, England and the United States. Clouds in Kalocsa and trees in Kenley nearly succeeded in preventing observation, but the view of the Sun was unobstructed at exactly the right time. The drawings which Mr. Evershed kindly sends agree with M. Fényi's and our own except in the inclination to the limb, as has been mentioned.

As to the F line, we are inclined to doubt whether it will prove as useful for prominence photography as K, although the use of dyes may give plates a greater sensitiveness for this region. Our ordinary time of exposure in the last experiments with an open slit was about ½ second for K and the broad dark shade is an advantage of the greatest importance. F was used in some of our earlier experiments, and, though not considered so useful as K, a careful comparative test should be made, in order to settle the matter.

The Spectra of Sun-Spots and the Photosphere. In his important memoir, "Recherches sur la Rotation du Soleil," Professor N. C. Dunér not only gives a most complete discussion of his investigations on the rotation of the Sun, but also adds a description of the large and powerful diffraction spectroscope employed, together with some results obtained with this instrument in an examination of the Sun-spots and photosphere. The large size and special construction of the spectroscope makes its description particularly interesting, and as soon as we can procure a suitable photograph or drawing, a translation of Professor Dunér's account will appear as one of our series on *The Modern Spectroscope*. At present, we wish only to call attention to some of the results secured.

Adopting the wave-lengths of M. Fievez, Professor Dunér first gives a list of double lines which lie just within the resolving power of his instrument, and certainly the claim of rare optical qualities for the spectroscope is completely justified by the extreme closeness of some of these pairs. In speaking of the duplicity of the two D lines it is stated that a narrow thread of light may be seen without great difficulty in the center of D_2, and sometimes, though rarely, in D_1, when the fourth order spectrum is employed. In the fifth order the same appearance is much more easily recognized. The author goes on to add: "As to this fine line of light, I am almost convinced that it is only a double reversal, similar to those so often observed in the spectra of spots and prominences, and which would be seen over the entire disc of the Sun with a sufficiently powerful spectroscope. I have noticed another very curious phenomenon in the b group: a very considerable decrease in the intensity of the three wide lines which belong to magnesium. In the fifth spectrum this decrease of intensity is so marked that the more refrangible component of b_4 is only recognizable with some difficulty,—with more difficulty, in fact, than in the fourth spectrum; while the less refrangible component of b_4, as well as the two components of b_3, which are due to nickle and iron, retain all their sharpness. As is well known, b_2 is enclosed between two metallic lines. With a considerable, though not too great, dispersion b_2 is seen to be much stronger than even the more refrangible of these lines; but in the fifth spectrum of our spectroscope b_2 is sensibly fainter than the less refrangible of the lines. b_1 is also seen to be very much reduced in intensity. It would seem that these phenomena might be explained by a partial reversal, while the lines of the more refractory metals do not undergo a similar change. One objection might, however, be raised against such a supposition: the line of the solar corona (K 1474) which presents elsewhere, in general, the same reversal phenomena as the magnesium lines, is not in the least enfeebled in the spectrum of the fifth order."

The discovery recently made at the Kenwood Observatory, and noted in our last number, that the H and K lines are reversed in regions irregularly distributed over the entire disc of the Sun, should be considered in connection with Professor Dunér's observations. In the photographs of H and K, however, though there is some reason to think that the lines are reversed throughout their entire length, the reversals can be certainly seen only at intervals along the lines, while Professor Dunér's account gives the impression that a continuous reversal was seen in the lines of the *b* group. In the case of D, it seems that the reversal was not continuous, for it is remarked that with a sufficiently powerful spectroscope, it would probably be seen over the whole disc. As it has been found here that the regions in which H and K are most strongly reversed correspond with the faculae, it is likely that the reversals of magnesium and sodium occur in the same localities. Considering the relative frequency with which these various lines are reversed in prominences, it is not at all surprising, but rather to be expected, that in the faculae they should follow the same order. Thus hydrogen and calcium are always found to be bright, while magnesium and sodium appear so with much greater difficulty.

Professor Dunér found no difficulty in confirming Professor Young's resolution of the dark shade in the spectrum of a spot nucleus into a great number of fine lines. He remarks: "I have, in fact, seen spot-spectra entirely lose the appearance of a uniform band, darker than the rest of the solar spectrum, which they present in a spectroscope of medium dispersion, and showing very numerous dark lines, projected on a background of the same brilliancy as the general spectrum of the solar disc. These lines are *not* uniformly distributed, however, and at equal distances from one another like the bars of a grate. On the contrary it may be seen with perfect certainty, especially when attention is directed to the spaces which in the solar spectrum are free from all but faint lines—I mention as examples the open spaces 5352 . . . 5361, and 5287.5 . . . 5292—that they are grouped in doublets, triplets, etc., separated by interstices wider than those which separate the lines constituting these groups. All of these interstices, as far as I could determine, seemed to me to be of the same brilliancy as those which occur between groups of lines in the solar spectrum. By very carefully examining the solar spectrum in the prolongation of such a group in the spot spectrum I sometimes succeeded in discovering an exceedingly faint nebulous line. In a word, all that I have seen seems to me to prove that there is no fundamental difference between the general solar spectrum and that of the spots. It is, on the contrary, very probable that the latter is formed, so to speak, by the exaggeration of the essential characteristics of the former, the excessively feeble and almost imperceptible lines becoming readily visible, and the lines which are strong in the ordinary solar spectrum becoming broadened and strengthened.

The absorbing layer in the spots having, with slight modifications, the same chemical composition as that of the photosphere, it is difficult to imagine any other kind of spot than that of a cavity filled with metallic vapors, either in vortices as M. Faye maintains, or at rest as Secchi believed, although the constancy of the lines which properly belong to spot spectra, as determined by Professor Young and myself, seems more in accord with Secchi's theory. But it can hardly be admitted that the spots are of the nature of a cloud floating in the solar atmosphere. For clouds as we know them in the terrestrial atmosphere are partly fluid and partly gaseous, and they are, consequently, but slightly transparent. It would thus be necessary that the solar clouds should have a spectrum showing general absorption. A spectrum composed of numerous dark lines on a bright background could not be explained on this hypothesis. Professor Young has also expressed the same opinion, in the note just mentioned (*American Journal of Science*, Third Series, vol. XXV, pp. 333-336). He remarks: 'Of course the resolution of the spot spectrum into lines tends to indicate that the absorption which darkens the center of a Sun-spot is produced, not by granules of solid or liquid matter, but by matter in the gaseous form.' "

We may add that the fine lines in the spectrum of the spot nucleus have been frequently observed at the Kenwood Observatory, the appearance agreeing in all respects with that described above. In stating his belief that there is no fundamental difference between the spot spectrum and that of the general solar surface, we do not understand Professor Dunér to mean that the relative intensities of the lines is invariable, for of course, in spot spectra, some of the solar lines are very much more widened than others. What brings about this selective absorption, and why it varies from one spot to another, and also, probably, with the Sun-spot period, are some of the most interesting questions of solar physics.

CURRENT CELESTIAL PHENOMENA.

PLANET NOTES FOR APRIL.

Mercury will be visible to the naked eye, a little after sunset, in the first few days of April. He will then be in the constellation Aries, south of the brightest star. Mercury, however, will be brighter than the star, so that no doubt will exist as to the identification of the planet. One should look for Mercury about half an hour after sunset, almost due west and a short distance above the horizon. After the first few days of the month Mercury will move rapidly toward the west, coming to inferior conjunction with the Sun, April 19.

Venus cannot fail to catch the eye of the most unobservant in the early evening, as she is the most brilliant object in the sky with the exception of the Moon. Even during the day she can easily be seen without a telescope, if one knows just where to look. During April her brilliancy will be fifty per cent greater than now. The phase will be gibbous up to the last day of April, when almost exactly half of the disk will be illuminated. The diameter will increase during the month from 18″ to 24″. April 29, about 11 P. M. central time, there will be an occultation of Venus by the moon. It will be visible in Mexico, the west coast of South America, and some of the Islands of the Pacific ocean.

Mars during April will rise between one and two o'clock in the morning. He is in Sagittarius moving eastward. His brilliancy and red color will enable anyone to distinguish him from the stars of the constellation.

Jupiter rises too late in the morning to be well seen.

Saturn is now a beautiful object in the telescope. The rings are so nearly edgewise to us that they appear as one, but the belts and the shadow of the rings on the planet show well. For chart of Saturn's place in the constellation Virgo, see our January number, p. 81.

Uranus is also in Virgo (see chart, January No., p. 81) near the star λ. Uranus will be at opposition April 23, so that this month will be most favorable for observations of this planet. We would call especial attention to the occultation of Uranus by the Moon April 12, beginning, as seen from Washington, at 10ʰ 56ᵐ P. M., and ending at 12ʰ 22ᵐ A. M. central time. For other places the times of immersion and emersion will vary by several minutes, so that it will be well for the observer who wishes to observe these phenomena to begin watching a half hour or more early.

Neptune will set too early during April to be observed under favorable conditions.

Date 1892.	R. A. h m	Decl. ° '	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Apr. 5......	2 01.9	+15 43	5 56 A. M.	1 03.7 P. M.	8 11 P. M.
15......	1 57.9	+14 38	5 17 "	12 20.4 "	7 23 "
25......	1 37.0	+ 9 58	4 41 "	11 20.3 A. M.	7 00 "
			VENUS.		
Apr. 5......	3 50.8	+22 32	7 12 A. M.	2 52.3 P. M.	10 32 P. M.
15......	4 36.8	+24 58	7 06 "	2 58.8 "	10 52 "
25......	5 22.1	+26 26	7 04 "	3 04.6 "	11 06 "
			MARS.		
Apr. 5......	18 58.1	−23 23	1 37 A. M.	6 00.1 A. M.	10 24 A. M.
15......	19 22.3	−23 00	1 20 "	5 45.8 "	10 10 "
25......	19 45.4	−22 29	1 02 "	5 29.6 "	9 58 "
			JUPITER.		
Apr. 5......	0 18.4	+ 0 48	5 15 A. M.	11 21.4 A. M.	5 28 P. M.
15......	0 27.1	+ 1 44	4 41 "	10 50.8 "	5 01 "
25......	0 35.7	+ 2 39	4 06 "	10 20.0 "	4 34 "
			SATURN.		
Apr. 5......	11 46.5	+ 4 11	4 27 P. M.	10 46.7 A. M.	5 07 A. M.
15......	11 41.1	+ 4 26	3 44 "	10 04.9 "	4 26 "
25......	11 42.0	+ 4 38	3 02 "	9 23.6 P. M.	3 45 "
			URANUS.		
Apr. 5......	14 10.7	−12 38	7 58 P. M.	1 10.6 P. M.	6 23 A. M.
15......	14 09.2	−12 30	7 17 "	12 29.7 "	5 43 "
25......	14 07.5	−12 21	6 35 "	11 48.7 "	5 02 "
			NEPTUNE.		
Apr. 5......	4 21.5	+19 58	7 56 A. M.	3 23.0 P. M.	10 50 P. M.
15......	4 22.7	+20 01	7 17 "	2 44.8 "	10 12 "
25......	4 24.0	+20 04	6 39 "	2 06.8 "	9 35 "
			THE SUN.		
Apr. 5......	1 00.5	+ 6 28	5 32 A. M.	12 02.5 P. M.	6 32 P. M.
15......	1 37.2	+10 08	5 15 "	11 59.8 A. M.	6 45 "
25......	2 14.6	+13 31	4 59 "	11 57.8 "	6 57 "

Phases and Aspects of the Moon.

		Central Time. h m
First Quarter..	Apr. 4	12 21 A. M.
Apogee..	" 11	5 24 P. M.
Full Moon..	" 12	12 26 A. M.
Last Quarter..	" 19	12 00 midn.
Perigee..	" 26	3 12 A. M.
New Moon..	" 26	3 46 P. M.

Mr. Marth's Ephemerides of the Satellites of Saturn.

[From *Monthly Notices*, Nov. 1891.]

In this table the times have been changed from Greenwich Mean Time to Central Standard Time. The abbreviations *Rh.*, *Te.*, *Di.*, *En.*, and *Mi.*, stand for the names of the satellites Rhea, Tethys, Dione, Enceladus, and Mimas. The letters *a*, *b*, *c*, *d*, and *e*, stand for conjunctions of the satellites in order as follows: With the preceding end of the outer ring; with preceding end of planet's equatorial diameter; with center of planet; with following end of planet's diameter; with following end of ring. The letters *n* and *s* signify that the satellite at the time of conjunction is north or south of the point designated by the preceding letter; *Sh.* means that the shadow of a satellite is near the central meridian of the planet; *Ecl. D.* and *Ecl. R.*, the disappearance and reappearance of a satellite at beginning and end of an eclipse.

March 1892.		
5	12.3 am	Di en
	12.9	Te Ecl. D
	1.0	Mi an
	4.0	Te dn
	3.7 pm	En en
	6.0	Rh es
	6.2	Mi as
	8.6	Rh ds
	9.7	Te es
	9.8	En es
	11.6	Mi an
	11.7	Te ds
6	12.4 am	Rh bs
	1.5	Di es
	2.6	Te bs
	3.0	Rh bs
	3.7	Di ds
	4.1	En as
	4.6	Te as
	2.2 pm	En an
	4.8	Mi as
	8.3	Te an
	8.6	En en
	10.2	Te Ecl. D
	10.2	Mi an
7	1.2 am	Te dn
	3.2	Te en
	4.1	Mi en
	12.4 pm	Di Ecl. D
	1.0	En as
	3.4	Mi as
	3.8	Di dn
	6.0	Di en
	7.0	Te es
	8.8	Mi an
	9.0	Te ds
	11.1	En an
	11.9	Te bs
8	12.2 am	Rh an
	1.9	Te as
	2.6	Rh Ecl. D
	2.8	Mi en
	2.1 pm	Mi as
	3.5	En es
	5.6	Te an
	7.1	Di es
	7.5	Mi an
	7.6	Te Ecl. D
	9.3	Di ds
	9.9	En as
	10.5	Te dn
9	12.5 am	Te en
	12.6	Di bs
	1.4	Mi en
	2.8	Di as
	2.3 pm	En en
	4.3	Te es
	6.1	Mi an
	6.3	Te ds
	9.2	Te bs
	11.2	Te as
	12.0	Mi en
10	12.4 am	En es
	4.0	Di an
	12.8 pm	Rh bs
	2.9	Te an
	3.3	Rh as
March 1892.		
	4.7	Mi an
	4.8	En an
	4.9	Te Ecl. D
	7.8	Te dn
	9.8	Te en
	10.6	Mi en
	11.2	En en
11	12.8	Di es
	1.6	Te es
	2.3	Titan ds
	3.0	Di ds
	3.3	Mi an
	3.6	Te ds
	3.6	En as
	4.6	Titan Sh
	6.3	Di bs
	6.5	Te bs
	8.2	Titan bs
	8.5	Di as
	8.5	Te as
	9.2	Mi en
12	12.0 am	Titan as
	1.7	En an
	2.6	Mi es
	12.2 pm	Te an
	12.5	Rh an
	1.9	Mi an
	2.2	Te Ecl. D
	3.0	Rh Ecl. D
	5.1	Te dn
	6.2	En es
	6.9	Rh dn
	7.1	Te en
	7.8	Mi en
	9.5	Rh en
	9.6	Di an
	11.8	Di Ecl. D
13	12.5 am	En as
	1.2	Mi es
	3.1	Di dn
	3.8 pm	Te bs
	4.9	En en
	5.8	Te as
14	2.1	Di as
	2.4	Te dn
	4.4	Te en
	5.0	Mi en
	6.7	Rh es
	7.5	En an
	9.2	Rh ds
	10.4	Mi es
15	1.1 am	Rh bs
	1.8	En en
	3.6	Rh as
	1.1 pm	Te bs
	3.1	Te as
	3.3	Di an
	3.7	Mi en
	6.3	En as
	8.7	Di dn
	9.1	Mi es
	11.0	Di en
16	3.0 am	Mi as
	1.7 pm	Te en
	2.3	Mi en
	7.7	Mi es
	8.8	En es
March 1892.		
17	12.1 am	Di es
	12.8	Rh an
	1.6	Mi as
	2.3	Di ds
	3.1	En as
	3.4	Rh bn
	12.4 pm	Te as
	12.9	Mi en
	1.2	En an
	6.3	Mi es
	7.6	En en
18	12.2 am	Mi as
	4.1	Te an
	2.3 pm	Di Ecl. D
	2.4	Di dn
	4.6	Di en
	4.9	Mi es
	10.1	En an
	10.8	Mi as
19	2.7 am	Te es
	1.4 pm	Rh bs
	2.5	En es
	3.5	Mi es
	4.0	Rh as
	4.1	Titan an
	5.7	Di es
	8.0	Di ds
	8.0	Titan bn
	8.9	En as
	9.4	Mi as
	11.2	Di bs
20	1.4 am	Te an
	1.4	Di as
	1.9	Titan dn
	2.8	Mi as
	3.4	Te bn
	5.7	Titan en
	1.3 pm	En en
	2.1	Mi es
	8.0	Mi as
	11.4	En es
	12.0	Te es
21	1.4 am	Mi an
	2.0	Te ds
	2.6	Di an
	4.8	Di bn
	4.9	Te bs
	1.1 pm	Rh an
	3.7	Rh bn
	3.9	En an
	6.7	Mi as
	7.5	Rh Ecl. R
	7.6	Rh dn
	10.1	Rh en
	10.2	En en
	10.7	Te an
22	12.1 am	Mi an
	12.7	Te bn
	3.6	Te Ecl. R
	1.6 pm	Di ds
	2.6	En as
	4.9	Di bs
	5.3	Mi as
	7.1	Di as
	9.3	Te es
	10.7	Mi an
	11.3	Te ds
March 1892.		
23	12.7 am	En an
	2.2	Te bs
	3.9 pm	Mi as
	5.2	En es
	7.3	Rh es
	8.0	Te an
	8.2	Di an
	9.3	Mi an
	9.9	Rh ds
	10.0	Te bn
	10.4	Di bn
	11.5	En as
24	12.9 am	Te Ecl. R
	1.7	Rh bs
	1.7	Di Ecl. R
	2.9	Te en
	3.2	Mi en
	3.9	Di en
	4.3	Rh as
	2.5 pm	Mi as
	4.0	En en
	6.6	Te es
	7.9	Mi an
	8.6	Te ds
	11.5	Te bs
25	1.5 am	Te as
	1.8	Mi en
	2.1	En es
	12.7 pm	Di as
	1.1	Mi as
	5.3	Te an
	6.5	En an
	6.5	Mi an
	7.3	Te bn
	10.2	Te Ecl. R
26	12.2 am	Te en
	12.4	Mi en
	12.8	En en
	1.5	Rh an
	4.0	Rh bn
	1.9 pm	Di an
	3.9	Te es
	4.1	Di bn
	4.1	Mi an
	5.3	En as
	5.9	Te ds
	7.4	Di Ecl. R
	8.8	Te as
	9.6	Di en
	10.8	Te as
	11.0	Mi en
27	3.4 am	En an
	4.4	Mi es
	8.0	Titan es
	11.9	Titan ds
	2.5 pm	Te an
	3.7	Mi an
	3.8	Titan Sh
	4.5	Te bn
	5.7	Titan bs
	7.5	Te Ecl. R
	7.8	En es
	9.5	Te en
	9.5	Titan as
	9.6	Mi en
	10.7	Di es
28	12.9 am	Di ds

March 1892.		
	2.1	En as
	3.0	Mi es
	4.2	Di bs
	1 2 pm	Te es
	2.1	Rh bs
	2.3	Mi an
	3.2	Te ds
	4.6	Rh as
	6.1	Te bs
	6.6	En en
	8.1	Te as
	8.2	Mi en
29	1.6 am	Mi es
	1.1 pm	Di Ecl. R
	1.8	Te bn
	3.2	Di en
	4.8	Te Ecl. R
	6.7	Te en
	6.9	Mi en
	9.1	En an
30	12.3 am	Mi es
	3.5	En en
	12.5 pm	Te ds
	1.6	En es
	1.8	Rh an
	3.4	Te bs
	4.4 pm	Di es
	4.4	Rh bn
	5.4	Te as
	5.5	Mi en
	6.6	Di ds
	7.9	En as
	8.4	Rh Ecl. R
	9.8	Di bs
	10.8	Rh en
	11.9	Mi es
	12.0	Di as
31	2.2	Te Ecl. R
	4.6	Te en
	4.1	Mi en
	9.5	Mi es
	10.4	En es
April 1892		
1	1.2 am	Di an
	3.4	Di bn
	3.4	Mi as
	2.7 pm	Te as
	2.7	Mi en
	2.9	En an
April 1892.		
	8.0	Rh es
	8.1	Mi es
	9.2	En en
	10 5	Rh ds
2	2.0 am	Mi as
	2.4	Rh bs
	12.2 pm	Di ds
	1.3	Mi en
	1.8	Te en
	1.7	En as
	3.5	Di bs
	5.7	Di as
	6.7	Mi es
	11.8	En an
3	12.6 am	Mi as
	4.2 pm	En es
	5.3	Mi es
	6.8	Di an
	9.0	Di bn
	10.5	En as
	11.2	Mi as
4	12.5 am	Di Ecl. R
	2.1	Rh an
	2.5	Di en
	3.7	Te an
	1.7 pm	Titan an
	3.0	En en
	3.9	Mi es
	5.6	Titan bn
	9.9	Mi as
	(11.5	Titan dn)
	11.6	Titan Ecl. R
5	1.1 am	En es
	2.4	Te es
	3.3	Mi an
	3.4	Titan en
	3.7	Di es
	2.6 pm	Mi es
	5.5	En an
	8.5	Mi as
	11.9	En en
6	1.0 am	Te an
	1.9	Mi an
	3.0	Te bn
	2 7 pm	Di bn
	2.7	Rh bs
	4.3	En as
	5.3	Rh as
	6.2	Di Ecl R
April 1892.		
	7.1	Mi as
	8.2	Di en
	11.7	Te es
7	12.5 am	Mi an
	1.7	Te ds
	5.7 pm	Mi as
	6.8	En es
	9.3	Di es
	10.3	Te an
	11.1	Mi an
	11.5	Di ds
8	12.3 am	Te bn
	1.2	En as
	2.8	Di bs
	3.4	Te Ecl. R
	2.5 pm	Rh an
	4.3	Mi as
	5.0	Rh bn
	5 6	En en
	9.0	Te es
	9.4	Rh Ecl. R
	9.7	Mi an
	11.0	Te ds
	11.5	Rh en
9	1.9 am	Te bs
	1.8 pm	Di en
	2 9	Mi as
	7.6	Te an
	8.2	En an
	8.3	Mi an
	9.6	Te bn
10	12.7 am	Te Ecl R.
	2.2	Mi en
	2.5	Te en
	2 5	En en
	3.0 pm	Di es
	5.2	Di ds
	6.2	Te es
	6.9	En as
	6.9	Mi an
	8 2	Te ds
	8.5	Di bs
	8.6	Rh es
	10.7	Di as
	11 2	Te bs
	11.2	Rh ds
11	12.9 am	Mi en
	1.2	Te as
	3.1	Rh bs
April 1892.		
	4.9 pm	Te an
	5 6	Mi an
	6.9	Te bn
	9.5	En es
	10.0	Te Ecl R
	11.5	Mi en
	11 8	Di an
	11.8	Te en
12	2.0 am	Di bn
	5.7	Titan es
	9.5	Titan ds
	1.9 pm	En an
	3.0	Titan Sh
	3.3	Titan bs
	3.5	Te es
	4.2	Mi an
	5 5	Te ds
	7.2	Titan as
	8.3	En en
	8.5	Te bs
	10.1	Mi en
	10.5	Te as
13	2.8 am	Rh an
	2 1 pm	Di bs
	2.2	Te an
	2.8	Mi en
	4.2	Te bn
	4.3	Di as
	7.4	Te Ecl. R
	8.7	Mi en
	9 1	Te en
	10.8	En an
14	2.2	Te ds
	3 2	En es
	5.5	Di an
	5.7	Te bs
	7.3	Mi en
	7.7	Di bn
	7.7	Te as
	9 6	En as
	11.3	Di Ecl R
15	12.7 am	Mi es
	1.2	Di es
	3.4 pm	Rh bs
	4.7	Te Ecl R
	5.9	Mi en
	6.0	Rh as
	6.4	Te en
	11.3	Mi es

Occultations of Stars by the Planets.

Date		Central Time of Conjunction. h	m	Diff. of Decl. "	Maximum Duration. m	Magnitude of Star.
			STARS NEAR VENUS.			
Apr.	1	8	16 P. M.	+ 70	6.7	9.4
	4	7	00 "	− 28	7.0	9.4
	10	11	18 A. M.	− 35	7.5	9.2
	11	9	53 "	+ 3	7.6	8.5
	11	10	03 "	+ 18	7.6	6.5
	27	2	27 P. M.	+ 43	9.4	9.3
	29	2	44 A. M.	− 53	9.6	9.0
			STARS NEAR MARS.			
Apr.	6	5	16 P. M.	+ 24	6.1	9.0
	9	3	23 A. M.	− 4	6.2	9.0
	17	1	39 P. M.	− 27	7.0	9.5
	20	9	27 "	+ 52	7.3	9.5
	22	6	46 A. M.	− 63	7.5	9.0
	23	12	54 A. M.	+ 21	7.5	9.5
	26	6	07 P. M.	+ 42	7.9	9.2
			STARS NEAR SATURN.			
Apr.	5	6	30 P. M.	+ 9	1.8^h	9.3

Occultations Visible at Washington.

Date 1892.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h	m	Angle f'm N pt. °	EMERSION Washington M. T. h	m	Angle f'm N pt °	Duration. h	m
Apr. 1	κ Tauri..............	6	8	28	13	8	48	338	0	20
4	ω^2 Cancri..........	6	9	46	99	10	56	301	1	10
7	*i* Leonis.............	6	7	51	164	8	56	260	1	05
10	γ^1 Virginis........	3	6	54	202	7	05	220	0	11
10	38 Virginis........	6	16	08	173	16	48	247	0	40
12	Uranus..............		11	48	126	13	14	311	1	26
15	25 Scorpii..........	6½	16	16	111	17	43	273	1	27
29	125 Tauri........	6	9	42	114	10	28	248	0	46

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A................$0^h\ 52^m\ 32^s$
Decl.................$+81°\ 17'$
Period............$2d\ 11^h\ 50^m$

Apr. 1	8 P. M.
6	8 "
11	7 "
16	7 "
21	7 "
26	6 "

S ANTLIÆ.

R. A................$9^h\ 27^m\ 30^s$
Decl.................$-\ 28°\ 09'$
Period............$0d\ 07^h\ 47^m$

Apr. 1	8 P. M.
2	8 "
3	7 "
10	10 "
11	9 "
12	9 "
13	8 "
14	7 "
15	7 "
21	10 "
22	9 "
23	9 "
24	8 "
25	7 P. M.
26	7 "

δ LIBRÆ.

R. A...............$14^h\ 55^m\ 06^s$
Decl................$-\ 8°\ 05'$
Period............$2d\ 07^h\ 51^m$

Apr. 1	midn.
8	"
15	"
22	11 P. M.
29	11 "

U CORONÆ.

R. A...............$15^h\ 13^m\ 43^s$
Decl ....$+\ 32°\ 03'$
Period............$3d\ 10^h\ 51^m$

Apr. 9	4 A. M.
16	2 "
22	midn.
29	9 P. M.

U OPHIUCHI.

R. A...............$17^h\ 10^m\ 56^s$
Decl...............$+\ 1°\ 20'$
Period.......... $0d\ 20^h\ 08^m$

Apr. 4	2 A. M.
4	11 P. M.
9	3 A. M.
9	11 P. M.
14	4 A. M.

U OPHIUCHI CONT.

Apr. 14	midn.
19	5 A. M.
20	1 "
24	6 "
25	2 "
25	10 P. M.
29	7 A. M.
30	3 P. M.
30	11 "

Y CYGNI.

R. A...............$20^h\ 47^m\ 40^s$
Decl................$+\ 34°\ 15'$
Period...........$1d\ 11^h\ 56^m$

Apr. 3	6 A. M.
6	6 "
9	6 "
12	6 "
15	6 "
18	6 "
21	6 "
24	5 "
27	5 "
30	5 "

A Total Eclipse of the Sun April 26.—This will be visible as a total eclipse only in the South Pacific Ocean. Partial phase visible on the western coast of South America. The conditions of the eclipse render it of practically no scientific interest.

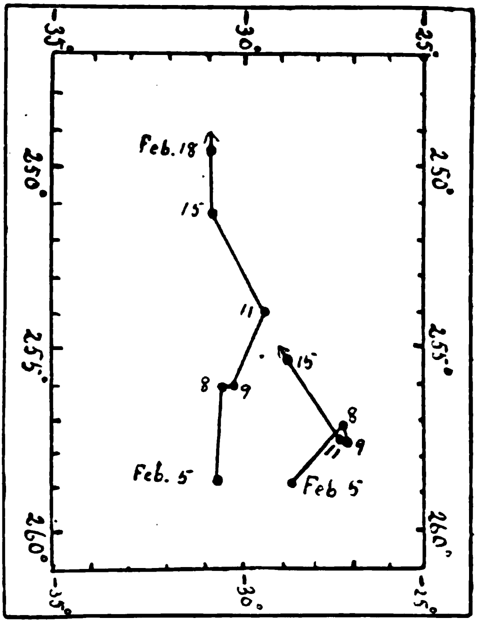
Two New Nebulæ. While looking for Winnecke's comet on Feb. 24 and 24 I came across two nebulæ which are not given in Dreyer's New General Catalogue. Both are very faint and can only be seen with large telescopes. Their approximate positions are:

	R. A.	Decl.
1	$13^h\ 03^m\ 20^s$	$+\ 21°\ 37'.6$
2	12 54	$+\ 22$ 26

In the same vicinity is the bright nebula M 64 = N. G. C. 4826, which the beginner in comet-seeking must not mistake for a comet. H. C. W.

A Great Sunspot. On Feb. 4, one of the largest sunspots which has been seen for many years, appeared on the east limb of the Sun. A few days later it was easily seen without the aid of a telescope, by protecting the eye with colored glass. Measures of a photograph taken Feb. 11 when the spot was nearest the center of the Sun's disk give for the dimensions of the large single penumbra 72,000 by 33,000 miles, while the total disturbed area was 135,000 miles long and 80,000 miles wide.

The Sun was photographed at Goodsell Observatory on the dates Feb. 5, 8, 9, 11, 15, 16 and 18, by Mr. A. G. Sivaslian, a student in advanced astronomy and mathematics, who has charge of the work of taking daily photographs of the Sun. On the first of the above dates, the spot was quite near the east limb of the Sun and on the last date part of the spot was actually on the west limb. From measures of these photographs we have calculated the latitude and longitude of the two principal black centers of the spot on the several dates. These are platted in the diagram, and indicate considerable motion in both centers, both moving backward in longitude, the one about twice as fast as the other.



				A.		B.	
		Central Time.		Longitude.	Latitude.	Longitude.	Latitude.
		h	m	°	°	°	°
Feb.	5	12	16	258.7	—28.7	258.8	—30.7
	8	4	12	257.1	—27.2	256.0	—30.5
	9	12	36	257.7	—27.1	256.0	—30.2
	11	12	37	257.5	—27.2	254.0	—29.4
	15	12	33	255.4	—28.8	251.2	—30.9
	16	12	48	255.4	—29.4	250.4	—31.0
	18	12	24			249.6	—30.9

The photograph of Feb. 16 was overlooked when the diagram was made.

Relative to a point half way between them the spots in ten days revolved through an angle of about 75° in the direction of the motion of the hands of a clock. It is evident from an inspection of the series of photographs that the large penumbra revolved with the two umbræ, but that the small outlying spots did not share in the rotary movement.

In the spectrum of the spot the C line was plainly reversed in many portions of the spot. In the north following portions of the two principal umbræ, on Feb. 15, the C line was very brilliantly reversed. In the D and F lines also the reversal was easily noticed. On Feb. 16 a photograph was taken of the H and K regions of the spot spectrum of the fourth order. This photograph shows H and K with a fine reversed line in each extending across the whole width of the spot spectrum.

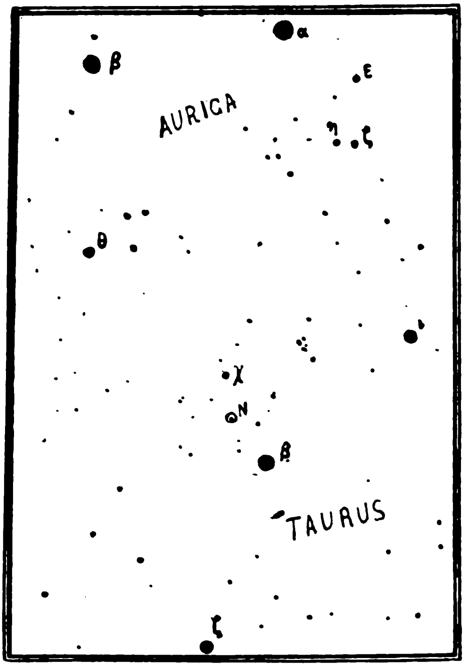
In looking over our photographs during January I find that the birth of this group of spots occurred between Jan. 15 and 18. On the 15th there was a single round spot in longitude 276°, latitude — 24°, with no others in the vicinity. On the 18th, a new group of very prominent spots was photographed just east of this spot. The movement of the new spots is well shown by the following measures:

			a.		*b.*	
			Longitude.	Latitude.	Longitude.	Latitude.
	h	m	°	°	°	°
Jan. 18	12	05	268.1	— 24.9	260.6	— 26.5
19	12	06	267.4	— 26.0	259.9	— 27.6
20	12	56	265.9	— 26.4	258.2	— 27.9

We may expect the spot to appear again on the east limb of the Sun about March 1.

H. C. W.

The New Star in Auriga. The most noticeable astronomical event of the past month was the discovery of a new star of the fifth magnitude in the constellation Auriga. This discovery appears to have been made by one who was not a professional astronomer, and who was unwilling to give his name. For a description of the new star and its spectrum we refer the reader to the articles by Messrs. Pickering, Crew and Hale, pp. 233, 228, and 231. The accompanying diagram, showing the position of the new star with reference to the principal stars of Auriga and the horns of Taurus, will enable the amateur to readily identify the star with an opera glass. It is about 2° northeast of the second magnitude star, *β* Tauri, at the point marked N in the diagram.



This region of the sky was photographed at Goodsell Observatory, Feb. 25, with a camera and Darlot projecting lens of 2½-inches aperture. The exposure was one hour with a Seed plate No. 26. On this plate the new star is almost exactly equal to *χ* Aurigæ and brighter than 26 Aurigæ.

The Aurora of Feb. 13, 1892.—This was noticed at Northfield at 6:20 P. M., and lasted until 7:20. The dark arch was about 40° high. The bright arch extended to 60° and at times to 85° altitude. The color of the auroral light was a beautiful pink during most of the time. At first there were streamers converging toward the zenith but these soon disappeared.

Mr. W. E. Woods, of Washington, D. C., reports spectroscopic observations of the aurora. He found four bright bands on a faint contintous spectrum. The most brilliant was in the red about where C should be, and could be seen with a very narrow slit. The second was in the beginning of the green and was strong with a narrow slit. The third was in the blue and the fourth, very faint, in the violet. H. C. W.

COMET NOTES.

Tempel's First Periodic Comet (1867 II). In *Astr. Nach.*, No. 3075, Mr. R. Gautier gives a search-ephemeris for Tempel's first periodic comet, which is due at perihelion about the first of April. We give below those parts of the ephemerides which apply to the months of March and April. This comet has been observed at three apparitions, 1867, 1873 and 1879, but escaped detection in 1885, because of its very unfavorable position. The time of its perihelion passage is somewhat uncertain, because of the effect of perturbations by Jupiter in 1881 and 1882, which according to Gautier increased the period from 5.98 to 6.51 years. In calculating his ephemerides Mr. Gautier has taken account of the perturbations by Jupiter from 1885 to 1892, obtaining thus corrections to the elements adopted by him for the apparition of 1885. The elements for 1892 are:

$$
\begin{aligned}
T &= 1892 \text{ April } 3.5 \text{ Berlin M. T.} \\
\omega &= 168^\circ\ 58'\ 10.8'' \\
\Omega &= 72\ \ 33\ \ 42.2 \\
i &= 10\ \ 50\ \ 27.8 \\
\varphi &= 23\ \ 53\ \ 57.0 \\
\mu &= 545.0''
\end{aligned}
\quad
\left.\begin{matrix} \\ \\ \\ \end{matrix}\right\} 1892.0
$$

Because of the uncertainty of the time of perihelion passage Mr. Gautier has computed three ephemerides, adopting as the dates of perihelion March 24.5, April 3.5 and April 13.5, and giving the preference to the middle date.

The position of the comet is a little more favorable than in 1885. It must be looked for in the morning in the south-eastern part of Ophiuchus, and north-western part of Sagittarius. This region is a part of the Milky Way, and the nebulous back-ground of the sky will doubtless make it difficult to find the comet.

Search Ephemeris for Comet 1867 II (Tempel's Periodic Comet.)

Perihelion = April 3.5.

1892.		R. A.		Decl.		log *r*.	log Δ
		h	m	°	′		
March	11	17	24.1	− 18	58.3	0.3184	0.2605
	16	17	32.2	19	21.5		
	21	17	39.9	19	44.4	0.3173	0.2333
	26	17	47.2	20	07.1		
	31	17	54.0	20	30.0	0.3169	0.2055
April	5	18	00.3	20	53.6		
	10	18	06.1	21	18.1	0.3170	0.1773
	15	18	11.2	21	43.9		
	20	18	15.6	22	11.3	0.3177	0.1194
	25	18	19.6	22	40.7		
	30	18	22.4	− 23	12.3	0.3189	0.1227

		Perihelion = March 24.5.				Perihelion = April 13.5			
		R. A.		Decl.		R. A.		Decl.	
		h	m			h	m	°	′
March	11	17	40.1	− 20	04	17	07.6	− 17	43
	21	17	57.0	20	47	17	22.2	18	30
	31	18	12.3	21	29	17	35.0	19	18
April	10	18	25.6	22	14	17	45.5	20	08
	20	18	36.8	23	03	17	53.4	21	03
	30	18	45.2	− 24	00	17	58.2	− 22	06

Brorsen's Short Period Comet. Mr. George A. Hill, in the last issue of your periodical (January 1892), gives some remarks on Brorsen's comet which require an answer.

Mr. Hill is "positive" that some errors have inserted themselves into Professor Schulze's calculation in *Astr. Nachr.*, vol. 93. page 177. But I found, as early as 1879 (*Astr. Nachr.*, vol. 95, page 45), that a slight variation of the perihelion time brought Schulze's elements very near to the observed path of Brorsen's comet in 1879. Dr. Wittstein in trying the same (*Astr. Nachr.*, vol. 94, page 351), was not even as much successful. Indeed, his ephemeris required, after some weeks, as great corrections as Professor Schulze's former calculation. You may judge from the following table of deviations (Obs.—Calc.):

		Schulze.		Wittstein.		Lamp.	
1879		$\varDelta\alpha$	$\varDelta\delta$	$\varDelta\alpha$	$\varDelta\delta$	$\varDelta\alpha$	$\varDelta\delta$
		s	′	s	′	s	′
April	20	− 1	− 39	+ 54	− 17	+ 1	0
	25	− 28	− 42	+ 42	− 25	+ 1	0
	30	− 89	− 44	− 5	− 34	+ 1	− 1
May	5	− 199	− 41	− 114	− 41	+ 1	− 1
	10	− 329	− 32	− 302	− 39	− 1	− 1
	15	− 395	− 19	− 462	− 28	− 3	− 1
	20	− 370	− 6	− 501	− 13	− 6	− 1

Moreover, Dr. Wittstein's calculation, which is based on two observations, 1879, March 19th, and March 26th, (only seven days apart from each other), brings the comet in 1873, *toto cœlo* apart from the observed places, whereas Schulze and Lamp are in conformity to them. Nor was it Dr. Wittstein's purpose to give anyhow definitive elements.

May I ask Mr. George A. Hill to forward the publication of the results of his own work? E. LAMP.

KIEL, STERNWARTE, 1892, Feb. 2.

Search Ephemeris for Comet Brooks, 1886 IV.

[From Astr. Nach. 3064, continued from page 169]

		Perihelion, March 1.					Perihelion, March 31.				
		R. A.		Decl.		Light.	R. A.		Decl.		Light.
		h	m	°	′		h	m	°	′	
April	10	20	36.9	− 25	27	0.19	19	13.9	− 24	09	0.51
	20	21	06.5	− 25	28	0.19	19	46.5	− 26	06	0.53
	30	21	33.2	− 25	25	0.18	20	16.3	− 27	55	0.53
		Perihelion, April 30.					Perihelion, May 30.				
April	10	16	30.4	− 9	20	1.82	12	24.0	+ 24	06	1.11
	20	16	50.0	− 14	30	2.11	12	17.6	+ 21	10	1.28
	30	17	07.0	− 20	47	2.31	12	15.1	+ 16	55	1.42
		Perihelion, June 29.					Perihelion, July 29.				
April	10	10	03.8	+ 33	49	0.31					
	20	10	06.2	+ 31	11	0.32	9	00.4	+ 34	28	0.12
	30	10	13.2	+ 28	06	0.34	9	12.0	+ 31	39	0.12

Ephemeris of Comet *e* 1891 (Barnard Oct. 2.) As the light of this comet is diminishing rather slowly and the comet will be well up in northern latitudes in March, I have computed an ephemeris from Campbell's co-ordinates in hopes it may be recovered and receive observation.

G. M. T.	App. R. A.			App. Dec.		Log. *r*.	Log. Δ	Br.
	h	m	s	°	′			
Feb. 29.5	16	22	18	− 22	2	0.2983	0.2211	0.12
Mar. 1.5		21	53	21	36			
2.5		21	25	21	10			
3.5		20	54	20	44			
4.5		20	22	20	18	0.3089	0.2155	0.12
5.5		19	46	19	51			
6.5		19	8	19	24			
7.5		18	29	18	57			
8.5		17	47	18	30	0.3193	0.2103	0.12
9.5		17	3	18	2			
10.5		16	17	17	34			
11.5		15	28	17	6			
12.5		14	37	16	37	0.3294	0.2055	0.11
13.5		13	44	16	9			
14.5		12	48	15	40			
15.5		11	50	15	11			
16.5		10	50	14	41	0.3392	0.2014	0.11
17.5		9	47	14	12			
18.5		8	42	13	42			
19.5		7	35	13	12			
20.5		6	26	12	42	0.3488	0.1982	0.11
21.5		5	15	12	12			
22.5		4	3	11	41			
23.5		2	48	11	10			
24.5		1	32	10	40	0.3582	0.1961	0.10
25.5	16	0	14	10	9			
26.5	15	58	54	9	38			
27.5		57	32	9	7			
28.5		56	8	8	36	0.3674	0.1952	0.10
29.5		54	42	8	5			
30.5		53	14	7	34			
31.5	15	51	44	− 7	2			

O. C. WENDELL.

HARVARD COLLEGE OBSERVATORY, Feb. 13, 1892.

NEWS AND NOTES.

This number is a few days late because we waited for information concerning the new star in Auriga, and for tardy proofs.

In the February number of *The Observatory* is found a biographical sketch of Sir George Biddell Airy, accompanied by a beautiful photograph which was taken on his 90th birthday. It is fittingly made the frontispiece.

Remounting the 26-inch Equatorial at Naval Observatory. Messrs. Warner & Swasey, Cleveland, Ohio, have been awarded, by government officers, the contract for re-mounting the 26-inch equatorial, preparatory to its transfer from the old to the new Naval Observatory.

An Improvised Chronograph. Being desirous of making some record of occultations during the total eclipse of the Moon Nov. 15, I used the following arrangement for a chronograph. A good spring telegraph register was put in circuit with a clock and with a key at the observing telescope. To avoid the friction of a spring contact a very light strip of platinum foil was attached to the lower part of the pendulum bob, and was made to swing through two drops of mercury which formed the terminals of the battery circuit. A second's mark was thus made on the paper about two millimeters long. The paper moved nearly four centimeters per second. An extra second hand on the axis of the escape wheel of the clock caused the tilting of a light lever once in a minute, which made another mercury contact, and this made a minute mark on the paper about 8 mm. long which was easily distinguished from the second's mark. An attendant marked with a pencil every five minutes the hour and minute opposite the minute mark.

The record of observation being made in 6 Morse letters there was no chance for ambiguity in interpreting the record except a short mark should have occurred *in* a minute mark. Even coincidence of a dot with a second's mark would hardly ever be so perfect that it could not be separated by careful spacing and measurement. The motion of the register was found to be quite uniform, so that a few measurements before and after a record would scarcely show any variation and the length would serve to decipher a record and fix the instant within one-fortieth of a second.

Given the exact local time, and a good clock and the personal equation, and very good work might be done with such apparatus. S. H. BRACKETT.

The Proper Motions of Stars. I recently examined the catalogue of the proper motions of the stars used by Mr. Dunkin in his computation of the position of the apex of the Sun's way (Mr. Main I believe is responsible for the catalogue) in connection with the *Draper Catalogue* of Stellar Spectra. Of the stars which I was able to identify and whose proper motion exceeded 0.2″ annually, 113 were referred in the *Draper Catalogue* to class 2 (solar stars) and only 32 to class 1 (Sirians). This result confirms generally the conclusions which I mentioned in your columns. But while a difference of 1.79 in magnitude would imply that a solar star was on the average about 2¼ times as far off as a Sirian of equal magnitude, I do not think the proper motions establish so high a ratio. Many explanations might be given of this circumstance. The solar stars may on the average have a larger mass (as seems to be the opinion of Mr. Maunder); or they may, on the average, move more slowly; or finally, there may be such an absorption of light in transmission as prevents a Sirian star from appearing as bright as a similar solar star when actually removed to 2¼ times the distance. Possibly all these causes may combine. I tried this in the case of the stars of the second magnitude (1.5 to 2.5 according to the *Harvard Photometry*) in consequence of the comparative slowness of their motions. I found as I expected that a majority were Sirians—20 Sirians to 15 Solars, more than one of the latter being marked with a query—but I further noticed that most of the Solar stars of this magnitude had a very slow motion and that their average proper motion did not exceed that of their Sirian compeers by more than 25 to 30 per cent. This proportion no doubt increases as we proceed and a faint Sirian star with large proper motion is almost unknown. Perhaps the broad distinction between Solar and Sirian stars is insufficient and that we must enter into the minute distinctions drawn in the *Draper Catalogue*. Indeed there are some startling differences in the photographic power of certain stars which even that catalogue refers to the same type. Thus β Cassiopeiæ is of magnitude 2.42 photometrically but only 3.63 photographically, whereas I find almost immediately after it a star in Pegasus (No 20 in the *Harvard Photometry*) referred to the same type (H) where the photographic magnitude is 6.58 and the photometric 6.63. And while the average brilliancy of the Sirian binary stars is much above that of the Solar binaries, γ Leonis which has a Solar Spectrum figures at the head of the list.

An interesting question is the position of the stars with spectra of the third type as regards brilliancy. As far as I am at present able to judge, they are more likely to rank above than below the Solar stars. One of Mr. Gore's double stars, 36 Andromedae, is referred, but doubtfully, to this type in the *Draper Catalogue*. Its relative brightness is 6.23 which is above the average for the Solar stars but below that of the Sirians. The same doubt exists as to π Cephei, relative brightness 11.07, though in that case the second type gets the benefit of the doubt. The average for the Sirians is over 12.0. The proper motions of stars of the third type, as far as I have examined, average more than those of the Sirians of equal magnitude but never attain the high figures which occur with some of the Solars. The evidence of their Intermediate position is indeed by no means conclusive, but it is suggestive of further inquiry. One thing that recent researches on this subject has, I think, rendered evident is that the promiscuous classing together of stars of nearly equal magnitude in such investigations as that relating to the Sun's motion in space is wholly inadmissible. The spectrum is an element of almost equal importance. W. H. S. MONCK.

DUBLIN, Jan. 9, 1892.

Manning M. Knapp was born in Bergen county, N. J., in 1823, and he was graduated from Rutgers College. He was admitted to the bar in 1846 and four years later was commissioned a Counsellor. He rapidly acquired fame as a learned lawyer and his knowledge of criminal law was so extensive that he was, in all important capital cases, assigned by the court to assist in the prosecution. When Judge Bedle was elected governor, he appointed the lawyer his successor on the bench in 1875.

Judge Knapp was re-appointed by Governor Ludlow, in 1882, and was, for a third time, appointed in 1889, by Governor Crew. On January 25th, he celebrated the seventeenth anniversary of his appointment as a supreme court judge. He expired suddenly, January 26th, while delivering a charge to the grand jury of Hudson county.

The dead man was a Democrat in politics but he was never a politician and never sought or held any elective office. He was one of the most expert judges of lenses for astronomical instruments in the country. Early in life he developed a love for the study of astronomy, but so frequently found lenses that did not suit him that he made them for his own use.

"At his home in Hackensack is a most complete workshop for the manufacture of lenses. He never sold any but frequently presented them to scientific societies. He was for years a close correspondent of Alvan Clark & Sons, the celebrated telescope lens makers, and his judgment of the quality of a lens was considered almost invaluable."—*N. Y. Tribune*, Jan. 27.

A Personal Explanation. It has occurred to me that some of your readers may possibly come across a copy of the morning's San Francisco *Examiner*, February 28, containing an article over my signature on *Astronomical Photography*, and in this event it would certainly seem strange to find that many ideas, and even certain paragraphs, are borrowed from a well known lecture by Professor Barnard of the Lick Observatory, entirely without credit. By one of those curious accidents which will sometimes happen, even in so admirably managed a daily newspaper, a line containing the proper acknowledgement was omitted, even after an insertion in the revised proof.

Of course Professor Barnard stands in need of no credit, for his work is familiar enough, even to those whose acquaintance with astronomical subjects is derived from the casual newspaper article. Therefore the present explanation is principally intended to avoid adverse criticism of the writer, should it happen that a popular article, written by a layman for the public press, fall into the hands of those qualified to detect such plagiarism. CHAS. B. HILL.

San Francisco, Cal.

Queries for Brief Answers. The following queries have been sent in by one of our subscribers. As some of them are of general interest to amateur astronomers we print them with the request that any who feel competent will send us brief answers. We cannot promise to publish all replies that may be given, but will try to select the best:

1. Has Foucault's pendulum experiment to prove the rotation of the earth on its axis ever been tried at, or near the equator, or in south latitude; and if so with what result?

2. Has the experiment of falling bodies, to prove the rotation of the earth on its axis, by deviation from a vertical line, ever been tried at the equator or in south latitude; and if so with what results?

3. How far ahead have eclipses been predicted, and where can I obtain a list?

4. Has it been proven or do astronomers generally believe that the planet Mercury rotates on his axis in the same time that he completes a revolution around the Sun?

5. In Chambers' Astronomy explaining the occurrence of a high tide on that side of the earth opposite to the Moon, it says: "It is only necessary to bear in mind that not only does the Moon attract the upper mass of water, but also the solid globe itself, which is consequently compelled to recede from the waters beneath, leaving them behind, and in a sense heaped together." This, or words to the same effect, is the explanation usually given in text-books on Astronomy and Physical Geography. Can that be explained to pupils in a simple way so that they, at least, will not be skeptical about it?

6. Who was it that said, "The undevout astronomer is mad?" G. I. H.

Government Astronomer H. C. Russell at Sydney, Australia, has favored Goodsell Observatory with a number of valuable papers on Astronomical themes as follows:

On the Nebula and Stars about η Argus, March 1871.
The Colored Stars about Kappa Crucis, May, 1872.
Double Stars Results, 1871—1881.
Some Double Stars and Southern Binaries, June 2, 1880.
Recent Changes in the Surface of Jupiter, December 1, 1880.
Transit of Mercury, Nov. 8, 1881, December 7, 1881.
New Double Stars September 5, 1883.
On the Increasing Magnitude of Eta Argus, June 6, 1888.
On Some Celestial Photographs Recently taken at Sydney Observatory, November, 1890.
On an Electrical Control for Driving Clocks, November, 1890.
On Some Photographs of the Milky Way, Recently Taken at Sydney Observatory, Aug. 1890.
Results of Double Star Measures, 1891.
Preparations Now Being Made in Sydney Observatory for the Photographic Chart of the Heavens, July 1, 1891.
Notes on Some Celestial Photographs Recently Taken at the Sydney Observatory, Sept. 26, 1891.

Camden Astronomical Society. At the regular meetings the Camden Astronomical Society held during last year, the following papers were read—

The Astronomy of the Ancients—Rev. Chas. Bowden.
The Manufacture of Astronomical instruments—A. B. Depuy.
Greenwich Observatory—H. H. Furness, Jr.
Personal Equation in Double Star Observation—Professor F. P. Leavenworth.
The Law of the Sun's Rotation and the Periodicity of Sun Spots—a translation from the German of Dr. F. Wilsing—Professor E. S. Crawley.

Mr. A. B. Depuy having moved from the city he tendered his resignation as secretary and Mr. H. H. Furness, Jr., was elected to fill the vacancy. R.

Meeting of the Astronomical Society of the Pacific, Jan. 30, 1892. The first meeting of the year was held in the lecture hall of the California Academy of Sciences, and was very largely attended. At the meeting of the directors held in the Society's rooms immediately before the regular meeting thirty-eight candidates were duly elected to membership, as follows:

A. B. Alexander, Richard H. Allen, W. S. Andrews, F. R. Bissell, Miss Mary E. Byrd, Miss Caroline A. Clark. Charles A. Crackbon, Frank H. Dickey, Charles R. Eastman, Geo. Stuart Forbes, Charles Graves, T. P. Gray, Alva J. Grover, Stephen M. Hadley, H. S. Herrick, John R. Lewis, J. A. Lighthipe, Marsden Manson, David Miller, James Moore, Chas. Nordhoff, Miss Clara A. Pease, Thomas Porter, M. Reimans, George A. Ross, John R. Ruckstell, Roger Sprague, Miss Henrietta Strong, Mrs. Wm. Emerson Strong, C. L. Taylor, Senor Enrique Toriella, Professor L. W. Underwood, Professor L. G. Weld, James A. Wilson, Wm. C. Bonsfield, Adolph Lietz, Professor Wm. Lymmons, Joseph C. Sala.

At the regular meeting President Pierson presided. The thanks of the Society were voted to the California Academy of Sciences for the free use of the auditorium. A number of presents were announced by the secretary, who called attention to the beautiful colored lithograph of the partially eclipsed moon of November, 1888, drawn by Professor, Weinek, of Prague, who had presented the society with 1,000 copies for the Publications of the Society.

The following papers were presented:

a. The Rotation of the Sun (translation from the German of Dr. Schmidt) by A. C. Behr, of Chicago.
b. Pogson's Comet and the Bielan Meteors, by W. H. S. Monck, of Dublin, Ireland.
c. The McKim Observatory, by Professor W. V. Brown, of Greencastle, Ind.
d. When shall we have Another Glacial Epoch? by Garrett P. Serviss of New York City.
e. The total Eclipse of the Moon, January 28, 1888, by Professor Weinek, of Prague (translated by F. R. Ziel, San Francisco).
f. Lantern Slide Exhibition, Lecture by W. W. Campbell of the Lick Observatory.

The President appointed the following committees to report at the annual meeting March 26th.

A committee to nominate Directors and publication committee: Messrs. José Costa, F. H. McConnell, Hon. Arthur Rogers, Harry Durbrow and Edward R. Young.

A committee to audit the accounts of the treasurer: Messrs. M. M. O'Shaughnessy, Otto Von Geldern and F. W. Zeile. The hall was then darkened and seventy-five lantern slides exhibited by Professor Campbell illustrating the methods and results of the Lick and other Observatories.

The president announced that a branch of the society was being organized in Pittsburg similar to the Chicago branch.

The meeting then adjourned.

CHARLES BURCKHALTER, Secretary.

Astronomy and Astro-Physics.

NEW SERIES NO. 4. APRIL, 1892. WHOLE NO. 104.

GENERAL ASTRONOMY.

ON A SIMPLE MOUNTING FOR A LARGE TELESCOPE IN THE FIELD DURING ECLIPSE OBSERVATIONS.*

PROFESSOR FRANK H. BIGELOW.

The importance of obtaining suitable observations on the phenomena exhibited by the solar corona during eclipses is becoming more pressing than ever, in the interests of the development of some branches of cosmical science. The value of any photograph of the corona depends upon the amount of structural detail that can be found on a picture of comparatively large linear dimensions. Since the diameter of the image of the Sun on the plate is a direct function of the focal length of the object glass of the camera, in order to obtain any picture in which the Sun's disk will be represented by a circle one-half inch in radius, or more, it will be necessary to mount a large telescope at the station of observations. Those who have tried it know very well the difficulty and cost of transporting the heavy mounting, the clock work and tube to the place, to say nothing of the labor of setting up the same on any proper foundations.

An attempt was made to solve this problem practically, in the late eclipse expedition to West Africa, December 22, 1889, and I propose to give in this paper an outline of the plan, in order that those preparing for the eclipse of April, 1893, may be able to avail themselves of the results of such experience. This anticipation of the regular report of the expedition is with the consent of the Director, Professor D. P. Todd.

It is not proposed at this time to consider the optical qualifications of the telescope employed, or the best focal length that should be adopted, these questions being left to the members of an expedition. The mounting to be described was applied successfully to an object glass having a focal length of nearly forty feet, and in spite of the weight of the apparatus, which was of course considerable for so long a tube, it showed that it could be

---

* Communicated by the author.

controlled to follow the afternoon or descending path of the Sun with a precision and steadiness seldom excelled in the best fixed instruments of a regular Observatory.

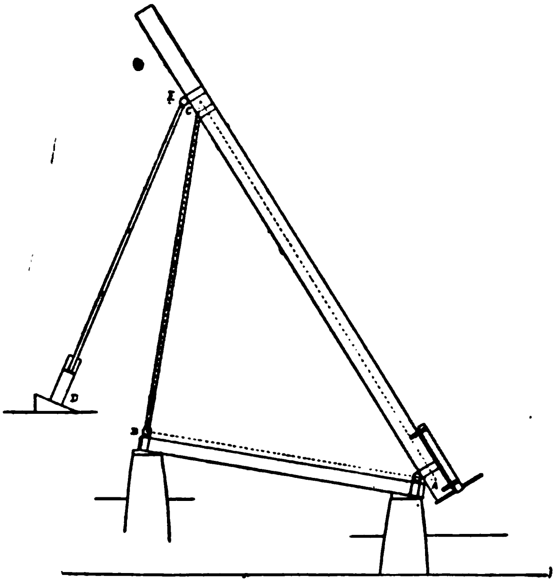


FIGURE 1.

The accompanying diagram presents the principle of the apparatus, and nearly explains itself. The essential geometrical idea involved in the equatorial telescope is that of a triangle, whose base is parallel to the axis of rotation of the earth, revolving about its base, the hypothenuse being elevated to the angular polar distance of the object. It is necessary then to support the sight line of the telescope at the proper angle, and provide for its rotation about the base fixed at elevation of the pole, and in the plane of the meridian. The dotted lines represent such a triangle.

The sight line, AC, is determined by the optical axis of the object glass; the base, AB, by the position of the axis of rotation; and the altitude BC by the value of the angle BAC, the polar distance of the Sun at the time of observation. The circles A,B,E, indicate a set of ball and socket joints, allowing free motion in any direction; C is a plane joint admitting motion only in the plane of the meridian. A and B are attached by clamp collars to a cylindrical iron tube, which rests upon cast iron forms holding the tube and anchor plates. For piers there were used a set of oak iron-bound casks, filled with stone and cement, in which were embedded the anchor plates, suspended at some distance below the castings by four strong iron bolts. The contraction of the casks at the top, when once filled with the cemented material, kept the tops of the foundations in place, whenever subjected to strong lateral pressure, as was the case when the angle BCD had a considerable value. The use of casks in the field is recommended for these purposes; they serve in transportation, and permit the employment of loose stones and dirt mixed with cement in place of good brick or stone; they are much more quickly constructed and stand more wear and tear than any built up pillar piers; and they can be repacked for transportation, the only expense having been the cement.

Ball joints are needed at the points A,B,E, to preserve free motion of the sight line; they consist of solid iron spheres, which receive two sets of abutting screws at right angles. At C, the joint must be strong and constructed to prevent any rotation of the telescope about its axis of collimation, or else the position angles will need a correction. The thrust of the rod DE against the joint C effectually prevents such motion. We had the rod BC trussed with three rods running from end to end, elevated at the middle by three arms. The telescope was also supported against flexure by five such rods from A to C.

The rod BC, therefore, being stiff, could not introduce an error of rotation into the position angles, as the hour angle from the meridian increased. Near the lower part of this rod was introduced a heavy double threaded turn-buckle, by means of which, when once the length of the rod had been adjusted to produce the required angle BAC, small variations in this angle by way of adjustment could be produced. An assistant was stationed there, and by direction of the observer raised or lowered the telescope so as to bring the image of the Sun to any parallel of the photographic plate. The rod, DE, was built up of lengths, which could be rearranged for the altitudes occurring during the important phases of the eclipse, the required combination of parts being ascertained by a little computation, or by trial during the preparations for the observations. The parts were screwed together, and for this purpose it is convenient to have some bar wrenches adjusted to the size of the rod. The parts of the apparatus AB, BC, DE are hollow tubes, and ordinary two and four-inch gas pipes are strong enough for very large instruments, smaller diameters being sufficient for a twenty-foot tube. It will be observed that the method of support on the piers, by which the ends of the tube are immediately secured, instead of suspending the telescope by the center as in the Fraunhofer mounting, reduces to a minimum any tendency to vibrations from the wind, and favors photographic operations in a marked degree. One of the motives in mounting a forty foot telescope direct, instead of parallel to the horizon, as was done in the case of observations on the transit of Venus, was to avoid all the questions arising in the use of the mirror, and at the same time secure rigidity, as was done in this disposition of weights on a tripod. The distances AB, BD and AD are so great, in respect to the size of the telescope, as to favor to the utmost stability of support.

The important problem to be solved was the imparting the requisite motion in hour angle about the axis AB, without the employment of a regular clock. A sand piston was substituted for it, and the success attending its trial gives us a valuable auxiliary for all such observations. The end of the rod ED terminates in a flat circular plate, which rests upon sand in a strong piston, the cap at the top guiding the rod, the flow from the piston being controlled by a valve invented for the purpose, set into the center of the bottom, and finally the whole piston resting upon a base that allowed it to move through any conical angle produced by the action of the rod ED. The use of sand for such a purpose has given trouble heretofore by the fact its flow is not steady under ordinary conditions. The tendency is to move by jumps; the sand congests and then flows spasmodically. This is due to two causes, first the presence of moisture in the sand, which gives a viscous sort of friction, and second to the shape of the orifice which generally has been circular.

The first difficulty was overcome by heating the sand thoroughly over the fire, before using it. The moisture once having been evaporated, the movement of the sand particles becomes perfectly uniform so far as friction is concerned. The sand was from the beach, washed free from dirt and carefully screened fine, so that the grains should be as nearly of the same size as possible.

The valve and form of the orifice which overcame the second obstacle to uniform flow was constructed as follows. The diagram represents in full size the valve that was used at Cape Ledo. A brass cylindar screws into the bottom of the sand piston; near the middle, on the inside, two conical ledges project a short distance towards the center; from the bottom, carried by a screw, a longer cone projects upwards, its axis coincident with the axis of the cylinder, and its sides parallel to the sides of the fixed cone, as shown in the figure, which is a drawing of a section through the middle. By lowering or raising the cone, which can be done accurately, the passage through which the sand flows can be changed to any desired amount, up to the size of the opening between the fixed ring, or it can be closed entirely. The sand escapes through some holes into the cone which is hollow, and drops out at the bottom. It will be seen that the action of the cone is to pierce the flowing solid stream of sand at the center and convert it into a thin band in the form of an annulus. This stops the irregular action caused by congesting and freeing of the sand at a circular opening, and allows the flow to become steady and continuous. One other precaution should be taken with the sand piston, namely, the diameter must be large, about six inches, and the piston head must be free round about its edge by at least one-fourth of an inch. In this way the particles of sand work up between the piston head and the sides, forming an excellent friction surface, which works smoothly; and by having a large column of sand, there is no chance to congest under pressure as it falls away with the load. It was surprising to see how readily the sand piston carried a varying weight, ranging from 100 to 800 pounds, with apparently no impression upon the rate of speed as controlled by the valve. This speed was also sensitive to a half or even a sixteenth of a revolution of the cone, showing that the sand acts practically like a solid moving column. With this arrangement the Sun could be maintained tangent to the reticle threads for a considerable length of time. The pot used was about 2½ feet long and gave an effective flow to the forty-foot telescope for eighteen minutes, which was ample time to take all the pictures desired of any phase of the eclipse.

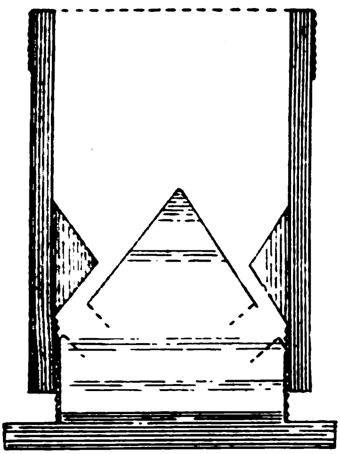


FIGURE 2.

Regarding the adjustment of the polar axis in altitude and azimuth, it is to be observed that the long rod of support, BC, lends itself to this purpose, by reason of the large triangle, ABC, of which it is a part. Calculating the angle BAC for any date, and the length of the rod corresponding, it is necessary simply, having made the end A fast, to set the telescope on the Sun at noon by raising the end B over the pier, and again on the same day near the horizon for the azimuth. Or if preferred, by following the Sun during a given hour angle and observing the change in the length of the rod BC, as shown by the turns in the buckle, an easy computation will give the resolved part of this change in altitude and azimuth. For eclipse work, it would be hard to conceive a more expeditious way to set up accurately and firmly a large telescope than the one described. Instead of using sand, it might be, on some accounts, better to have an hydraulic piston and then by making the rod ED available at two points D and D′, one for raising and the other for lowering the telescope, it would be equally useful for forenoon and afternoon observations. At Cape Ledo the total eclipse occurred at 3 o'clock in the afternoon.

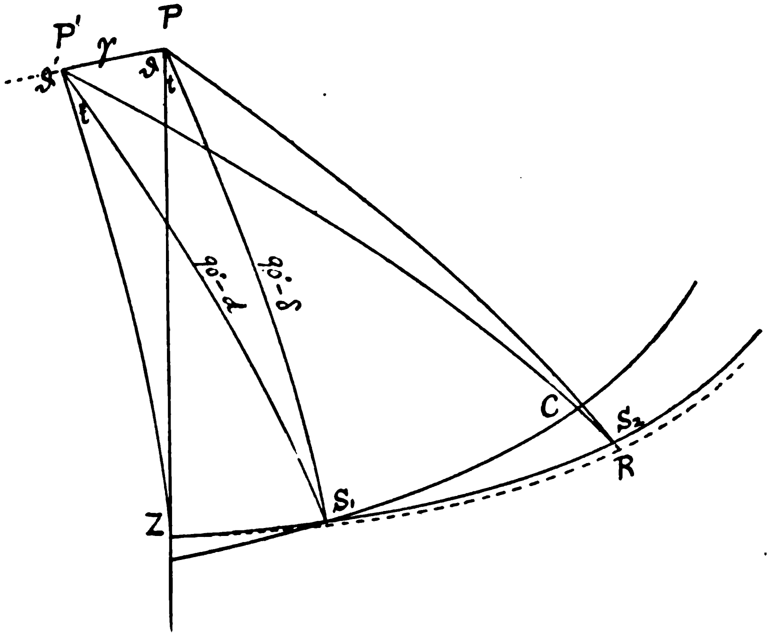


FIG. 3.

The instrumental corrections were easily obtained by the method which is indicated briefly at this time. In fig. 3 let P represent the true south celestial pole, P′ the instrumental pole, that is the intersection of the line AB with the celestial sphere, PZ the meridian, Z being the point at which the Sun crosses it; let S_1 represent the place of the Sun on its true path ZS_1S_2, at the hour angle t, or t' by the instrument; the dotted line ZR is the apparent path as modified by the action of refraction. Let ϑ, γ, be the co-ordinates of P′ as referred to P,$PS_1 = 90° - \delta$ the true pola distance, and $P'S_1 = 90°-d$ the instrumental polar distance. The component of refraction resolved from the zenith altitude into the direction of the pole will give the point S_2 relatively to R at the time of an observation. Suppose at any time, t, the Sun is seen at S_1, then $90°-\delta$ is known from the Almanac, and $90° - d$ by computation from the triangle ABC. It is necessary once for all to measure accurately these linear distances, the great size of the triangle making it easy to secure the angles very exactly. At another time, t_2, the Sun appears at S_2, and the telescope is brought upon it by changing the length of the rod BC. This variation being found by counting the movement of the threads at the turn buckle. Hence by means of this variation and the linear distance AC, we compute the angular change CS_2. Now $S_1C = (t_2 - t_1) \cos \delta$, S_1CS_2 is a right spherical triangle, and the angle CS_1S_2 can be found, this being also the angle PS_1P'. Thus three parts of the triangle PS_1P' are known, and we obtain the required γ, ϑ, which can be readily changed into difference of altitude and azimuth of the instrumental pole. The linear dimensions of the triangle ABC and the variation of BC between two observations, are sufficient to determine the position of the instrument. The temperatures may be reduced to a standard temperature by introducing a coefficient of expansion for the tubes; it is best to take the two observations about three hours apart; a standardized steel tape, measuring the distances between proper marks on the tubes, the marks being referred to the inaccessible points, A, B, C, by suitable methods, will give us the linear dimensions at any time with great accuracy.

In the mounting of the telescope for eclipse observations, the objects aimed at were a minimum of expense and a maximum of stability; in the construction of the photographic apparatus it was attempted to secure invariable actinic conditions and rapidity of exposure during totality. We had an opportunity to test the same during the phases, but the totality was wholly obscured by clouds. The diagram (Fig. 1), shows the general position of the parts. A strongly built finding telescope is firmly attached to the main tube by ring struts, which carry abutting screws for adjustment. The axes of these telescopes are made parallel; the finder is used for viewing the region of the sky operated upon and for fixing the position of the camera. This consists of a large plate of plane glass, the surfaces being parallel planes, bound about by a thin brass ring, one-half an inch in width, one edge carrying a lip flange against which the plate is cemented with shellac. This plate is pierced at the center, receives and is screwed to a hollow axis with wide flange, this axis fitting and revolving upon the finder, so that the plate itself turns in front of the large telescope. In this way there is a wide annular surface of the plate that is available for photographic purposes in front of the field, successive circular surfaces being taken by turns, as the plate is moved from step to step. We used a 22-inch plate which gave ten 4½-inch circles without overlapping. The portion of the plate, on the side opposite to the objective, was spread over with radii and concentric circles ruled by a diamond, which referred any portion of this surface to co-ordinates whose origin is the axis of rotation. It is particularly to be observed that the focal plane, once secured by adjusting the finder in its bearings, is maintained constant throughout the observations, and that the surface of the plate, being perpendicular to the axis of the finder, is always also perpendicular to the optical axis of the objective, two conditions of great importance. Thus far we have described the essential features of the apparatus, the further process of manipulation depending upon the resources and the tastes of the observer.

Our photographic film was spread upon large circular plates, fitting inside the brass ring, the reticle lines and the film touching each other, so that there could be no parallax effect between them. Thus in one rotation of the plate ten independent pictures under identical conditions were secured, each image of the field available being 4½-inches in diameter. It was found practical to take a complete picture, once every six seconds, or the whole ten in one minute. If it is not thought best to use so large plates, it is evident that ten compartments can be constructed into which small plates can be inserted, and removed in regular order on the unemployed side, while the exposures are made on the other side of the plate. There is some trouble in making, handling and developing large plates, but in many respects, they are superior to a series of small plates, especially in referring them to the co-ordinates for measurements.

In conducting the exposures it is necessary to have two screens also revolving upon the axis of the finder, just in front of the plate between it and the open end of the tube, one to carry the slit and one opaque; each screen also revolving in one direction by the pressure of a spring. The order of action is (1) movement of the opaque screen, (2) passage of the slit screen for exposure, (3) return of the opaque screen in front of the tube, (4) return of the slit screen to place for a new exposure, and (5) the advance of plate through one-tenth of the revolution. We employed a rather complicated automatic apparatus, acting by means of compressed air, which carried out all these motions automatically, so that the observer had only to exchange plates after each ten pictures, but a simple contrivance can be made to work by hand, that will do just as well and will not cost so much. The slit screen must be a sector covering rather more than twice the width of the tube, and the opaque screen more than once its width; they must strike against soft cotton batten for buffers, so as to impart no vibration to the telescope. It was found that the rigidity of the end A was such as to permit any necessary manipulation of the camera without disturbing the image of the Sun. At Cape Ledo the clouds were passing over the Sun so rapidly, when it could be seen at all, that it was not possible to use the automatic apparatus which had been planned, to execute prearranged intervals of exposure, by control from an electric dial invented for this purpose; and what we secured was obtained by watching the image on the opaque screen, as could be done perfectly from the side, there being a free space of about one half an inch, and letting fly the screens by hand, at any favorable instants of time. If one could practice with such apparatus I am sure that the pictures desired could be obtained with the least loss of time and under the most uniform conditions. It should be said that a small dark room was erected over the photographic end of the telescope so that all these operations went on under ruby light, being fully protected from causes that tend to ruin such delicate work. Black canton flannel secured over the large opening and around the telescope admits of all the freedom of motion needed by the instrument. Such a dark room can be constructed cheaply and quickly, and it seems to me that it is an indispensible part of an eclipse outfit.

There is one more problem that it is hoped was successfully attacked, namely the determination of the position angle. The position angle, or the position of the lines of reference of the plane of the ecliptic and the Sun's axis of rotation, is a question of extreme importance in the solution of the location of the coronal axes, along the lines of investigation described in other papers, and it is the weakest part of the work hitherto accomplished in taking coronal photographs. A picture of the corona, with such lines only roughly indicated, are not worthy the expense and labor otherwise bestowed upon them, and they miss one of the most important parts of this problem. All observers know the difficulty of securing this line of reference. What is needed is the direction of motion of the center of the Sun across the plate, as the telescope rotates about its axis; or the telescope being fixed this direction as the Sun passes over the field. If the celestial and the instrumental poles PP′, coincided on the sphere, these two directions would be the same.

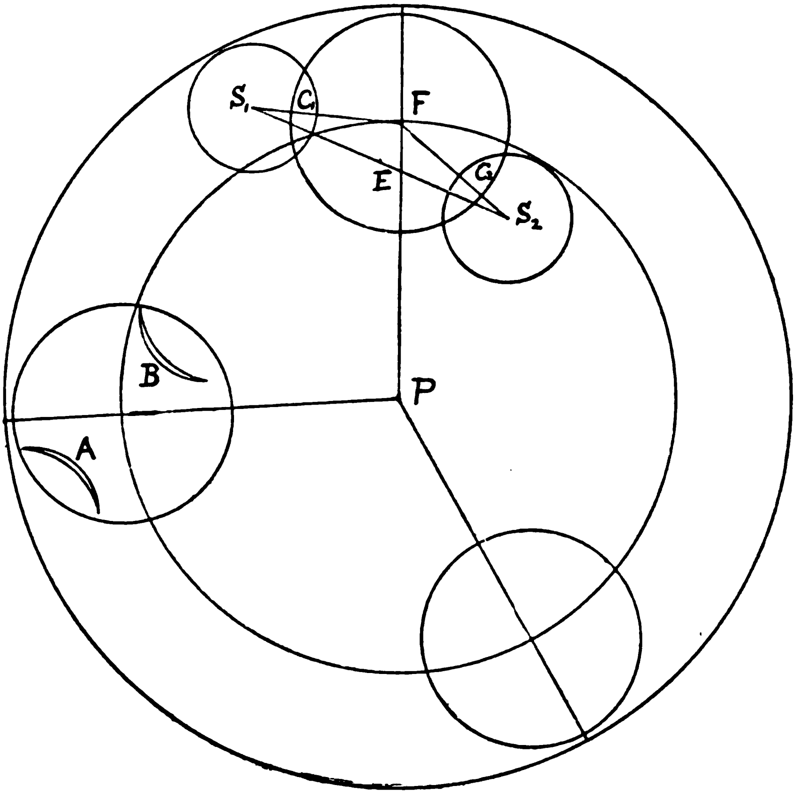


FIGURE 4.

Hence both of these lines should be determined, as a check and as a term in the problem of computation. In Fig. 4 let P represent the axis of rotation of the photographic plate, upon which are shown their circles and three radii belonging to the rotating reticle. Let F be the center of one of the fields from the objective, adjusted to coincide with the axis of collimation by means of a circular screen at the lower end of the instrument. This screen should also carry two threads at right angles, the center being adjusted to the optical axis of the telescope, and one thread parallel to the equator. S_1 and S_2 are the positions of the centers of the Sun at two exposures on the same field, the first after the cusp C_1 has entered and the second C_2 as the Sun is leaving the field, the telescope being fixed and the Sun moving, or the telescope running past the Sun, by a rapid flow from the piston, as mentioned above. The general light of the sky is always sufficient to throw down the field with clearly defined edges. The points of the cusps C_1 and C_2 are sufficient to determine the directions FS_1 and FS_2 respectively, while the curvature of the edges of the Cusps serves to fix the positions S_1 and S_2. Hence the line S_1S_2 is the direction of motion of the Sun over the field, and the angle S_1EP refers this to the center of polar co-ordinates P. If now the thin cusp A, just before Contact II, and the thin Cusp B, just after contact III, are taken on the same field, one before and the other after totality, it is obvious that we should have room for nine pictures of the corona on the same plate, giving time for some long exposures if desired. The curves of the edges of the Sun and the moon can respectively be extended to the circumference of the field, and thus the direction of the motion of each of these bodies be accurately obtained. It is felt to be very unfortunate that our ill luck at Cape Ledo prevented us from carrying out these plans fully. A number of plates (10) of phases were obtained, which show all the mathematical lines that have here been indicated, but they are not as yet measured up and computed.

There is space remaining for only three isolated remarks. The first is that the evidence is very strong, as shown in a paper on "Standardizing Photographic Films," which appeared in the SIDEREAL MESSENGER of Nov. 1891, that in the present state of our knowledge regarding the actinic problems of photographic films, it is quite useless to repeat the process of standardizing the films by squares, and comparing with the effects of deposit produced under exposure to the corona. The second is that it is highly important to develop the plates as soon as possible after the exposure, if it is expected to retain all the impression produced. There are now several experiences on record that show that the images do fade out with the lapse of time. Some of our plates were developed at San Paulo de Loando in a few days after the eclipse, and others in the United States after the return of the expedition. The latter had all faded away seriously as compared with the Loando plates, and there were no precautions spared to prevent this result. In spite of the practical difficulty of developing plates in hot climates, and with insufficient means, it is better to do so, and if the work is done at night in a cool place, the best will have been done that is possible. The third remark is that from a careful study of the corona pictures available, I find that those produced by the old colodion process, such, for example, as that used by U. S. Naval Observatory parties in 1878, gives a better working picture than any of the gelatine dry plates. They are more homogeneous, the lines being much more continuous in their courses under the microscope, and they preserve this continuity much better from near the edge of the Sun where the object is bright, towards the extremities of the streamers where the corona disappears in the general brightness of the sky. There is time enough for sufficiently long exposures to use colodion, since it is a mistake to expose a quick gelatine film (Seed No. 27) for more than about three seconds.

There are many other processes that were undertaken by the expedition, especially in the way of automatic exposures, as conducted by Professor Todd himself, which show that the old method of hand manipulation ought to be abandoned, in view of the value of the available minutes. Of course nothing can take the place of a good observer, but wherever it is proposed to supplement such observations with photographic records, there can be no doubt that the introduction of mechanical operations has been a step in the right direction.

NOTE ON THE NEW BINARY, β 612.*

S. W. BURNHAM.

In THE SIDEREAL MESSENGER for August, 1891, I called attention to the rapid motion of this new system, and gave all the measures I had any knowledge of at that time. With these observations, owing to the uncertainty of the quadrant, it was impossible to say whether the motion was direct or retrograde, since the components are very nearly equal, and the several positions might lie in the same quadrant. The direction of the motion seemed to depend upon the general accuracy of Engelmann's angle in 1884, and that made the orbital motion in a retrograde direction.

Since that paper was written, I have received some very valuable unpublished measures from Schiaparelli, made in 1889, 1890 and 1891, and from Hall in 1891; and in addition to these observations, I have recently measured it with the 36-inch equa-

---

* Communicated by the author.

torial. These observations show beyond question that the motion is direct, and that the angular motion since 1878 is about 140°. There seems to be a large error in the position-angle of 1884, which it is difficult to explain. The period will be short, and with the measures of the next two or three years, it can probably be determined with approximate accuracy. At the present rate, with a uniform motion of 10° per year, the period would be only 36 years, but it is not at all unlikely that the angular motion may be accelerated during the remainder of the apparent orbit.

HISTORY OF THE COLOR OF SIRIUS.[*]

T. J. J. SEE, BERLIN.

In the *Philosophical Transactions* for 1760 Mr. Thos. Barker of Lyndon, in Rutland, has a paper "On the Mutations of Stars," in which he calls attention to a supposed change in the color of Sirius, and cites as a proof that the star was formerly red the testimony of a number of ancient authors, including Aratus, Cicero, Horace, Seneca and Ptolemy. The argument advanced seemed so conclusive that for a long time the change of color appears to have been accepted as an item of scientific belief. Recently, however, an effort has been made to discredit belief in the ancient redness of Sirius by throwing doubt upon some of the evidence cited by Mr. Barker, especially the weighty testimony of Ptolemy, Seneca, and Cicero. Therefore, to satisfy my own curiosity, I undertook a critical investigation of all of the ancient authors hitherto examined, and a great many others, with a view of deciding definitely whether in antiquity Sirius was really red. The results of the research seem to establish beyond doubt the ancient redness of the star, and therefore, since the investigation will be interesting to astronomers who are studying problems of Cosmical Physics, I shall now proceed to give briefly the evidence of the ancient authors and to review in the proper place the criticisms hitherto advanced, nearly all of which happen to be erroneous. We shall proceed usually in chronological order.

HOMER.

The only distinct allusion to Sirius in the Homeric poems is that in the Iliad (Bk. XXII, 29-32,) where Homer compares

---

[*] Communicated by the author.

Achilles' shield (of copper, as we know from recent Archælogical discoveries) to the star:

> "ὅν τε κύν' Ὠρίωνος ἐπίκλησιν καλέουσιν·
> λαμπρότατος μὲν ὅ γ' ἐστί, κακὸν δέ τε σῆμα τέτυκται·
> καί τε φέρει πολλὸν πυρετὸν δειλοῖσι βροτοῖσιν·
> ὣς τοῦ χαλκὸς ἔλαμπε περὶ στήθεσσι θέοντος."

We have here no distinct record of color, but the association of "πυρετός," meaning "fever" (the same word is used by Hippocrates), with Sirius, indicates that there must have been some reason for ascribing the presence of a disease which the Greeks evidently connected with "fire" or "heat" to Sirius rather than to other stars. The evil omens attributed to Sirius were perhaps the natural outcome of astrological superstitions widely spread in antiquity respecting the "influences" of bodies of a ruddy color, which were looked upon as "angry" deities. It is well known that Mars (the god of war) and the sign of Scorpion (owing without doubt to the "angry" appearance of the ruddy Antares) were objects to which astrologers attributed all manner of evil. It is also well known that the "influences" of clear bright bodies like Venus and Jupiter were considered "salutary;" therefore it is difficult to imagine why the ancients should have attributed evil omens to Sirius if it shone with its present "salutary" appearance. But certain it is, as we shall see in the course of this paper, that throughout the Greek and Roman world the Dog Star was regarded as the cause of the intense heat of the "Dog Days," as the source of the sickness and droughts attending that season of the year, and consequently an object of the greatest superstitious terror. It is easy to see how these evil forebodings would arise in the minds of the ancients if Sirius were red, so as to present the appearance of "burning," but if the star were white (clear and "salutary") an explanation of these superstitions seems nearly impossible.

Homer, moreover, by comparing the shining of a copper shield to the "Dog of Orion" has used language consistent with the idea that Sirius shone with a ruddy light, and it may be that he has thus unconsciously preserved for us the color of the star 3000 years ago. This suggestion is confirmed by the following comparison of the helmet and shield of Diomede to the "Autumn Star," which critics are agreed is Sirius:

> "δαῖέ οἱ ἐκ κόρυθός τε καὶ ἀσπίδος ἀκάματον πῦρ
> ἀστέρ' ὀπωρινῷ ἐναλίγκιον, ὅς τε μάλιστα
> λαμπρὸν παμφαίνῃσι λελουμένος Ὠκεανοῖο·

τοῖόν οἱ πῦρ δαῖεν ἀπὸ κρατός τε καὶ ὤμων,
ὦρσε δέ μιν κατὰ μέσσον, ὅθι πλεῖστοι κλονέοντο."

(Iliad, Bk. V. 4-8).

Homer therefore affirms the similarity in the appearance of the "imperishable fire;" streaming from Diomede's copper armor to that coming from the "Autumn Star;" and the repetition of "*πῦρ*" not only emphasizes the agreement in color, but assures us that the objects were fiery red. Now Homer's similes and comparisons are admitted by all critics to be in general proverbially accurate; therefore it is very improbable that he has here committed so great an error as would be implied by the same comparison at the present day—a comparison, indeed, very appropriate for a red star like Aldebaran or Betelgeux or Antares, but entirely inadmissible for the bluish white Sirius with which we are all familiar. It must be remembered also that the Greeks of the Homeric age knew nothing of the white lights and fires resulting from oil, gas, and electricity, but that their primitive wood fires presented a ruddy tinge. In remarking that the star "appears more brilliant when washed by the ocean." Homer has left us a record of scintillation—certainly the very earliest that exists—but his language does not imply that his judgment of the color has been influenced by atmospheric effects upon the light of the star. Scintillation, indeed, causes the flashes of a red star like Aldebaran to appear extraordinarily red, and the flashes of a bluish white star like the present Sirius to appear extraordinarily blue; therefore in the present color of Sirius not even scintillation could justify the comparison with "imperishable fire" or the ruddy glow of burnished copper; whereas, with a color like that of Antares such a comparison would not only be admissible but the most natural that could be imagined, whether scintillation existed or not. Accordingly, although the two foregoing independent and very ancient records of Sirius have come down to us from a poet, Homer is generally very accurate in his descriptions, and therefore his testimony ought to lay claim to considerable confidence.

HESIOD.

The name *Σείριος* first appears in Hesiod ["Works and Days" (415, 585, 607) which probably dates from the 8th century B. C.,] and seems to mean the "burning one." For *Σείριος* is evidently intimately connected with the verb *Σειρέω* (otherwise *Σειρόω*, or *Σειραίνω*) which means to "burn," "consume," "dry up" or "sear." Hesiod says:

> "ἐπεὶ κεφαλὴν καὶ γούνατα Σείριος ἄζει."

A general name for Mars among the ancients was πυρόεις, the "fiery one," which shows that the color of this planet was carefully noted. If "Σείριος," as we have suggested, means the "burning one," the meaning in the two cases is essentially the same. Antares seems to be redder than even Mars, and hence it has been suggested that the name of the star is derived from ἀντι-Ἄρης, the "rival of Mars." The linguistic evidence certainly favors the idea that these three bodies were formerly of the same color.

EURIPIDES.

The language of poets is always very uncertain, but one passage in Euripides is given for what it is worth:

> "Σείριος ἔνθα πυρὸς φλογέας ἀφίησιν δσσων αὐγάς."
>
> (Hecuba, 1080)

APPOLLONIUS RHODIUS.

This writer has the following remark on Sirius:

> "Ἦμος δ' οὐρανόθεν Μινωίδας ἔφλεγε νήσους Σείριος."
>
> (2, 517).

ARATUS.

In verse 329 of the "Phenomena" Sirius is called ποικίλος, which is susceptible of several translations. The most usual is "highly colored," or "various colored," either of which can be justified by classic authority. For example, there was a gate at Athens called Ἡ ποικίλη (with or without στοά) from the circumstance that Hyron had adorned it with paintings in bright colors (red, blue and green). Now, since Aratus uses words in their correct sense, and does not use ποικίλος of any other star, it is to be presumed that the appearance of Sirius was something extraordinary; and in the present case about the only meaning that can with any probability be assigned to ποικίλος is "ruddy."

In 331-2 Aratus continues:

> "δς ῥα μάλιστα
> ὀζέα σειριάει· καί μιν καλέουσ' ἄνθρωποι
> Σείριον;"

This remark confirms the derivation of the name Sirius just given in speaking of Hesiod, and shows clearly that Σείριος means the "burning one."*

It may be added that there is an extant commentary on Aratus by the great astronomer Hipparchus, who points out many

---

* The derivation of Σείριος given by Ideler in his "Sternnamen" is certainly erroneous.

errors in the celestial geography of his author, but makes no comment on ποικίλος. Considering the scrupulous care which characterized all of Hipparchus' work, it would seem that he must have considered ποικίλος a correct description of Sirius.

Using Buhle's edition of Aratus (Leipsic, 1796) we shall now consider the Roman translations.

(1). THE TRANSLATION BY CICERO.

This appears to be in general a fairly faithful rendering of the original. In verses 326-7 we read:—

> "Namque pedes subter rutilo cum lumine claret
> "Fervidus ille Canis, stellarum luce refulgens."

The word ποικίλος is thus rendered "rutilo cum lumine," apparently because the word had that meaning, or because Cicero knew from observation that Sirius shone "with a ruddy light." In the whole of his writings, as I have found by careful investigation, Cicero does not use the word "rutilus" (or any other word meaning red) in speaking of any other heavenly body except the planet Mars, which in the Somnium Scipionis (Cap. IV.) is styled "rutilus terribilisque terris." No foreigner ever understood Greek better than Cicero, and therefore he can not have been ignorant of the meaning of his text, nor is there the slightest ground for saying that he was a "rhetorician rather than a natural philosopher," as one critic has asserted. For it is a matter of universal knowledge that Cicero devoted great attention to the Greek philosophy, consecrated, as it was, in so large a degree, to theories of the system of the world; it is therefore certain that he was perfectly familiar with the appearance of all the conspicuous heavenly bodies, and especially of so famous and prominent a body as Sirius. Considering the out-door life of the Romans, we can not doubt that Cicero had observed the Dog Star hundreds of times; hence when he wrote "rutilo cum lumine" he recorded the color with which he had long been made familiar.

(2). THE TRANSLATION BY GERMANICUS CÆSAR.

The fairly good translation left us by this Roman general singularly contains no rendering of the Aratus' ποικίλος, probably because the word was accidentally overlooked. However, in the same passage as ποικίλος, but 12 verses further on, Germanicus distinctly implies the redness of Sirius:—

> "Urgetur cursu rutili Canis ille per æthram"
> (verse 341).

"Cursu rutili" may therefore be taken as the equivalent of ποικίλος. Germanicus' use of words throughout the translation is classic, and I have found by careful examination that "rutilus" is used of no other star, not even Antares, which he evidently alluded to when he speaks of the Scorpion as "ardenti cum pectore" (653). Therefore, since it is certain that Germanicus was familiar with the appearance of the conspicuous heavenly bodies, his testimony for the redness of Sirius ought not lightly to be set aside.

(3). THE PARAPHRASE BY LUCIUS FESTUS AVIENUS.

This author is supposed to have flourished towards the end of the 4th century A. D. His translation is only a very rough paraphrase of the original, and the words are very loosely used. Therefore but little importance can be attached to what he says in speaking of the Dog:—

> "Multus rubor imbuit ora."
>
> (verse 727).

THEON.

This Alexandrian mathematician wrote a commentary on Aratus about the end of the 4th century A. D., and in explaining ποικίλος says the light of certain stars is "not composed of one ray, but various colors," (Buhle's Aratus, vol. I., p. 291). Theon thus says that Sirius is ποικίλος, but his use of words does not seem very classic. An unknown scholiast has explained ποικίλος as equivalent to "πορφυρίζος" (Buhle's Aratus vol. I., p. 83) which can be translated "purple," but here perhaps the rendering should be "ruddy."

[TO BE CONTINUED.]

A FURTHER NOTE ON COMETS AND METEORS.*

W. H. S. MONCK.

Besides the four meteor-showers which are usually regarded as cometary, Professor A. S. Herschel communicated a long list of supposed accordances to the Royal Astronomical Society in the year 1876, which was included in the report of the Council for that year; and in the *Monthly Notices* for 1878 appeared a further development of this list also by Professor Herschel. No correction of these lists has, so far as I am aware, hitherto ap

---

* Communicated by the author.

peared, and the Royal Astronomical Society decided on not publishing a criticism by the present writer, I presume because the list had received the *imprimatur* of the Council. It may not, therefore, be amiss to show briefly that the great majority of these accordances are purely imaginary and have not been borne out by subsequent observation, and especially that they are not to be found in the great catalogue of Mr. Denning, published in the *Monthly Notices* for May, 1890—a catalogue containing the results of some twenty years of accurate observation by a most pains-taking observer.

Professor Herschel's idea of what constitutes an accordance differs widely from mine. Take, for instance, the very first comet in his list, the second comet of 1792. Meteors attached to this comet would have (according to Weisse) a radiant at 194° + 24°.5, the date being January 5th. The supposed accordance is with these meteor-radiants, one at 183° + 28° from Schiaparelli and Tezioli on January 11-12, and the others at 180° + 35° and 183° + 36° respectively, extending through the greater part of January, one resting on the authority of Colonel Tupman, and the other of Grey and Herschel. The two latter evidently represent the same radiant, but the accordance does not approach within 10° either in right ascension or in declination, and the shower lasts for at least three weeks after the earth has passed the cometary node, the inclination being 49°. Schiaparelli and Tezioli's radiant approaches nearer in declination, but its right ascension is wrong by over 10° and the date erroneous to the extent of a week. If we allow ourselves this amount of latitude there is probably not an observed meteor-radiant for which we could not find a comet, or a cometary radiant for which we could not find an observed meteor-shower. For as both meteor-radiants and (theoretical) cometary radiants are reckoned by the hundred and are distributed over all parts of the sky, such accordances must take place; but I believe equally good accordances could be obtained for points and dates selected at random, provided that the selected portion of the sky was suited for meteor-observation at the time. In this instance Mr. Denning's observations confirm the discordance. His nearest shower is from 180° + 24° on the 25th of January and the column "*Other nights of observation*" is a blank. Mr. Denning did not observe any meteors from the cometary radiant and I am not aware of any one who did.

The table itself is indeed sufficient to show the hap-hazard manner in which its results have been arrived at. Two supposed coincidences are introduced into the table in deference to Weiss and Schiaparelli respectively (see Report of the Council for 1876), though the great distance of the earth from the comet's orbit renders Professor Herschel very doubtful as to the connexion; but the coincidences are quite as good as in the majority of other cases. Professor Herschel, in computing the radiant for the first comet of 1870, made a serious arithmetical error, the result being that an excellent coincidence was detected; but on the error being corrected, a new coincidence, not quite as good as the former one, immediately came to light. And no doubt if a second correction had become necessary, a third coincidence would have been discovered; for the whole region of Perseus and Andromeda swarms with meteor-radiants about the 12th of August when the earth reaches the node of this comet's orbit. I may take another example from the early part of Professor Herschel's table—the fourth in his list. The comet of 1746 gives a radiant at 60° + 40° with the date January 16. The nearest of Professor Herschel's supposed agreements is wrong by 15° in declination. Mr. Denning discovered one of his stationary or long-enduring radiants near this point, but it so happens that one of the months during which the shower appears to be quiescent is the month of January.

The table as such is, I think, worthless, but it may be worth inquiring whether any of the radiants comprised in it are borne out by Mr. Denning's and other recent observations. The examples of this kind are perhaps not more numerous than chance will account for, but they seem worth giving in detail in order that further investigation may lead to some definite conclusions with regard to them.

1. Comet III 1759 has a radiant at 210° — 15°,* date January 19. On January 22 ("other days of observation" January 19, 20, 25), Mr. Denning observed a radiant at 210° — 8°. The difference in declination is considerable but the shower is worth watching. There are, however, some indications of a stationary radiant near this point, Mr. Denning having observed meteors from it in February and April which could not be ascribed to this comet.

2. Comet 961 is assigned a radiant at 308° + 12° for March 23, and Comet 1857 V a radiant at 302° + 11° for April 4. Mr. Denning deduced from Italian observations a radiant at 304° + 12° for the period March 31 to April 12, and observed a

---

* Professor Herschel's radiants seem to have been arrived at by a graphical construction and are probably not very accurate. Mr. Corrigan or Mr. Winlock might find the table worth going over from this point of view.

radiant at 303° + 13° on April 19. As there are no radiants for the early part of April in his catalogue an earlier display of this shower may have escaped his notice. The shower agrees better with the comet of 1857 than with that of 961. This comet is an elliptic comet. There are some indications of a stationary radiant near the point.

[One of the next agreements in Professor Herschel's table is between the Comet I 1847, whose distance is very considerable at the node, and a meteor-shower in April from nearly the same point. The date of the cometary shower, however, is April 11, while Mr. Denning's observations of the meteor-shower extend from May 7 to May 18. The identity in this case may therefore be rejected though the agreement in position is very good. For similar reasons the comet of 1746 (radiant at 296° + 1°.5 on March 26) cannot be connected with a stationary radiant observed near the same point by Mr. Denning, the nearest agreement in date being April 15th.]

3. Comet II 1844, radiant at 288°.5 + 5° on April 21st. Mr. Denning observed meteors from 286° + 5° on April 19 and the point does not seem to be a stationary radiant. The comet is supposed to be elliptic.

4. Comet I 1737 gives a radiant at 235° — 15° for May 8. Mr. Denning observed meteors from this radiant on April 16-21. The accordance is very doubtful.

5. Halley's comet gives a radiant at 337° + 0° for May 4. Mr. Denning observed meteors from 337° — 2° from April 30 to May 6.

6. Comet I 1781 gives a radiant at 338° + 57° for June 14. Mr. Denning observed meteors from 335° + 57° from the 10th to the 28th of June; but among the stationary or long-enduring radiants enumerated by him is one at 334° + 58° which continues active from July to January. This throws considerable doubt on the connexion between the comet and the meteors.

7. Comet I 1850 gives a radiant at 312°.5 + 60°.5 for June 20. More than one of Mr. Denning's radiants are in fair agreement with this; but the question, as in the last instance, is complicated by the existence of a stationary radiant, and the nearest agreement in date is one of the worst as regards position. It is at 302° + 64° on June 14 and 17. On June 13 meteors were traced to 310° + 61°, and on July 1 to 6, to 313° + 60°, a point which was also active on June 4. Meteors from pretty near the same point were observed in August, September and October. Schiaparelli's date is July 10 and Mr. Denning obtained the same

result from Italian observations July 15 to August 2. The comet is believed to be elliptic.

8. Another doubtful accordance is between Comet IV 1822, radiant 348°.5 + 28° on June 25 and a shower from 344° + 27° observed by Mr. Denning on July 7. This comet is also elliptic. There appears to be a shower of some duration from about 333° + 27° of which Mr. Denning's radiant on July 7 may be an outlier.

9. Equally doubtful is the accordance of Comet 1764 (radiant at 49° + 45°.5 on July 25) with several radiants observed by Mr. Denning. One of the best established stationary radiants on his list, which is active from July to January, is situated at about 47° + 44°. Its position for the 25th of July appears to be at 48° + 43°.

10. The comet II 1877 has a radiant at 32° — 18°.5 on August 9. On July 28th, 1878, Mr. Denning met with a shower from 33° — 20°. The comet is supposed to be elliptic.

11. Comet II 1780 has a radiant at 3°.5 + 38°.5 for August 14. Radiants in tolerable agreement may be found in Mr. Denning's Catalogue, but there is a well-established stationary radiant, active from June to October, whose mean position is given by Mr. Denning at 7° + 35°. The declination of the observed radiants seems to be always less than that of the cometary radiant, while the R. A. is usually greater.

12. Donati's Comet of 1858 has a radiant at 100° + 59° for September 8. Mr. Denning observed meteors from 100° + 58° on September 5 and 7. The comet is elliptic. There are, however, some indications of a stationary radiant. Mr. Denning obtained 100° + 60° from Italian observations October 29 to November 13 and Schiaparelli 100° + 59° for December 9. Mr. Sawyer obtained meteors exactly corresponding with the cometary radiant.

13. Comet 1769 gives a radiant of 21°.5 + 17°.5 for September 28, this being of the kind which Professor Herschel calls an appulse. Mr. Denning observed radiants at 20° + 14° on September 19, 23° + 17° on October 5-7, and 21° + 14° on October 13-19. The agreement is not very good but is suggestive of further inquiry. The comet is believed to be elliptic.

14. Comet VI 1847 has a radiant at 54° + 52°.5 for October 4. Mr. Denning obtained meteors from 56° + 52° on October 5-8. The point however, lies very near to the permanent Perseid radiant and in particular to Col. Tupman's radiant for September 7 to 15.

15. Comet II 1825 has a radiant at 134° + 77° for October 7. Mr. Denning observed meteors from 133° + 79° on that day; but there seems to be a stationary radiant at this point, as he obtained meteors from 134° + 78° in July, from 135° + 78° in August and from 136° + 77° in November and December. The last observation was confirmed by Italian observations which gave a radiant at 140° + 77° in January. This stationary radiant seems to be distinct from another which is situated about 10° farther S.

16. Comet II 1850 has a radiant at 2° + 54° for October 19. Mr. Denning traced meteors to 7° + 51° on October 15, 19 and 20. Besides the difference of some degrees in position there seems to be a stationary radiant near 7° + 51° which is most active in July and appears also in August and November.

17. Comet II 1842 has a radiant at 81° + 57° for October 21, and Comet I 1848 at 78° + 60° for October 25. Mr. Denning observed a radiant at 78° + 57° on October 14-15; but one of the stationary radiants in his list at 77° + 56½° lasting from September (he might, I believe, have said August) to November.

18 and 19. There is a somewhat similar agreement between the Comet of 1739, radiant at 157° + 39° on Oct. 22, and Mr. Denning's stationary radiant at 154° + 40½°, September to December; and also between Comet 1582, radiant at 89° + 36° on Nov. 9, and a number of radiants situated at about 87° + 34° observed by Mr. Denning from September to December. The orbit of the latter comet is very uncertain and no reliance could, in any event, be placed on the apparent coincidence.

(As a specimen of Professor Herschel's powers of identification, I may mention that he connects both the Orionids of October and the later Taurids at the end of November with the Comet of 1821, radiant at 86° + 19°.5 on November 11. No one would, I presume, now identify the two showers or connect the comet with either.)

20. Comet I 1813 has a radiant at 147° + 0° for Nov. 24. Mr. Denning observed meteors from 148° + 2° on Nov. 25–28. These meteors, however, are probably connected with others from 145° + 7° in December and 146° + 4° in January. Mr. Denning recognizes a stationary radiant at 145° + 7°, Nov. 26 to Feb. 27.

21. Comet VII 1846 has a radiant at 200°.5 + 4°.5 for Dec. 12-17. Mr. Denning has a radiant at 201° + 4° for Dec. 21–28. There seems to be no stationary radiant here. The comet is elliptic.

22. The great Comet of 1680 has a radiant at 132° + 21°.5 for December 26. Mr. Denning observed meteors from 129° + 19° on Dec. 21, 22 and 24. The comet is elliptic.

If we add to the foregoing list the four comets usually referred to and Comet I 1870, the corrected radiant of which agrees pretty fairly with a shower from Andromeda which occurs simultaneously with the Perseids, the list will, I think, be found nearly complete. The weight which should be attached to the agreements is a different matter. According to a theory still current, according to which a comet is, in fact, a swarm of meteors, the weight seems to me to be very small in most cases. If, for instance, the cometary theory supposed such a rapid shifting in the radiant as Mr. Denning is supposed to have observed in the case of the Perseids, the mere difference in date would often convert a supposed accordance into a discordance. Thus an advance of 1° *per diem* in the R. A. of the radiant would give a difference of 16° instead of 4° in R. A. in the case of No. 8. But if, as I have previously maintained, the chief effect of a cometary node is to render all stationary radiants in that part of the sky more active, a connection of this kind may perhaps be traced in several cases.

In some instances, however, the stationary radiant seems to be unusually quiescent at the time that we reach the comet's node. The best coincidences in the list occur with elliptic comets. Those with the comets of Halley and Donati and Comets II 1844, and VII 1846, must be regarded as very close. The result with regard to the great comet of 1680 is peculiar. Two observations made in different years give exactly the same deviation from the cometary radiant, and the effect of this deviation (according to the orbits computed by Dr. Kleiber) is that the meteors, instead of grazing the Sun, will fall into it—some of them almost centrally. With regard to these computed orbits I may remark that in almost every case in which an apparent coincidence occurs the perihelion distance of the meteors is greater than that of the comet (the comet of 1680 is of course an exception), as if the meteor-train was dragged on after the comet and never approached the Sun as closely as the comet's nucleus.

The orbits computed by Dr. Kleiber for Mr. Denning's radiants do not exhibit that preference for high inclinations which Professor Newton regards as evidence of an origin beyond the limits of the solar system in the case of the comets. The connection between the two is therefore perhaps acquired rather than original, and elliptic comets which remain for ages moving within the limits of the solar system display this acquired connection most clearly.

SOPHIE KOWALEVSKI.*

CHARLOTTE C. BARNUM.

Mme. Sophie Kowalevski (or Sonja Kovalevsky) was born in Moscow, Dec. $\frac{15}{27}$, 1853. Her father, Gen. Corvin-Krukowsky, was a man of marked ability and a member of the old aristocracy, being a direct descendant of Mattias Corvin, king of Hungary. Her mother belonged to the Schubert family of mathematicians and astronomers, and was herself an unusually gifted woman. Sophie's father retired from active service while she was very young, and took up his abode at his ancestral castle at Palibino, a lonely spot which, at certain seasons, was entirely cut off from the outside world. She began her studies under an English governess. A little anecdote of her childhood has found a place in several learned journals, but the moral is slightly obscure. When she was ten years old, the castle was re-papered, but when the paper came from St. Petersburg, it was found that there was none for the nursery. For this room was used a lithographed course of Ostrogradski on mathematical analysis, a survival of her father's student days; and, to the despair of her governess, she was continually reading these mathematical dissertations covered with incomprehensible hieroglyphs. When, at the age of sixteen, she began to study calculus, her professor was astonished at the quickness with which she understood him, "just as if it were a reminiscence of something you knew before," he told her. The continual reading of the wall-paper had left some unconscious traces on the child's mind.

From eight to fifteen years of age, her tutor was Mr. J. Malevitsch a fine teacher who, under the wise supervision of her mother, devoted himself with zeal and success to her education, and exerted a marked influence on the rapid development of her brilliant powers. Her literary ability was so marked that her tutor predicted for her a brilliant future as a writer, and he was not mistaken in his estimate of her powers in this line. Her *Reminiscences of Childhood*, translated into Swedish and Danish under the title, *The Rajewsky Sisters*, is spoken of in *Nature* as "one of the finest productions of modern Russian literature," and its publication was welcomed in Russia, Sweden, and Denmark as an event in literature, and it was said a new Tolstoi had been born in Russia.

---

* Read before the Mathematical Seminary of Johns Hopkins University, Jan. 6, 1892.

Her special interest in mathematics was awakened by her uncle Schubert, and she chose that specialty in her fourteenth year. She had studied by herself a text-book on physics, found among her father's books. The author, a friend of her father's, was once visiting him at Palibino, when Sophie told him she had studied his book. He laughed and said it was impossible, as she did not know trigonometry. But it appeared in course of the conversation that the girl, from the knowledge she then possessed, had deduced in her own way the fundamental formulæ of trigonometry. Astonished at so remarkable a proof of her intellect, the visitor urged her father to have her talent cultivated in spite of the aristocratic and conservative view of the education suitable for a lady of high rank. Her father thinking her passion for the study was only a caprice, readily consented, and she was allowed to study a year at St. Petersburg. But when, at the age of fifteen, she seriously asked permission to study in a foreign university, there was a terrible scene in the family. Her father could not have taken it more to heart if she had committed a grave fault.

In order to understand what follows, it is necessary to remember that at that time in Russia a girl who studied was considered a nihilist. There was indeed a political and patriotic enthusiasm in the burning desire for study which had seized the rising generation. It was a wish to impel their beloved country towards the light of liberty. This enthusiasm had produced a curious phenomenon,—marriages contracted for the purpose of freeing the girl from her father's authority and giving her the chance to study abroad. For this reason Sophie Korvin-Krukowsky, at the age of fifteen, married Vladimir Kowalevski, legally, but with the understanding that both should be free to devote several years to study. With her husband, her sister, and a friend, she went to Germany, and he entered one university, while the three girls went to the only German university open to women,—that at Heidelberg. The University of Berlin was so tightly closed that when, a few years later, she was a professor at Stockholm, and wished to attend a course of lectures at Berlin, she was refused permission, and finally obtained admittance only by the direct intervention of the Minister of Education as a great personal favor.*

After a year at Heidelberg she went in the autumn of 1870 to

---

* An American girl, Miss Ruth Gentry, the holder of the European fellowship of the Association of Collegiate Alumnæ, is, however, now attending mathematical lectures at the University of Berlin, where she says she is shown "all the courtesy and kindly consideration" she could wish.

Berlin, and timidly asked Weierstrass for private lessons, as she could not be admitted to his lectures. He thought at first that the girl would become only a *dilettante* in science, and he did not wish to waste time teaching her. But during the conversation he discovered in her such wealth of ideas, and so remarkable an intuitive grasp of the more difficult questions of the science that it became a pleasure for the great mathematician to instruct her. Four years she spent as his private pupil, her studies being interrupted only by a visit to her family in Russia and by some other trips. Being unable to obtain a degree at Berlin, she took the oral examinations at the University of Göttingen, presented a remarkably original thesis "On the Theory of Partial Differential Equations," and obtained the degree of Ph. D., being the second woman to receive this degree at Göttingen.

Her husband received his degree at the same time, and was appointed Professor of Paleontology in the University of Moscow, where he soon attained a position of distinction among the Paleontologists of the world. She was twenty-one when they returned to Russia, and established their home in Moscow. With her enthusiastic temperament, she devoted herself completely to whatever work she undertook. At first her home duties absorbed nearly all her time and thought. Then she took up her husband's specialty with such success that for some time, while he was otherwise occupied, she wrote his lectures for him. Then, being in a literary atmosphere, her taste for literature revived, and she wrote a novel entitled *The Private Teacher*, dealing with University life in Germany, and published it anonymously in a Russian journal. Thus passed several years of rare domestic happiness in their beautiful home in Moscow.

Professor Kowalevski was full of grand ideas and of enthusiasm, but exceedingly visionary. He fell under the influence of an adventurer, who drew him into dangerous speculations in petroleum wells and other industrial enterprises. She used all her efforts to break the spell of this false friend, but the fever of speculation was too strong, and he risked all his inheritance and his wife's and lost. Although he had committed no crime, he felt the disgrace so keenly that he left his home and position to resume his solitary studies abroad. Probably his mind had become unbalanced by their financial ruin. Soon came the startling news that in a fit of despair he had committed suicide. Thus the burden which had proved too heavy for him fell upon her alone, together with this great additional sorrow. Her parents were dead, her wealth had been thrown away, and as soon as she recovered a little from the shock of the tragedy she found herself for the first time forced to consider the question of money. She must support herself and her four-year-old daughter. In Russia the best she could do was to teach arithmetic to one of the lower classes in a girl's school. Then came in the autumn of 1883 a signal illustration of the liberal spirit and kindness which mathematicians and astronomers almost invariably show to the women working in their departments. Mittag-Leffler, who had also been a pupil of Weierstrass, was at this time organizing the University of Stockholm, and, although she had published no mathematical work during the nine years since she had left Germany he invited her to deliver at Stockholm a course of lectures on partial differential equations. Meanwhile he succeeded in obtaining the money necessary to establish and sustain a chair of higher mathematics, created especially for her. She lectured the first year in German, afterwards in Swedish. Her clear, inspiring teaching, her intellectual ability, and her personal popularity attracted to her classes many able students, some of whom were already professors. In 1885 she was made associate editor of *Acta Mathematica*, and later was elected corresponding member of the Royal Academy of Science of St. Petersburg. The French Academy proposed as the subject of the Bordin prize in 1888 the problem "To complete in an important point the theory of the motion of a solid body." The commission not only unanimously awarded her the prize, but upon their recommendation the amount was increased from 3,000 to 5,000 francs on account of the "extraordinary service rendered to mathematical physics by this work." She traveled in all parts of Europe, making friends wherever she went, and continued to fill her position at Stockholm until February of last year. After only four days' illness she died of pleurisy Feb. 10, 1891, at the age of thirty-seven.

Her mathematical works consist of the following papers:—

I. On the Theory of Partial Differential equations (Thesis for Ph. D.),—published 1875. *Journal fur die reine und angewandte Mathematik*, Vol. LXXX, p. 1 (32 pp.).

II. On the Reduction of a certain class of Abelian Integrals of the third Rank to Elliptic Integrals,—published 1884. *Acta Mathematica*, Vol. IV, p. 393 (22 pp.).

III. On the Propagation of Light in a Crystalline Medium,—published 1884. "*Ofversigt af svenska veterskapsakademiens forbandlingar*, Vol. XLI, p. 119 (3 pp.).

IV. On the Propagation of Light in a Crystalline Medium,—published 1884. *Comptes Rendus*, Vol. XCVIII, p. 356 (2 pp.).

V. On the Refraction of Light in Crystalline Media,—published 1885. *Acta Mathematica*, Vol VI, p. 249 (56 pp.).

VI. Remarks and Observations on Laplace's Researches on the Form of Saturn's Rings,—published 1885. *Astronomische Nachrichten*, Vol. CXL, p. 37 (12 pp.).

VII. On the Problem of the Rotation of a Solid Body about a Fixed Point,—published 1889. [Résumé of IX.] *Acta Mathematica*, Vol XII, p. 177 (56 pp.).

VIII. On a property of the system of differential equations which defines the rotation of a solid body about a fixed point,—published 1890. *Acta Mathematica*, Vol. XIV, p. 81 (13 pp.).

IX. Memoir on a particular case of the problem of the rotation of a heavy body about a fixed point, where the integration is effected by aid of the hyperelliptic function of the time,—published 1898. *Recueil des Savants etrangers*, Vol. XXX, p. 1 (66 pp.). [This is the work crowned by the French Academy.]

X. On a theorem of Mr. Bruns. *Acta Mathematica*, Vol. XV, p. 45 (19 pp.).

She wrote seven literary works.

I. The Private Teacher, published anonymously as an appendix in a Russian journal.

II. Reminiscences of Geo. Eliot. *Rousskaia Mysl* (Russian Thought), July 1885.

III. Vae Victis. Novel published in Swedish in the journal *Jul Almanack*, 1889.

IV. Recollections of Childhood (in Russian), 1890. *Vestnik Europy* (Messenger of Europe), Vol. 7-8, 1890.

V. The Rajevsky Sisters, 1890. The same as IV, but published in the form of a novel in Swedish and in Danish.

VI. The Family of the Vorontsoffs. 1890. Novel in Swedish under the pseudonym of Tanja Rajevsky. It was left complete in manuscript, and the first chapters had been published in the Swedish journal, *Nordisk Tidskrift*.

VII. The Struggle for Happiness. 1890. Under this title two dramas were written jointly by her and Anna C. Leffler, (wife of P. de Pezzo, duke of Cajanello, who is professor of higher geometry in the University of Naples).

In her thesis on partial differential equations, Mme. Kowalevski extended Weierstrass's method of proving the existence of an integral of a given system of ordinary differential equations, and proved the exitsence of an integral of a given partial differential equation. Also she showed in general that the original functions can be expressed in a series of integral powers of the independent variable convergent within a determinate circle, and discussed carefully the case in which this series becomes divergent.

The Commission of the French Academy, before they knew the name of the author, gave the following summary of the memoir which received the Bordin prize: "This remarkable work contains the discovery of a new case in which we may integrate the differential equations of the motion of a heavy body fixed by one of its points. The author is not content with merely adding a result of the highest interest to those which we have had transmitted by Euler and by Lagrange. He has made, from the discovery which we owe to him, a profound study, in which are employed all the resources of the modern theory of functions. The properties of the theta-functions of two independent variables permit of giving the complete solution in the most exact and elegant form; and we have thus a new and remarkable example of a mechanical problem, in which these transcendental functions occur, whose applications have been hitherto limited to pure *analysis or to geometry*." The President of the Academy, M. Janssen, in announcing the decision of the commission, said, "Our associates of the section of Geometry, after examining the memoirs presented in competition, have recognized in their work, not only the proof of a knowledge extensive and profound, but also the mark of a great inventive mind."

In Kronecker's editorial in *Crelle* we find the following general estimate of Mme. Kawalevski: "She united with an extraordinary talent, as well for general mathematical speculation as also for the technical knowledge necessary in special researches, tireless industry; and, in spite of the most intense activity, in her specialty, her mind was always open to other intellectual interests, and she preserved always therewith her womanliness, and gained and held also the sympathy of those who stood outside the circle of her special knowledge. The history of mathematics will have to speak of her as one of the most noteworthy lights among the class of original investigators everywhere extremely rare. While her memory will endure in the entire mathematical world through her published works (not numerous indeed, but very valuable), the memory of her remarkable and charming personality will live on in the hearts of all those who had the pleasure of knowing her."

NOTE.—The above paper is founded on the following four sketches, all published in 1891:—*Annali di Mathematica, Milano*, 1891, Vol. XIX, No. 3, pp. 201-11. By Anna C. Leffler, Duchess of Cajanello.—*Rendiconti del Circolo Matematico di Palermo*. Vol. V, No. 3, pp. 121-28. By Mme. E. de Kerbedz.—*Journal fur die reine und angewandete Mathematik, Berlin*, 1891. Vol. CVIII, No. 1, p. 88. Editorial by Kronecker.—*Nature*, Feb. 19, 1891, pp. 375-6. The following are promised:—Sketch with portrait in *Acta Mathematica*.—Continuation of *Reminiscences of Childhood*, from the date of her marriage. Edited by Anna C. Leffler, Duchess of Cajanello.

HISTORICAL NOTE RELATING TO THE SEARCH FOR THE PLANET NEPTUNE IN ENGLAND IN 1845-6.

BY EDWARD S. HOLDEN.

In 1876 I was in England for several months and one of my greatest privileges was the acquaintance and friendship of Mr. Lassell, the celebrated astronomer, whom I frequently visited. During one of my visits to Ray Lodge I learned the following circumstances from Mrs. Lassell, and they were subsequently confirmed and explained to me by Mr. Lassell himself.

With the innate delicacy of his character he had taken every precaution that they should not become known during the lifetime of Professor Adams, and I think he seldom or never alluded to them. At this time, when the great mathematician has gone from us, it seems to be right that they should be mentioned and, with the permission of the Misses Lassell, I reproduce in what follows the brief notes I made at the time of Mr. Lassell's confidences, as a contribution to the history of the great discovery of Adams and of Le Verrier.

It is known that in October, 1845, Professor Adams, then an undergraduate of Cambridge, submitted to Sir George Airy, Astronomer Royal, the results of his computations on the perturbations of *Uranus* and the elements of a new planet—*Neptune*—which would account for the observed disturbances in the orbit of the former.* The distinguished observer, the Rev. W. R. Dawes, visited the Royal Observatory about this time, and the letters and computations of Adams were shown to him by Airy. It is known that the Astronomer Royal had, very naturally, grave doubts as to the sufficiency of these researches; but it appears that Dawes was much impressed by the letters of Adams, and that he at once wrote to Lassell to beg him to search for *Neptune*, in the region designated by Adams, with his powerful two-foot reflecting telescope (which was then mounted at Starfield, near Liverpool).

There is no doubt whatever if such a search had been made by such an observer and with such a telescope, that the planet would have been quickly found and recognized by its disc. We have but to remember that to the same telescope and observer we owe the discovery not only of the satellite of *Neptune* but also that of the two inner and faint satellites of *Uranus*.

It chanced that the letter of Mr. Dawes reached Liverpool when Mr. Lassell was confined to his sofa by a sprained ankle,

---

* See Gould on the history of the Discovery of *Neptune*. Washington, 1850.

and that it was laid on his writing table near by for subsequent attention. Mr. Lassell, also, was impressed with the importance of a search for the predicted planet and had fully resolved to make such a search.

After his recovery he sought for the letter of Mr. Dawes which gave the predicted place of the planet. The letter could not be found as it, together with some other papers, had been removed and destroyed by a too zealous maid-servant.

I think, though I am not sure, that renewed inquiry was made by Lassell of Dawes as to the data in question. However this may have been, they were never recovered, and the mistaken zeal of the maid-servant had its full effect.

The new planet was never sought for by the most powerful telescope and the most skilful observer in England. The search of Challis, at Cambridge, was fruitless, as is well known. The planet was finally found by Galle and D'Arrest, at Berlin, on September 23, 1846, after the Berlin Observatory had received the letter of Le Verrier pointing out its situation.

This was many months after the letter of Dawes to Lassell.

This incident of the history of the search for *Neptune* is well worthy of record, as it shows by what a narrow chance Professor Adams escaped the distinction of being the *sole* discoverer of *Neptune*.

It is also worthy of remark how this and other accidents have helped to forward the Science of Astronomy. England had no higher rewards and opportunities to offer than those which she has given to Adams. But if Le Verrier had been deprived of his share in the discovery it is very much to be doubted whether we should now possess that long series of elegant and laborious researches which he was able to carry out by the facilities afforded him in his situation as head of the National Observatory of France.

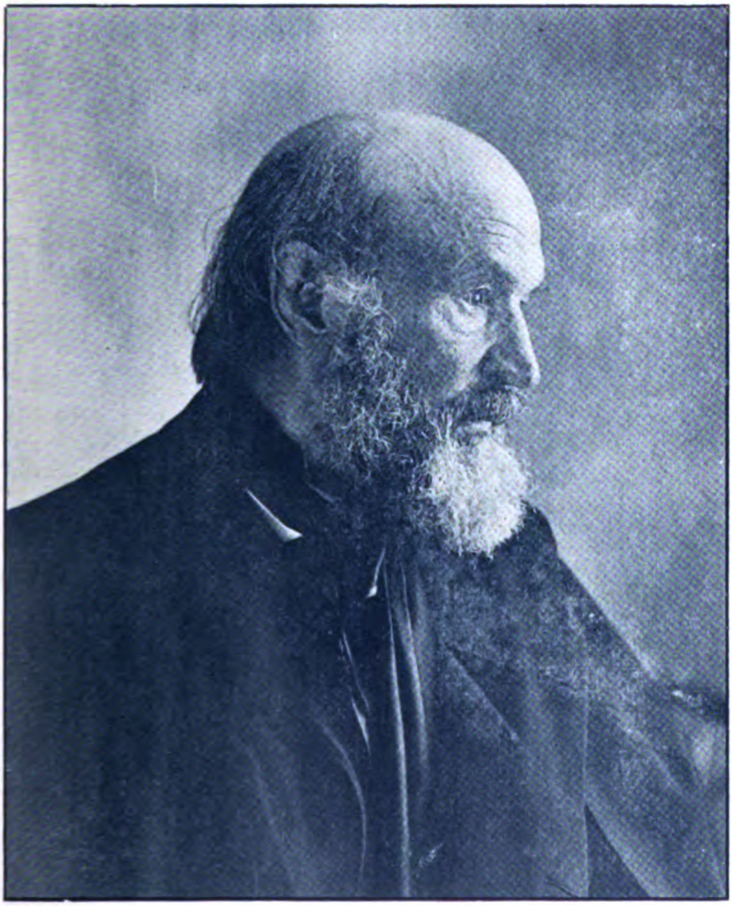
The whole relation of Professor Adams to this great discovery is again called up by this incident and the elevation of his character and the dignity of his conduct are again brought to mind.

The delicate consideration of Mr. Lassell, who for a long lifetime kept this secret in order that no possible shade of regret should be inspired during the lifetime of Professor Adams, is no less honorable. It is a pleasure to be able to link in this way the name of England's great mathematical astronomer with the name of her great observer—worthy successors of Newton and of Herschel as they were.—*Pub. of Astr. Soc. Pacific, No. 21.*

MT. HAMILTON, Jan. 30. 1892.

NOTE: By the great kindness of a friend in England I am able to reproduce here the last picture taken of Professor Adams, which was made in Cambridge in September, 1891.

PLATE X.



PROFESSOR JOHN COUCH ADAMS.

SEPTEMBER, 1891.

Plate by kindness of Professor E. S. Holden, Lick Observatory.

Astronomy and Astro-Physics, April, 1892

[illegible] laid on his writing [illegible] near by for subsequ[illegible] [illegible] Lassell, also, was [illegible] with the impor[illegible] [illegible] predicted [illegible] fully resolved [illegible]

[illegible] ter of Mr [illegible] The [illegible] be [illegible] oved [illegible]

[illegible] ary w[illegible] [illegible] Howe[illegible] [illegible] covered [illegible] mistaken [illegible] dect.

[illegible] ght for [illegible] most powerful telesc[illegible] server in [illegible] The search of C[illegible] fruitless, [illegible] ll known. The planet [illegible] Galle and [illegible] st, at Berlin, on Sep[illegible] Berlin O[illegible] tory had received the [illegible] ing out its [illegible] on.

[illegible] tter the le[illegible] Dawes to Lassell.

[illegible] tory of th[illegible] h for *Neptune* is well wort[illegible] ws by wh[illegible] arrow chance Professor Ad[illegible] nction of [illegible] the *sole* discoverer of *Neptune*.

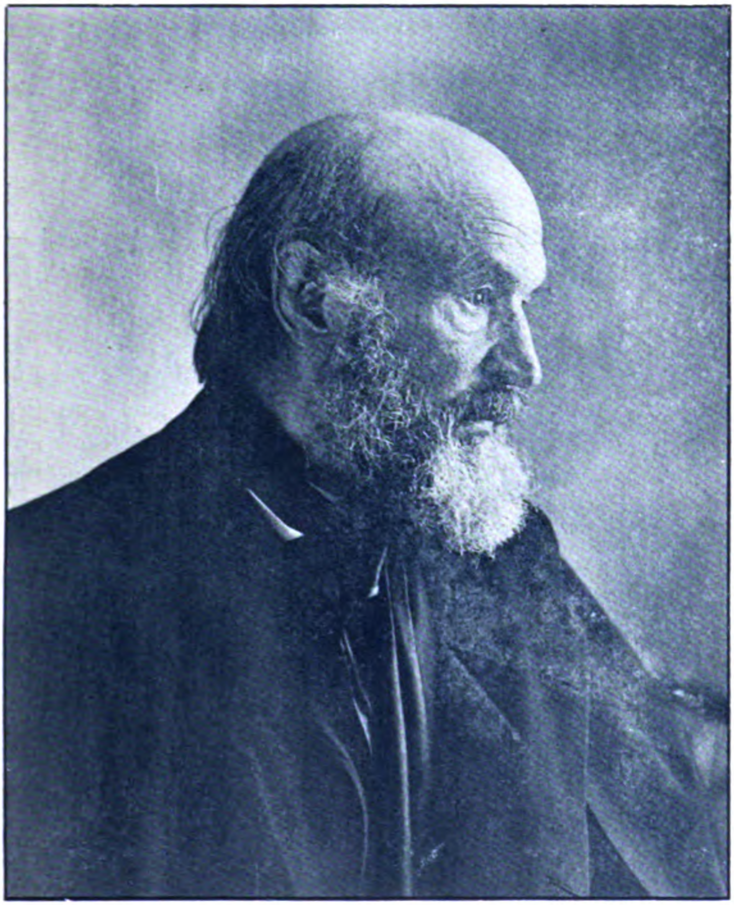
It is also w[illegible] remark [illegible] this and other accidents [illegible] helped to [illegible] the Scie[illegible] Astronomy. England had [illegible] higher rewar[illegible] and opport[illegible] to offer than those which [illegible] has given to Adams. But [illegible] errier had been deprived of [illegible] share in the discovery it is [illegible] much to be doubted whether [illegible] should now possess that [illegible] series of elegant and laborious [illegible] rches which he was abl[illegible] carry out by the facilities afforded [illegible] in his situation as [illegible] of the National Observatory of [illegible]nce.

[illegible] whole relation of [illegible] sor Adams to this great discovery [illegible] in called up by th[illegible] dent and the elevation of his char[illegible] and the dignity of [illegible] conduct are again brought to mind. [illegible] delicate conside[illegible] n of Mr. Lassell, who for a long life[illegible] ept this secret [illegible] order that no possible shade of regret [illegible] be inspired d[illegible] the lifetime of Professor Adams, is no[illegible] rable. It is [illegible] easure to be able to link in this way the [illegible] England's [illegible] at mathematical astronomer with the [illegible] er great [illegible] ver—worthy successors of Newton and of [illegible] as they w[illegible] —*Pub. of Astr. Soc. Pacific, No. 21.*

[illegible] MILTON [illegible] 30. 1892.

[illegible] the g[illegible] kindness of a friend in England I am able to reproduce [illegible] picture [illegible] of Professor Adams, which was made in Cambridge in [illegible]891.

PLATE X.



PROFESSOR JOHN COUCH ADAMS.

SEPTEMBER, 1891.

Plate by kindness of Professor E. S. Holden, Lick Observatory.

Astronomy and Astro-Physics, April, 1892

and that it was laid on his writing table near [illegible] attention. Mr. Lassell, also, was impressed with [illegible] of a search for the predicted planet and had fully re[illegible] such a search.

After his recovery he sought for the letter of Mr. [illegible] gave the predicted place of the planet. The letter [illegible] found as it, together with some other papers, [illegible] and destroyed by a too zealous maid servant.

I think, though I am not sure, that renewed [illegible] made by Lassell of Dawes as to the data in question. [illegible] were never recovered, and the [illegible] its full effect.

The [illegible] was never sought for by the most [illegible] telescope and the most skilled observer in England. [illegible] of Challis, at Cambridge, was fruitless, as is well known. [illegible] planet was finally found by Galle and D'Arrest, at Berlin, September 23, 1846, after the Berlin Observatory had re[illegible] the letter of Le Verrier pointing out its situation.

This was many months after the letter of Dawes to Lassell.

This incident of the history of the search for *Neptune* [illegible] worthy of record, as it shows by what a narrow chance Professor Adams escaped the distinction of being the *sole* discoverer of *Neptune*.

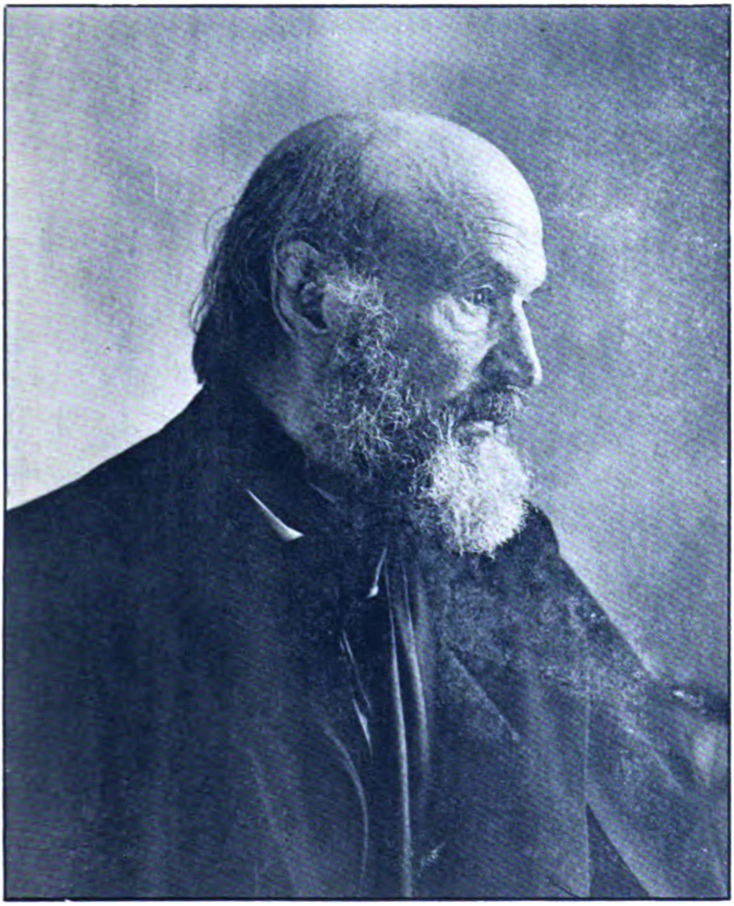
It is also worthy of remark how this and other accidents have helped to forward the Science of Astronomy. England has no higher rewards and opportunities to offer than those which she has given to Adams. But if Le Verrier had been deprived of his share in the discovery it is very much to be doubted whether we should now possess that long series of elegant and laborious researches which he was able to carry out by the facilities afforded him in his situation as head of the National Observatory of France.

The whole relation of Professor Adams to this great discovery is again called up by this incident and the elevation of his character and the dignity of his conduct are again brought to mind. The delicate consideration of Mr. Lassell, who for a long life time kept this secret in order that no possible shade of regret should be inspired during the life time of Professor Adams, is no less honorable. It is a pleasure to be able to link in this way the name of England's great mathematical astronomer with the name of her great observer—worthy successors of Newton and of Herschel as they were.—*Pub. of Astr. Soc. Pacific, No. 21*

MT HAMILTON, Jan. 30. 1892

NOTE: By the great kindness of a friend in England I am able to reproduce here the last picture taken of Professor Adams, which was made in Cambridge in September, 1891.

PLATE X.



PROFESSOR JOHN COUCH ADAMS.

SEPTEMBER, 1891.

Plate by kindness of Professor E. S. Holden, Lick Observatory.

Astronomy and Astro-Physics, April, 1892

ASTRO-PHYSICS.

OBSERVATIONS OF THE NEW STAR IN AURIGA, MADE AT PRINCETON, N. J.*

PROFESSOR C. A. YOUNG AND TAYLOR REED.

On Saturday, Feb. 6, the spectrum was observed with the 23-inch telescope and a single-prism Clark spectroscope, without cylindrical lens. The sky clouded, however, before a set of measures could be made.

C was vivid; D (?) distinct. There were two knots of luminosity between C and D, and I strongly suspected another a short distance below C. Near b and below it four bright lines or bands were easily made out, and two more between b and F. F was conspicuous, and $H\gamma$ (near G) was obvious. There was a faint line about one-third of the way from G towards F; and I thought I could glimpse h ($H\delta$). In all thirteen bright lines were fairly seen between C and F inclusive, and two others were suspected outside those limits.

Bad weather and other circumstances prevented further observations until Feb. 12, when a series of measurements was made with the 9½-inch telescope and the Clark spectroscope, by means of the scale and occulting bar. The constants of the scale were determined by reference to the spectrum of the Moon. Ten lines were measured with the results for wave-length which are given in the appended table.

On the 13th, a second set of measures was made with the 23-inch, and a single reflecting prism of Hastings' design, on the Brashear spectroscope. The prism is moved by a tangent-screw which carries a vernier over a graduated circle, and the measures were made by bringing the lines to the faintly illuminated cross wires of the micrometer and reading the circle, the reference points being obtained from the spectrum of the Moon as before. The method proved rather unsatisfactory, the graduation of the circle not being fine enough to correspond with the optical power of the apparatus: the results for the eight lines measured are given in the table.

Before the Hastings' prism was put in place, the brightest part of the star spectrum was examined with the Rowland grating of 20,000 lines to the inch, in order to determine whether the lines

---

* Communicated by the author.

were true *lines*, or whether they were *bands*, sharply defined on the more refrangible edge, and fading away towards the red. An impression of this sort had been received from some of the observations with the small spectroscope, but it was found to be incorrect. The lines were diffuse indeed, like C and F from hydrogen under some pressure; but the shading was sensibly symmetrical each way from the middle of the line. The two lines nearest F (4922 and 5015) made the impression of being *multiple*; but they were not bright enough to permit a narrowing of the slit sufficient to settle the question.

On Feb. 15th, the same instruments were used as upon the 13th, but a different plan of work was adopted, by limiting the measures to a single field of view, extending from F to some distance below; the special purpose being to determine whether or not the two principal nebula lines (λ 5004 and 4957) were present in the star spectrum. The prism was firmly clamped, and the measures were made wholly by the micrometer, the reference points being derived from the nebula of Orion and the Moon. The results for the six lines measured are given in the table, and may, I think, be depended upon with an error not to exceed one, or possibly two, in the last figure. It was intended to extend the measures to other parts of the spectrum, but clouds prevented.

I regret extremely that the non-completion of the prism-train for the Brashear spectroscope made it impossible to attempt photographs of the spectrum.

As regards the identification of the lines, C, F and Hγ are beyond doubt. One would expect to find D_3, but the measures seem to indicate a lower position for the bright line observed, not far from the sodium lines themselves. It may be worth noting that the red line at 632 and the yellow one at 559 (according to the measures) are near the positions of the two aurora lines at 557.1 and 630*, possibly within the limits of error. The line at 449 may perhaps be the always present chromosphere line known as f, (λ 4472), or, perhaps more probably may correspond to the three lines at 4490 and 4501; indeed, it is not unlikely that all four of the lines named might be confounded into a single diffuse band in observing that faint part of the spectrum with (necessarily) rather widely opened slit.

As regards the lines in the green the micrometer readings seem to be irreconcilable with the presence of the two brightest nebula lines. The lines at 5015 and 4957 are more probably identical

---

* My own observation of the wave-length of this line on Feb. 13th made it 633.5.

with two rather remarkable groups of lines frequently present in the chromosphere spectrum at 5015-18, and 4918-23 respectively. The line at 5165 is almost coincident with b_4 (5167), but the absence of the other magnesium lines makes the identity improbable. The line at 5304 is not far from the corona line (5316), but the difference appears to be quite beyond the possible limit of error. The line at 5260 was very faint and its position is not so well determined as the other four figure places. It falls very near E.

On Feb. 6th the star was easily visible to the naked eye, and was estimated as about a quarter of a magnitude brighter than χ Aurigæ; by the 15th it had fallen off very sensibly, and was about a quarter of a magnitude fainter than χ.

From six meridian circle observations of the star in connection with β Tauri, Mr. Reed has found for its mean place, Jan. 1, 1892, $\alpha = 5^h\ 25^m\ 3^s.30$, $\delta = +\ 30^\circ\ 21'\ 49''.2$.

Bright lines in the Spectrum of Nova Aurigæ—α 5^h 25^m $3^s.30$; δ 30° $21'$ $49''.2$. [1892.0].

Date	1	2	3	4	5	6
Feb. 12	434 (Hγ)	449	486 (F)	493	501	516
" 13	......	......	486	492	502	515
" 15	......	......	4861	4922	5015	5165

Date	7	8	9	10	11	12
Feb.	......	531	559	588, D?	faint	656 (C)
"	faint	530	......	591	631	656
	5260	5304	......	......	......	......

PRINCETON, Feb. 20, '92.

THE TEMPORARY STAR IN AURIGA.*

G. RAYET.

The temporary star in Auriga, the existence of which was announced by a telegram from Mr. Copeland dated February 1st, and which was discovered by an anonymous amateur, has been observed twice with the instruments of the Bordeaux Observatory, on the 10th and 11th of February.

The position of the new star for 1892.0 is: R. A. $5^h\ 25^m\ 3^s.47$, P. D. $59^\circ\ 38'\ 9''.5$.

The new star is not given in Argelander's zones, and it is therefore probable that its previous magnitude was less than the 9th.

---

* Translated from *Comptes rendus* (Paris), Feb. 15, 1892.

On the 10th and 11th, the star was about 5th magnitude, comparable with 26 Aurigæ: its color was noted as yellow orange or straw yellow.

The spectrum of the star, which I have examined twice with a spectroscope having a single prism of heavy flint, and mounted on the 14-inch Bordeaux equatorial, consists of a continuous spectrum, in which the red and violet seem very brilliant, with four bright lines or bands in the green. My measures give the following wave-lengths for these lines:

First line	518 $\mu\mu$ near b; probably b.
Second line	501
Third line	493
Fourth line	487 near F; very probably F.

The second and third lines are the brightest; they have, as is always the case, a banded appearance.

The spectrum of the new star in Auriga differs very sensibly from that of the new star in Corona (May, 1866) observed by Huggins, M. Wolf and myself; from that of the star in Cygnus (November, 1876) described by Vogel, Cornu, Copeland and Backhouse; and, finally, from that of the star in Andromeda (August, 1885) studied by Vogel, Maunder and Perry. The light of all these stars showed bright lines in the red and violet, particularly the lines $H\alpha$ and $H\beta$ of hydrogen; the lines of the present star are all four comprised between b and F. It must be remarked, however, that in the case of the star in Cygnus, the outer lines of hydrogen disappeared before F and the line $501\mu\mu$; this, perhaps, explains why the $H\beta$ line is the only one visible in the light of the star in Auriga.

P. S. A new observation, made on the night of February 14-15, allows me to add to the four preceding lines the bright line $H\alpha$ of hydrogen in the red, and that of sodium.

THE MODERN SPECTROSCOPE.

IV.

The New Spectroscope of the Halsted Observatory.[*]

PROFESSOR C. A. YOUNG.

Through the liberality of one of the best friends of Princeton College the Halsted Observatory has lately received a powerful

---

[*] Princeton College Bulletin, November, 1891.

spectroscope, which in several respects is more perfect and complete than any other before constructed. It has been designed as a sort of universal instrument, to cover, as nearly as possible with a single apparatus, all the ground of Astronomical Spectroscopy. It is arranged for solar work, either in the study of Sun-spot or chromosphere spectra, or for the observation of the prominences; also for the study of stellar spectra with high dispersion in order to follow up the work of Vogel and others upon the motion of stars in the line of sight; and it has a low-dispersion prism which makes it available for observations upon the spectra of comets or other faint objects. Moreover, the construction is such that the observations can be made either visually or photographically.

Naturally, the attempt to cover so much ground with a single instrument renders it somewhat complicated; but it has not been necessary to sacrifice, nor even seriously to compromise, any one object in order to attain others.

The instrument has been constructed by Mr. Brashear of Allegheny, the same optician who made the spectroscope for the Lick Observatory; and great credit is due him and his foreman, Mr. Klages, for the great skill and ingenuity with which they have carried out the general plan, and for the admirable accuracy and finish of the workmanship.

A stiff but light framework of four steel tubes carries the spectroscope, and is attached to the great telescope by two rings which slip over the seven-inch brass tube that forms its tail-piece. This mode of attachment permits the spectroscope to be rotated freely around the optical axis of the great telescope, and to be clamped firmly in any position. The collimator is mounted centrally in this framework in such a way that it can be adjusted with respect to the optical axis, and also can be moved longitudinally a distance of about four inches in order to bring the slit-plate accurately into the focal plane for rays of any color. (The focus of the 23-inch object-glass for the violet portion of the spectrum near the lines H and K is more than three inches beyond the focus for the green rays).

The slit-plate is an elaborate and beautiful piece of workmanship; the jaws of the slit are most carefully finished, and there are arrangements for varying the opening from zero to half an inch in width, and from zero to an inch in length, as well as for moving it sideways. The plate carries a set of colored screens which can be interposed at pleasure; also (when needed) a "comparison reflector" for throwing into the slit the light of an electric spark, the electrodes between which the spark is formed being carried by a holder attached to the steel tubes of the supporting frame. There is also a "rotation prism," which can be attached at pleasure, and enables the observer to make any portion of the Sun's limb parallel to the slit without having to rotate the spectroscope into uncomfortable positions.

The collimator has an object-glass two and a half inches in diameter, with a focal length of thirty inches, and the same is true of the view telescope. This is supported by a pair of light but stiff arms which are firmly attached to the steel tubes, and it is held by these arms in such a position that it receives centrally the rays from the grating or from the prism-train as the case may be. When the grating is in use a short pair of arms is used which holds the view-telescope in a rigidly fixed position; when the grating is replaced by the train of four prisms used in stellar work, a second and longer pair of supports is substituted, so arranged, as to permit the necessary motion of the view-telescope over a considerable arc, but with the means of clamping it firmly in any position. The necessity of making such a change is of course objectionable, but it is unavoidable, and Mr. Brashear has ingeniously reduced the inconvenience to a minimum without sacrificing the indispensable firmness.

The collimator and view-telescope are each provided with two separate object-glasses, one pair to be used for all visual observations, the other for photography. It was originally intended to have but one pair, with the component lenses made of the new Jena glass, giving a practically perfect color-correction through the whole range of the spectrum. But Mr. Brashear, after considerable experience in the matter, has reluctantly come to the conclusion that it is not yet practicable to construct such lenses, or rather that such lenses when constructed cannot be relied on to keep their polish for any great length of time; the glass soon "rusts."

The tube of the view-telescope is made in two sections, so that the eye-piece end with its micrometer can be easily removed and replaced with a camera tube carrying a 4 × 5 plate-holder.

In focussing the spectroscope the two object-glasses of the collimator and view-telescope are moved simultaneously and equally by a very ingenious arrangement which couples them together and still leaves the view-telescope all the necessary freedom of motion. It may be stated here that all the instrumental adjustments of every kind are managed by milled heads easily accessible by the observer without removing his eye from the eye-piece also that there are graduated scales to each important adjustment, so that a record can be made of the precise state of the instrument at any observation.

For solar work the "dispersion piece" is a magnificent five-inch Rowland grating of 20,000 lines to the inch ruled on a speculum metal plane. The definition of this grating is superb, and its spectra are remarkably free from "ghosts," though not absolutely so. At present, through the kindness of Mr. Brashear, we have also on loan a second, smaller but very fine grating of 14,400 lines to the inch, which can be at any time substituted for the other, and used for verifications. The grating is so mounted that it can be rotated by the observer in the plane of dispersion as usual, and also so that it can be slightly adjusted in a plane at right angles to this, as is sometimes necessary, and this, as has been said, without taking the eye from the instrument.

The prism for comet work has faces about 3½ inches by 3, with a refracting angle of about 25°; it is silvered on the back, and when substituted for the grating furnishes by reflection a short but brilliant spectrum, without requiring any other change of adjustment or arrangement.

For observation of stellar spectra there is a train of four large compound prisms of Jena glass faced with wedges of crown glass. The faces of the prisms measure about two and a half inches by three, the back of the prism being fully four inches long. The angles are calculated to transmit the H and K lines of the spectrum with a minimum deviation of about 165°. The prisms are mounted in a metal box, and connected with each other in such a way that the adjustment for minimum deviation is easily made for all four at once by simply moving a sliding rod at the eye end of the view-telescope. When this prism is used the grating-box with its appendages is removed and the prism-box substituted; the view-telescope also has to be taken off and replaced with the proper supporting framework. The whole operation can be performed in less than ten minutes.

The optician has encountered considerable difficulty in connection with these prisms; one of the four originally sent proved to be unsatisfactory on account of unequal density in the glass, and the prisms are now in the maker's hands to have the faulty one replaced. Nothing, therefore, has yet been done with the instrument used as a prismatic spectroscope.

With the grating some preliminary work has been done, both in the way of visual observations and by photography. About fifty plates have been exposed, more or less successfully, and a c

tc

“1

T

the

repl

In

mato

by a v

and sti

motion.

ments of

ble by th

PLATE XI.

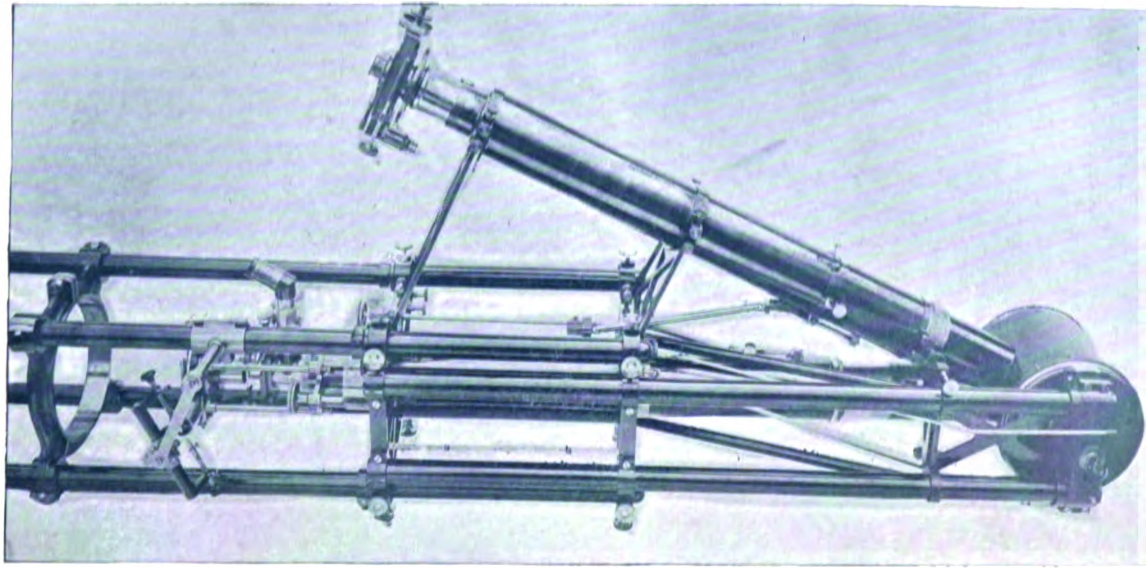


Plate accompanying Professor Young's paper on the New Spectroscope of the Halsted Observatory.

ASTRON. AND ASTRO-PHYSICS, March, 1892.

considerable number of good negatives have been obtained, mostly relating to the ultra-violet portion of the spectra of the chromosphere and prominences, with a few spectra of Sun-spots.

The plates confirm entirely the results first photographically reached by Hale of Chicago early last summer, and since then by Deslandres in Paris, as to the constant and brilliant reversibility of the H and K lines in the spectra of Sun-spots, and of the chromosphere and prominences. (The fact of this reversibility had been known ever since 1872 as the result of the *visual* observations made by the writer at Sherman, Wyoming.) The photographs also show, as do those of Hale and Deslandres, in the spectrum of the solar chromosphere, the remarkable ultra-violet series of bright Hydrogen lines which are so conspicuous and characteristic as dark lines in the spectra of the stars of the first or Sirian type, but are hardly visible in the spectrum of the photosphere of the Sun, and in the spectra of the Sun's stellar congeners.

A partially successful attempt has also been made to photograph the spectrum of a star with a grating; in the negative of the spectrum of Vega, made with an exposure of half an hour, the principal lines are unmistakably visible; but the impression is extremely faint, and the result is interesting only as being, so far as I know, the first instance in which any impression at all has been obtained of a star-spectrum by means of a grating.

As a first fruit of visual observations with the new instrument may be mentioned the discovery that the bright red line, which often appears in the active prominences at 6679 of Angstrom's scale, (No. 2 of the catalogue of chromosphere lines), is distinctly less refrangible than the Iron line of which it has hitherto been supposed to be the reversal. The behavior of this line has always been a mystery, since there was no obvious reason why it should behave so differently from the other Iron lines of the spectrum near it. It is now certain, however, that, whatever may be the substance to which this line is due, it is not Iron.

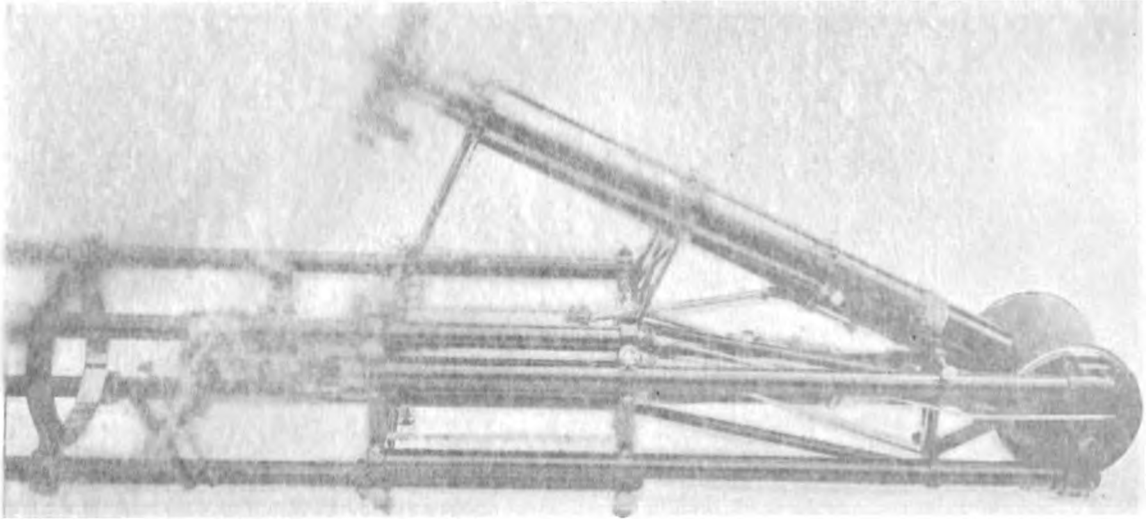
ON THE LIMIT OF VISIBILITY OF THE DIFFERENT RAYS OF THE SPECTRUM.*

CAPTAIN W. DE W. ABNEY.

In certain photometric experiments it became necessary to find the limit of visibility of the different parts of the spectrum, and

---

* Proceedings Royal Society, No. 301.



[illegible] the New Spectroscope of the Halsted Observatory

…d,
…of the
…ts
…lly
…by
…ity
…chro
…had
…*d* observa-
…The photo-
…and besides, in the
…remarkable ultra-violet
…so conspicuous and
…of the stars of the first
…the spectrum of the pho-
…of the Sun's stellar con-

…has also been made to photo-
…with a grating; in the negative of
…an exposure of half an hour, the
…sible; but the impression is ex-
…resting only as being, so far as
…any impression at all has been
…means of a grating.

…ervations with the new instrument
…that the bright red line, which
…mmences at 6679 of Angstrom's
…chromosphere lines), is distinctly
…of which it has hitherto been
…sed. The behavior of this line has al
…there was no obvious reason why it
…from the other Iron lines of the spec-
…certain, however, that, whatever may be
…this line is due, it is not Iron.

…OF VISIBILITY OF THE DIFFERENT RAYS OF THE SPECTRUM.*

CAPTAIN W. DE W. ABNEY.

…otometric experiments it became necessary to find
…sibility of the …ferent parts of the spectrum, and

…l Society, No. 301.

PLATE XI.

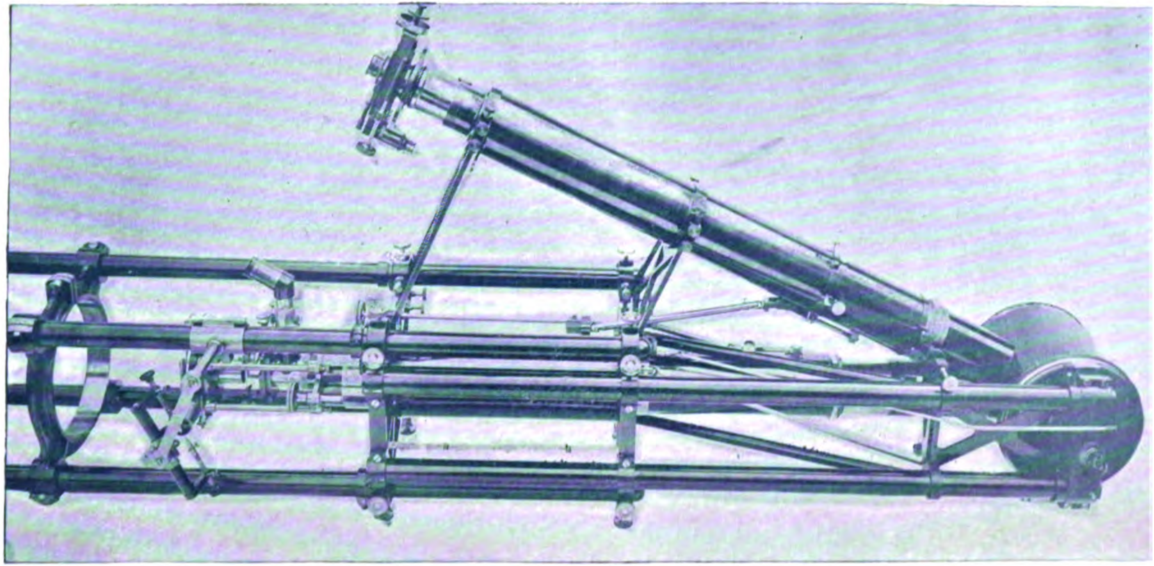


Plate accompanying Professor Young's paper on the New Spectroscope of the Halsted Observatory.

Astron. and Astro Physics, March, 1892.

also to ascertain what ratio this limit would bear to some fixed luminosity. It should be borne in mind that this question is totally different from acuteness of vision, which some have confounded with it. The two are independent one of the other, and can scarcely be compared.

The instrument used in these experiments was similar to that described in the note on the examination of a case of Tobacco Scotoma, &c., but the dimensions were modified:—A square tube, 3 feet long, had an aperture of 2 inches cut in its side at 2 feet 6 inches from one end, and covered over with ground glass. Within the tube, and close to the ground glass, was a mirror, which reflected the light coming through the ground glass on to the end of the tube, and if the ground glass was illuminated by any light the reflection illuminated a card placed at the end of the tube. The illumination of the card could be viewed through a circular hole at the other end of the tube, in which was fixed a smaller tube, fitting closely into the eye. If a color patch from the spectrum was thrown on to the ground glass, evidently the card at the end of the tube would be illuminated by the color used, and its disappearance could be effected by means of rotating sectors closing and opening at will, placed in front of the patch. This simple piece of apparatus answered its purpose most effectively.

The first point to ascertain was the ratio of illumination of the card to that of the patch thrown on the ground glass. The following arrangement was made to effect this:—The end of the tube, against which the card was placed, was removed, and a card with a square hole, of ¾-inch side, was inserted instead. This was covered on the side away from the tube with a piece of Saxe paper, and when viewed from the outside, and when illuminated by the light from the ground glass, showed as a square patch of light. Outside of this, and of double the width, but of the same height, a mask of black paper, with an oblong aperture, was placed so that the illuminated square occupied one-half of the oblong, and the other half showed no white paper. An amyl acetate lamp (0.8 of standard candle), placed at a fixed distance from this oblong, and in a line with the axis of the tube, illuminated both squares; but a rod placed in proper position cast a shadow on the translucent square, allowing only the opaque white half to be illuminated. When the sectors above alluded to were placed in front of the lamp, the two brightnesses could be equalized, and the intensities of the light transmitted passing through the paper estimated.

Now there is a ray very near D in the spectrum, whose color is very closely, if not quite, identical with the color of the light emitted by the burning amyl acetate, and for making the measures this ray was used. When the measure had been made, the screen, with the square aperture, was placed in the position of the ground glass, and the amyl acetate lamp placed on the side of the screen, away from the color patch, and the rod placed in position to cast the shadow necessary. The rotating sectors were then placed between the spectrum and the screen, and the light reduced so that the illumination of the translucent and opaque white square, *viewed from the side of the lamp*, was equalized. Knowing the distance of the lamp in the two cases, and the aperture of the sectors, the relative illumination of the two surfaces was ascertained. For convenience, the aperture of the ground glass was limited by means of a diaphragm, or by placing a diaphragm in front of the first prism.

Two sets of measures showed that if the illumination of the ground glass be represented by 1, the illumination of the card at the end of the tube was $\frac{1}{700}$; that is, any light falling on the ground glass was diminished to that extent.

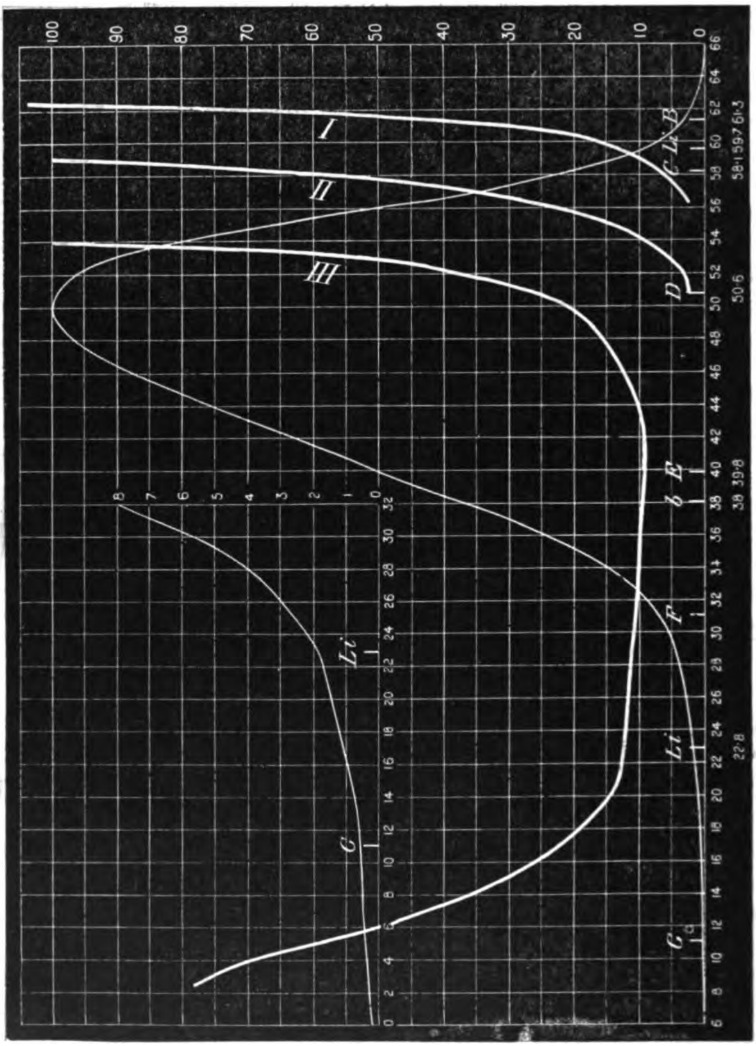
The actual measures were $\frac{1}{690}$ and $\frac{1}{714}$, but we may take $\frac{1}{700}$ as sufficiently close to the truth.

The color-patch apparatus to which reference is made is described in the Bakerian Lecture, 1886 (Abney and Festing, "Color Photometry"). The only addition to it that was made was to use an adjustable slit to move through the spectrum. There was thus a treble means of altering the intensity of the light, viz., by altering the aperture of the slit of the collimator, by altering that of the slit of the slide, which was shifted at will into different parts of the spectrum, and by the rotating sectors placed in front of the spectrum. The mode of proceeding to measure the luminosity at which light disappeared was as follows:—The dullest part of that portion of the spectrum which it was desired to extinguish was allowed to pass through the slit in the spectrum, and a patch was formed on the ground glass, which, it may be remarked, had a tube fitted over it, to prevent any chance of extraneous light reaching it. The card at the end of the square box was viewed, and the slits closed till all trace of light disappeared. (It may be as well to call to mind what is well known, that faint light of all colors appears as white). In some sets of experiments the sectors were set at fixed angles, and rotated in front of the patch, and the slit in the spectrum moved from a position in which faint light appeared to one in which it just disappeared, the position in the spectrum being noted by the scale at the back of the moving slide carrying the slit. In other cases the slit was placed at different positions in the spectrum, and the rotating sectors closed till all light had vanished, when the aperture was noted. The first plan is the more convenient of the two, and gives very accurate results; though in some positions of the spectrum the second method must be adopted, since the graphic curve formed from the readings becomes almost a horizontal straight line at one portion of the spectrum. As wil be seen from the table, it is quite evident that no one aperture of the slit of the collimator and of that in the slide would suffice to give the entire range of disappearance of the spectrum, and that at least three settings are necessary. At each change the D light falling on the ground glass was measured, and the necessary factors to make the readings on one scale were derived from these measurements.

Four sets of measures throughout the spectrum were made on different days. No one differed to any appreciable extent from the other. A mean of the four has been taken as representing the truth, and the measures given in the first table are those of that which most nearly approaches this mean. It may be stated that very rarely did one curve differ more than 4 per cent. from another at any portion of the spectrum. The readings were taken when the eye had rested in darkness some time, and were often repeated a considerable number of times, the first parts measured being re-measured last. That the eye was equally sensitive throughout the time may be judged from the fact that the two sets of readings scarcely ever differed. The process of making these measures of extinction is very fatiguing, and probably rather detrimental to the eyesight; owing to the strain on the eyes, one set of readings is usually as much as can be properly carried out on any one day, if accurate results are to be looked for.

It is now three years ago since I began this research, and, after trying various plans, I have come to the conclusion that the method now described is the most easy, as it is the most simple.

There is one point in the method which might be open to criticism, and that is that the cutting off the light by rotating sectors might cause some error in the results. This criticism, I may say, I raised in my own mind at its very commencement, and found that it was unnecessary. Polarising the light entering the slit of the collimator, and then dimming it by means of a Nicol's prism placed in front of the color patch, proved an unsatisfactory method for answering the criticism, as in no case could a total disappearance of a bright light be brought about; but by diminishing the area of the color patch by placing different apertures of diaphragms in front of the last prism of the



The ordinates of Curve II are ten times that of I, and of Curve III 100 times that of I.

color-patch apparatus (and thus throwing on the ground glass discs of light of various areas), the truth of the results was readily verified. The two sets of measures, one made in this way and the other as just described, gave identical results within the limits of the errors necessarily due to observation.

The method adopted gave the extinction of light on the whole retina, for not only was the central part used, but the extinction was carried so far that it was complete for every part of the eye. As there is a considerable absorption in the yellow spot this is necessary, but the absorption exercised in this part of the eye, which occupies from 4° to 6° angular aperture, can be fairly measured if only the light on a small area be extinguished and this part of the retina be alone used. A very simple way of see-

TABLE I.

No. 1.

Scale No.	Sector aperture.	Sector aperture reduced.
55.2	180	180
5.3	180	180
54.0	90	90
9.3	90	90
53.2	60	60
10.6	60	60
52.3	45	45
13.3	45	45
51.3	32	32
15.9	32	32
50.5	25	25
16.3	25	25
50.0	22.5	22.5
17.3	22.5	22.5
48.4	15	15
19.3	15	15
45.4	11	11
26.3	11	11

D light had to be reduced to 0.17789 its luminosity to equal the light from an amyl lamp at 48 cm. from the ground glass.

No. 2.

Scale No.	Sector aperture.	Sector aperture reduced.
57.3	180	456
2.1	180	456
55.9	90	228
4.3	90	228
54.1	38	97
8.3	38	97
53.1	20	51
12.3	20	51

Luminosity of patch on No. 2 = 2.56 that of No. 1.

No. 3.

60.8	180	2700
..	..	..
59.4	90	1350
58.3	45	675
56.9	22.5	337
53.4	5	75

Luminosity of patch No. 3 = 15 that of No 1.

No. 4.

Scale No.	Sector aperture.	Sector aperture reduced.
52.3	180	45
14.3	180	45
49.8	90	22.5
17.3	90	22.5
44.3	45	11.25
26.3	45	11.25
43.3	40	10
35.3	40	10
25.3	45	11.25
30.3	43	10.75
34.3	40	10
38.3	37	9.2

Luminosity of patch in No. 4 = 0.25 that of No. 1.

No. 5.

61.9	180	6000
60.9	90	3000
60.2	60	2000
59.0	30	1000
57.6	15	500
56.5	9	300

Luminosity of patch in No. 5 = 22.2 times that of No. 1.

A measure showed that 63 required double the aperture of 62 to be extinguished.

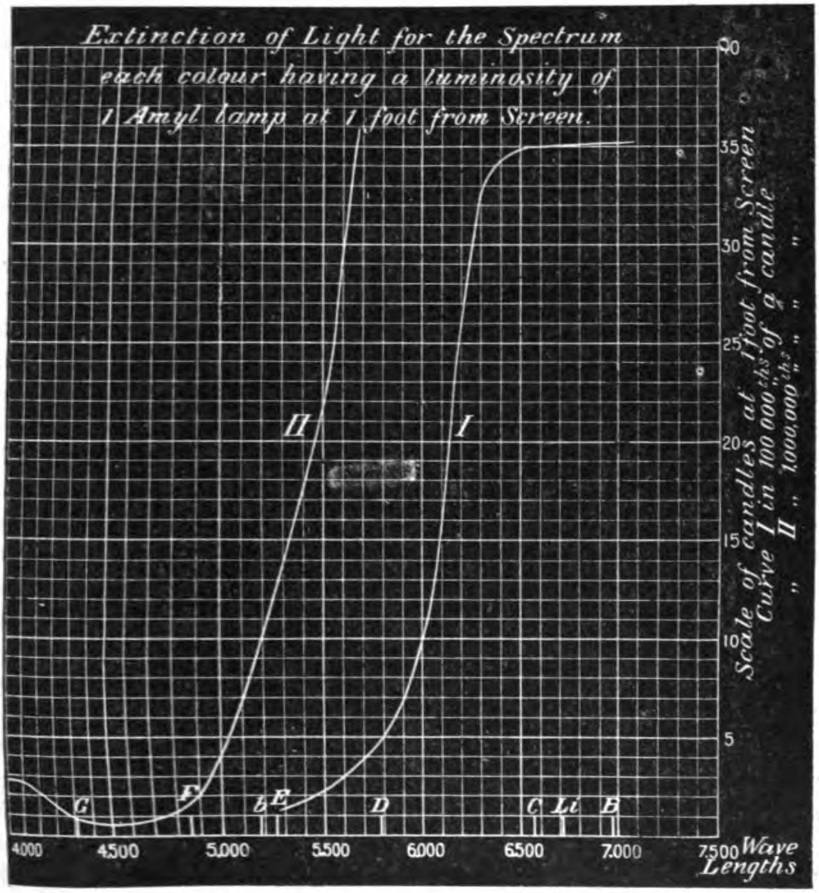
ing the absorption of the yellow spot is to form a feeble spectrum some 3 inches long on a ground-glass screen. If the eye looks at the green, a dark band extending to the blue will be seen, but if the eye be turned towards the red end or violet, the green is seen outside the central spot and the color reappears. I propose to return to this in a fuller discussion of the subject.

TABLE II.

Extinction of Rays of Equal Luminosity, the Luminosity being 1 Amyl Lamp at 1 foot from a Screen.

Scale No.	λ.	Reading.	Luminosity of rays.	Extinction of equal luminosities.	.00001 of an amyl lamp 1 ft. off screen.
63	7082	13,000	1	13,000	36.11
62	6957	6,400	2	12,800	35.5
61	6239	3,100	4	12,400	34.4
60	6728	1,800	7	12,600	35.0
59	6621	1,000	12.5	12,500	34.7
58	6520	600	21	12,600	35.0
57	6423	380	33	12,540	34.8
56	6330	240	50	12,000	33.3
55	6242	160	65	10,400	29.0
54	6152	100	80	8,000	22.2
53	6074	55	90	4,950	13.75
52	5996	38	96	3,640	10.11
51	5919	28	99	2,772	7.70
50	5850	21	100	2,100	5.83
49	5783	17	99	1,682	4.65
48	5720	16	97	1,552	4.31
47	5658	14	92.5	1,294	3.59
46	5596	12.4	87	1,078	2.99
45	5535	11.6	81	906	2.517
44	5481	10.0	75	750	2.083
43	5427	9.8	69	686	1.905
42	5373	9.6	62.5	600	1.666
41	5321	9.6	67	546	1.516
40	5270	9.6	50	480	1.333
38	5172	9.6	36	346	0.911
36	5085	9.8	24	236	0.655
34	5002	10.0	15	150	0.4166
32	4924	10.2	8	82	0.2277
30	4845	11.0	5.5	50	0.1388
28	4776	11.2	4	43.6	0.1166
26	4707	11.6	3	35	0.0972
24	4643	12.0	2.2	26.4	0.0733
22	4578	12.4	1.6	20	0.0555
20	4519	14.0	1.4	18	0.0500
18	4459	18	1.2	21.6	0.0600
16	4404	26	0.9	23.4	0.0650
14	4349	36	0.7	25.2	0.0700
12	4298	50	0.6	30	0.0833
10	4247	70	0.55	36.4	0.1011
8	4197	104	0.5	52	0.1444
6	4151	160	0.4	64	0.1777
4	4105	240	0.35	84	0.2333
2	4058	350	0.3	105	0.2916
0	4010				

The first table shows the actual observations in the spectrum. The second table attached shows the extinction of light of a luminosity of one amyl lamp placed at a foot from the screen. It will be seen that the extinction of the red rays is effected when they are reduced to about 36/100,000 of this standard, whilst the rays near F require a reduction of 5/10,000,000, that is, the sensitiveness of the eye is 700 times greater for the latter color than the former, and this has a bearing on the extinction of white light of different qualities.



It is worthy of remark that the reduction of the rays from about C to the visible limit of the red necessary to cause extinction from the standard luminosity is practically the same, and points to the fact that this part of the spectrum is probably monochromatic; if admixture of any other color sensation were present, the curve would rise or fall instead of remaining horizontal. The same apparently applies to the violet end of the spectrum, though, owing to the small luminosity, exact measures of it are less certain. The experiments show that the rays having the wave-length of about λ 4770 are the last perceived. The shift in the position of maximum resistance to about λ 4510, as shown in Table II, is due to the fact that equal luminosities of each color have been considered as being reduced.

Some interesting experiments were carried out by placing slits in different parts of the spectrum, and forming a mixture of light on the ground glass of the apparatus. An intense D light mixed with a faint light near F formed a color patch, and this mixed light was extinguished and found to require 9° of aperture of the sector. The D light was then shielded and the single ray of blue-green light was extinguished, when it was found that the same aperture was required to extinguish this beam alone. Red and green and various other mixtures were tried, all showing that in the extinction of light the green-blue light was the last visible, and was equivalent to extinguishing that light alone, although it might be mixed with very much brighter light in the red or yellow. In the blue the conditions somewhat change, as will be seen in the diagram, but if slits of equal aperture were used the same results were obtained.

The diagram shows that in the spectroscopy of feeble light the rays in the blue and green are the first to be perceived, and that rays of far greater intensity in the yellow and red may exist without exciting the sense of light. This may account for some of the varied results recorded in eye spectroscopic observations of sources of feeble luminosity, in which the yellow and red lines are absent.

In extinguishing white light, the fact of the total extinction of the blue-green light is of importance.

It is not the *light* at that particular wave-length which disappears last, but some one *sensation* which is principally existent at that point, but which extends over a great portion of the spectrum which has to be extinguished. For instance, in extinguishing the light from the reflected beam of the electric light already alluded to, it was found that the light illuminating the ground glass was 720 times brighter than that reaching the screen. To extinguish 0.014 of the light from an amyl lamp on the ground glass the sector had to be closed to 21, that is the light of one amyl lamp luminosity, falling on the screen at 1 foot distance, had to be reduced to $\frac{14}{1000} \times \frac{1}{720} \times \frac{21}{180}$ or $\frac{1}{441,000}$ of the original light. Had the luminosity of the unit of luminosity been due entirely to the color at λ 4776, it would have to be reduced to about $\frac{1}{900000}$ of its luminosity before it became invisible. Thus the electric light gives about half the sensation of this light that the monochromatic light of that color and luminosity would give, and hence we may conclude that about half the luminosity of the white light is due to this sensation, of course distributed unequally through its spectrum. This is a very close approach to the area of the green sensation curve of the spectrum when the luminosity is taken into account.

It would thus appear that by studying the extinction curves it may be possible to approximate to the three positions in the spectrum which the colors giving the nearest approach to the three fundamental sensations on the Young-Helmholtz theory occupy.

THE ASTRONOMICAL EXHIBIT AT THE WORLD'S COLUMBIAN EXPOSITION.

The four hundredth anniversary of the discovery of America by Columbus is to be fittingly celebrated at Chicago in 1893. In buildings which themselves sufficiently emphasize the progress of American architectural skill, the exhibits of the world will be so grouped as to render evident to the visitor the gradual development and the present condition of every art, science and industry. Only those who have recently visited the grounds of the Exposition, and watched the daily progress achieved by an army of nearly five thousand workmen, can have any adequate idea of the exalted standard of excellence which the directors have in view. Some of the buildings are practically completed, and it is already possible to faintly picture the Venice-like beauty which the waters of Lake Michigan and the winding lagoons will lend to the scene. But it is not with the evidence of material progress that we are now dealing. It is of more interest to learn that a space nearly 800 feet long and 300 feet wide has been set apart in the largest and best situated building on the grounds for the use of the Department of Liberal Arts, and in this space the astronomical exhibit will naturally be found.

The scope and nature of this exhibit will largely depend upon the liberality with which astronomers and instrument makers respond to the call for a full and complete display. Advices already received from Warner & Swasey, J. A. Brashear and Alvan Clark indicate that there will be no lack of instruments of the highest class. It is hoped that there will be at least one refracting telescope of fully 20 inches aperture, and among a number of smaller refractors it is probable that two will exceed an aperture of 12 inches. Reflectors will be shown in all sizes, while the mere fact that Brashear will exhibit is sufficient guarantee that spectroscopes of all kinds, gratings, prisms, flat surfaces, etc., will not be lacking. Two large domes have been arranged for, and a complete working model of the Lick Observatory is now being made. As many apparatus makers are yet to be heard from, the outlook in this direction is most encouraging.

The great advances in astronomy and spectroscopy which have resulted from the application of photography should be fully illustrated. At the Lick Observatory a large number of transparencies on glass, eight by ten inches in size, are being prepared from negatives of the Moon, Jupiter, etc., and the remarkable success of the Henry Draper Memorial will no doubt be exemplified by a large collection of photographs of the stars and stellar spectra from the Harvard College Observatory. It is to be hoped that Professor Rowland will send many specimens from the extensive series of photographs of solar and metallic spectra on which he is now engaged.

It is also proposed to include in the exhibit a collection of photographs of all telescopes in the United States of six inches aperture and upwards, together with all important spectroscopes and special instruments employed in astronomical or spectroscopic investigation. It is desirable that the photographs be, so far as possible, of the uniform size of eight by ten inches. They may be either glass transparencies, or *unmounted* paper prints. The latter will be properly mounted by those who have charge of their installation.

Finally, a large collection of American astronomical publications is desired. These will include complete sets of the publications of observatories and societies; periodicals; books and papers on astronomy and spectroscopy, etc.

It will be noticed that only American exhibits are here called for. The arrangements of the 52 foreign countries which have officially announced their intention of participating in the Exposition are such that the exhibits will be grouped by nations, rather than by subjects. While this natural system may possess some disadvantages as compared with a rigid classification by subjects, it will at the same time have the corresponding advantage of stimulating national pride. If, as we hope, every foreign country will give as much attention to an astronomical as to an industrial exhibit, the United States will need to look to her laurels. An *adequate* representation of our part in the progress of astronomy would undoubtedly substantiate our claim to an important position among the nations engaged in the advancement of research.

The pages of ASTRONOMY AND ASTRO-PHYSICS are open to anyone who wishes to express his ideas on the subject of an astronomical exhibit, and correspondence and suggestions, for publication or otherwise, are requested. The editor of ASTRO-PHYSICS is secretary of a committee on the Columbian Exposition appointed by the Astronomical Society of the Pacific, and is authorized to act in their behalf. Applications for space are desired as soon as possible, and should be addressed to Director-General George R. Davis, World's Columbian Exposition, Chicago. Information in regard to the installation of the astronomical exhibit may be obtained from Dr. Selim H. Peabody, Chief of the Department of Liberal Arts. It may be added that the foregoing has been published with his approval.

A NEW PHOTOGRAPHIC PHOTOMETER FOR DETERMINING STAR MAGNITUDES.[*]

W. E. WILSON.

I would like to bring before the notice of the Society the design of an instrument which I think will be of use in stellar photography, and especially in determining photographic magnitude of stars.

The instrument consists of a photographic plate and holder (6½ in. x 1 in.) moving in a slide in the direction of its greatest length. A spiral spring tends to pull the holder to one end of the slide, and a simple electro-magnetic escapement each time the magnet is excited allows the spring to advance the plate and holder $\frac{1}{16}$ inch. The entire apparatus screws into the eye-end of a photographic telescope.

A star whose magnitude is to be determined is focussed close to the end of the photo plate, and an exposure of say 100^s given. The magnet is then excited for a moment by the current from a

---

[*] *Monthly Notices*, January, 1892.

contact-maker, driven by a clock; the plate moves forward suddenly $\frac{1}{10}$ inch, and a second exposure is given, which lasts only 63^{s}. Again the plate moves forward to give a third exposure of $39^{s}{\cdot}8$, and the exposures are thus continued in the above ratio until they are reduced to 1^{s}. The telescope is then set on a standard star, such as *Polaris*. The holder is moved back to its original position, and *Polaris* is placed $\frac{1}{10}$ inch below the first exposure of star No. 1. The same series of exposures are then given, and the plate developed. The result will be like this:—

The relative number of images of the two stars will give their magnitudes to 0.5. The times of exposures will vary as the number whose log. is 0.2, but there is no reason why they should not be made to give 0.1 magnitudes.

The contacts are made by a wooden disc, revolving uniformly by the driving clock of the equatorial. On its edge are brass pins, which are placed so as to pass under a wiper at the correct intervals. The entire process is automatic once the star is set in its right place. Each plate will hold ten sets of exposures.

The instrument will also be of use for determining the actinic value of the sky before taking a stellar photograph. In this case, by taking a series of *Polaris*, and finding thus at what exposure it fails to record itself, the exposure necessary to record a star of another magnitude will be known.

Also, to determine the value of wire screens in front of the O. G., a series can be taken with and without the screen and the necessary value found.

I hope to exhibit some negatives taken with the instrument shortly before the Society.

1892 January 3.

NOTE ON THE SPECTRUM OF THE LARGE SUN-SPOT GROUP OF FEBRUARY, 1892.*

HENRY CREW.

This group, during the time the weather permitted it to be seen here, consisted essentially of two large umbræ, surrounded by a number of small spots. The outlines of these two larger umbræ

---

* Communicated by the author.

PLATE XII.

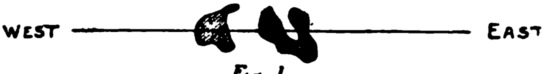


Fig. 1

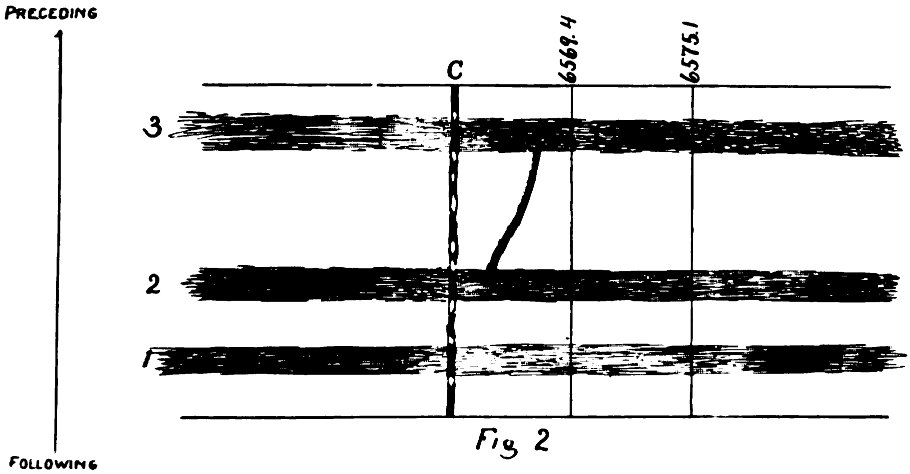


Fig. 2

Plate accompanying Dr. Henry Crew's paper on the Spectrum of the Large Sun-Spot Group of February, 1892.

are shown in Plate XII, *Fig. 1*, from which it will be seen that, when the slit of the spectroscope was placed across them in an east and west direction, and in the position indicated by the straight line in the figure, the spectrum presented the appearance of *three* umbræ, owing to the cleft in the spot to the right.

I examined this spot first on the 9th of February, with especial reference to some of the lines assigned to *coronium* in Professor Rowland's unpublished map of the spectra of the elements. But they appeared not to be affected in the slightest.

On February 10th, nothing was noticed, during half an hour's observation, that would distinguish the spectrum of this spot from that of what Langley has called the "typical Sun-spot."

C was brilliantly reversed in both nuclei, and showed a moderate amount of motion.

D_3 was bright in both nuclei and in the penumbræ. The lines b_1, b_2 and b_4, were disturbed and reversed a good part of the time, etc. But on the 11th, the region between the two umbræ presented the following phenomenon which, to the writer, at least, is entirely new. I was observing the spot in the third order of a Rowland 14438-line grating, attached to the 12-inch equatorial. The slit was placed in an east and west direction, in the position of the straight line in Plate XII, *Fig. 1*. The appearance presented in the neighborhood of the C line is shown in *Fig. 2*, which is copied directly from my observing book. Following the figure, I find these notes.

"C reversed in all the penumbræ and, at numerous points along the space between 2 and 3, very brilliant. This appearance remained practically unchanged for an hour."

"At 9^h 50^m, I observed a new dark line, very broad, extending in a diagonal direction between adjoining edges of spots 2 and 3.

Watched it for a full half hour, thinking it might be a part of C. I turned to F, to see if that was affected in a similar manner, but could not find any trace of the new dark line there."

"It appears the same in the second, third and fourth orders of the grating."

Plate XII, *Fig. 2*, gives a very fair idea of the phenomenon. The line was quite sharp and of nearly uniform width throughout its length. The point, at which the line appeared to leave umbra No. 2, was at $\lambda = 6566.0$; from here it ran across the interlying portion of the photosphere, and joined umbra No. 1 at $\lambda = 6567.5$. These figures may be out as much as two units in the first decimal place; not more, I should think, for I had Rowland's map before me. The difference of wave-length between the two ends thus corresponds to a velocity of between forty and fifty miles per second: in which direction, one cannot say without knowing the place of the line. On Rowland's map there are two, possibly three, lines visible between C and the iron line at $\lambda =$ 6569.3; but there is too much motion in the new line to say whether it corresponds to either of these. Hasselberg has a nitrogen line at 6566.47.

This phenomenon appears to be just the reverse of what ordinarily happens *viz.*, the line, instead of showing strong absorption in the umbræ and penumbræ, is not visible there at all; while in the regions between, the absorption is very striking.

Looking for this appearance again in the afternoon of the same day, I found no certain trace of it.

On the following day, (February 12th), the spot was re-examined; but no relic of the dark line was seen, though twenty-nine other lines, between C and *w. l.* 5727.9, were observed as thickened in the spot spectra.

Lick Observatory, 4th of March, 1892.

SPECTROSCOPIC OBSERVATIONS OF THE GREAT SUN-SPOT GROUP OF FEBRUARY, 1892.

GEORGE E. HALE.

This spot group was first seen at the Kenwood Observatory on the morning of February 4, and from that time it was observed as frequently as possible during its entire transit. The observations included: (1) photographs of the Sun at the focus of the 12-inch equatorial for position and form of the group; (2) photographs of the spot group and surrounding faculæ, made with the "spectroheliograph";* (3) photographs of the spectra of various members of the group; (4) visual observations with the helioscope; (5) visual observations with the spectroscope. In the present paper we shall confine ourselves mainly to observations under (3) and (5).

On Feb. 4 an eruptive prominence was observed on the limb where the spot group had entered the visible hemisphere, and an excellent photograph of it was made with the spectroheliograph. On Feb. 9 bright reversals were seen in both C and F over the largest umbra. With a wide slit the form of the reversed region

---

* The spectroscope with slits moved by a clepsydra and hydraulic accumulator, referred to in my previous papers on solar prominence photography.

could be easily observed in C.* The bright light of the photosphere was too dazzling to allow of a slit wide enough to include the entire reversed region, but by moving the instrument about, a sketch was easily made at $10^h\ 47^m$ (Chicago M. T.). At this time there was no evidence of motion in the line of sight, and when observed a few minutes later the D lines were not seen to be reversed. No trace of D_3, dark or bright, could be made out. A great number of lines in the solar spectrum were widened in the umbræ, but in this and the later observations the press of other work did not leave time to record them. Between $11^h\ 10^m$ and $11^h\ 28^m$ ten photographs were made of the spot spectrum, the slit crossing the largest nucleus. The fourth order of a 14438-line grating was employed. As is usual in spots, both H and K are reversed, but none of the ultra-violet hydrogen lines appear in the negative, if we except hydrogen ϵ (near H), of which there is a slight suggestion. As I found was usually the case in photographing the spectra of faculæ last December, H and K are *doubly* reversed, a dark line appearing in the center of the bright reversal. In the spot now in question the double reversal is most easily seen in the penumbra, where the bright line is widest. In the center of the spot the bright line is much narrower, but in a sharp negative the double reversal can be seen very close to the narrowest part of the line. There are portions of the line, in some cases comparatively wide, where no trace of double reversal can be made out. As I have previously found to be true in prominences, K is stronger than H, and the double reversals are also more pronounced in the former line.

At $2^h\ 40^m$ P. M., no particular change in the spectrum was noticed. The form of the reversed region could be seen even better than at the time of the morning observation, and a drawing of it was made. On comparing this drawing with a photograph of the faculæ made fifteen minutes before, it is found that the faculæ in the midst of the spot group correspond so closely in form with the reversed region as observed in the C line that there can be no doubt as to their identity.

I reserve for a future paper a discussion of the question of observing prominences projected on the Sun's disc. In the present instance the form shown in the photograph seems to be in all probability faculous, for the exposure was the same that is always given for faculæ, and this is insufficient for prominences of ordinary brightness on the limb. At the same time there is nothing to contradict the assumption that a very brilliant prominence was seen in the C line, and photographed in K. When I discovered that H and K are reversed in the faculæ[*], the resemblance between prominences and faculæ on the disc was more clearly brought out than ever, for the reversals in both are thus shown to be the same. The fact that the spectroheliograph allows photographs to be made of spots, prominences, faculæ, and the bright forms near spots (whatever they may be) as well, will enable me, I trust, to learn something more as to the relations existing between these various phenomena.[†]

Clouds prevented all but the regular photographic work on Feb. 10 and 11. As Dr. Crew's observation of a peculiar absorption line near C was made on the latter date (see page 308), I have examined the photographs then secured here. Exposures were made at the focus of the 12-inch at $10^h\ 10^m$, $10^h\ 20^m$ A. M., and $2^h\ 6^m$, $2^h\ 30^m$ P. M. None of these show anything unusual, though the spots are well defined in all the plates. Allowing for the difference in time between Mount Hamilton and Chicago, however, it is evident that none of the exposures happened to be made very near the time of Dr. Crew's observation. Photographs of the spots and faculæ were obtained with the spectroheliograph at $10^h\ 55^m$, $10^h\ 59^m$, $11^h\ 5^m$, $11^h\ 12^m$ and $11^h\ 15^m$ A. M. on the same day. Whether the phenomenon in question produced any effect which such photographs would have shown cannot therefore be answered, as no exposures were made at the proper time.

On Feb. 12 the spot spectrum was examined at 12^h M., and D_3 was once suspected as a dark line. C was considerably distorted in the largest umbra, but not so much so as in the last following member of the spot group, where at one point simultaneous displacements toward the red and violet were noticed. Reversals of C were numerous in the group, the brightest being seen over the largest umbra. On referring to plates made at this time with the spectroheliograph, the brightest reversed region is found to be south of the largest umbra, and the central one of its three branching arms passes between the two principal umbræ. These photographs of the spectrum confirm the results obtained Feb. 9, as to the double reversal of H and K in the penumbræ, and the

---

[*] See ASTRONOMY AND ASTRO-PHYSICS, Feb. 1892, p. 159 and March, 1892' Note on Progress in Solar Photography at Kenwood Observatory.

[†] Naturally the spectroheliograph does not give sharp and well-defined images of *spots*, for the second slit cannot be made sufficiently narrow in practice. The spots are also partly or wholly covered by the reversed regions, and it is these latter which the spectroheliograph is specially designed to record. The negatives give a very fair idea, however, of the position and general form of spots, and are studied in connection with spot photographs taken by the ordinary method.

PLATE XIII.

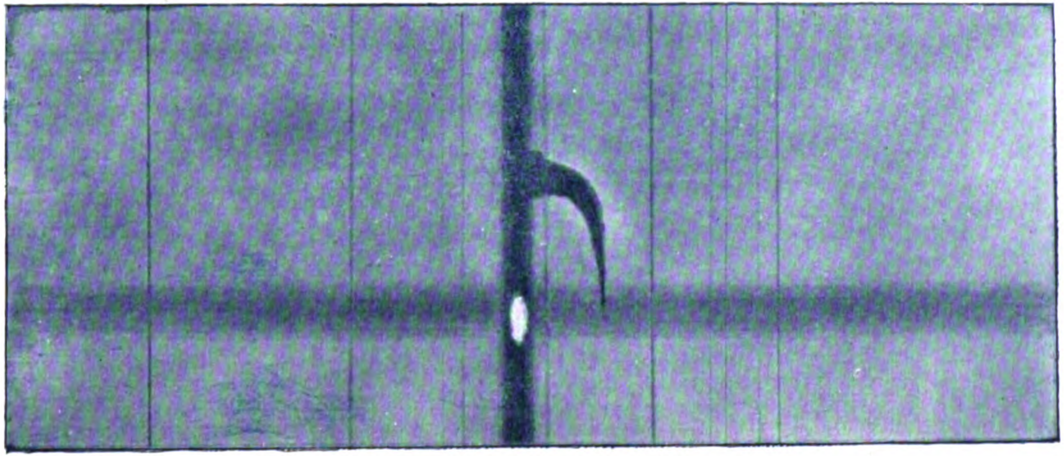


Plate accompanying Professor Hale's paper on Spectroscopic Observations of the Great Sun-Spot of February, 1892.

Astron. and Astro-Physics, April, 1892

narrowing of the bright lines towards the center of the umbra. As the bright lines narrow down in the umbra to about the width of the central dark line in the penumbra, it is evident that double reversal could hardly occur in the umbra without practically destroying both lines. Two facts of importance should be mentioned here: both point to a difference of some kind between the condition of the vapors from which C, a hydrogen line, and H and K, calcium lines, are emitted: (1) While C was distorted in the spot region H and K were perfectly straight, and gave not the least indication of motion in the line of sight. Moreover, I do not recall a single instance in which the H and K lines in spots have shown any distortion, while it is well known that C is almost always twisted and bent under like circumstances. (2) Double reversals are rarely (if ever) observed in the C line, while they are almost invariable in H and K over spot penumbræ and on the disc. This fact is perhaps not surprising, but the absence of motion of the calcium in the neighborhood of spots is not readily explainable.

Photographs of faculæ were made with the spectroheliograph on Feb. 13 at 10^{h} 45^{m}, 10^{h} 47^{m} A. M., and 2^{h} 58^{m}, 2^{h} 49^{m}, 3^{h} 6^{m}, 4^{h} 16^{m}, P. M. Between 10^{h} 54^{m} and 11^{h} 34^{m} A. M., six photographs were obtained of the spectra of various regions in the spot group, using the fourth order of the grating as before. The bright H and K lines extend entirely across the spots, narrower in the umbra than in the penumbra. In one spot the bright lines almost completely disappear at the center of the umbra, where they narrow down to about the width of the central dark line of the double reversal. But the most interesting thing brought out in some of these photographs is the probable presence of the line hydrogen ε (near H). In common with Professor Young, I have been perplexed at the non-appearance of this line in spots, for it so constantly accompanies H in prominences. It appears as a very faint line in these photographs, following H across spots and on to the surrounding photosphere. No other ultra-violet hydrogen lines are present, and as yet not the least trace of any of them has been detected in spots.

Clouds prevented further work until 3^{h} 45^{m} P. M., when considerable distortion was noticed in the C line of the second order. The figure in Plate XIII has been copied from a note-book sketch made at this time.[*] No great degree of accuracy can be claimed for this sketch, as the amount of displacement is only estimated, but it may serve for comparison with Dr. Crew's drawing in

---

[*] The scale of the figure is about that of Rowland's map.

Plate XII. The position of the narrow slit was such that it lay across the smaller of the two large umbræ; if the larger were shown on the plate it would appear about half way between the two lines to the right at λ 6569.4 and λ 6575.1, and the same distance below the horizontal absorption band, supposing the C line to represent the slit. As in Dr. Crew's observation, the distorted absorption line was outside of the umbra. It lasted only a few minutes, and I did not have sufficient time to examine it as I might have wished. C was reversed in the umbra as shown, and also in other points not given in the sketch. In the larger umbra a reversal of C was distorted toward the violet.

It would seem that the absorption line noted by Dr. Crew may be due to a motion of recession of the whole mass of absorbing hydrogen, the velocity increasing from one end to the other. It is strange, however, that F did not show similar evidence of motion.

The last spectroscopic observations of the spot group were made here on Feb. 15. C indicated some motion, and was reversed in many places. With a wide slit the reversed region could be fairly well seen. At a point where a radius through the group met the limb a prominence of some size was noticed, but no reversal could be traced from it to the spots. Clouds unfortunately prevented observations of the passage around the western limb.

KENWOOD ASTRO-PHYSICAL OBSERVATORY,
Chicago, March 14, 1892.

NEW RESEARCHES ON THE SOLAR ATMOSPHERE.*

H. DESLANDRES.

In a former note (*Comptes rendus*, August, 1891; also ASTRONOMY AND ASTRO-PHYSICS, January, 1892), I have described my investigations made by means of photography on the radiation of the solar atmosphere in a hitherto unexplored region, comprising the blue, violet and ultra-violet to λ 380. I have continued this study in the neighboring region of the invisible ultra-violet as far as λ 350.

Apparatus.—But, in this new region, the radiations are strongly absorbed by ordinary optical glass, and it has been necessary to change the original apparatus. For the projection of the solar

---

* Communicated by the author. (Presented to the *Academie des Sciences* February 8, 1892).

image I have employed the Foucault siderostat and an 8-inch silvered concave mirror. The prism spectroscope has also been replaced by a spectroscope with a Rowland grating and quartz lenses.

Results.—Each photograph gives the spectrum of the Sun's limb from λ 410 to λ 350, and shows all the chromosphere lines in this extended region, the arrangement adopted assuring the simultaneous focusing of all the rays on the slit.*

In several prominences in the second quarter of 1891 I red-iscovered the series of ultra-violet hydrogen lines observed for the first time by Mr. Huggins in the white stars. I have obtained as many as eight successive bright lines,† all narrow and sharp,‡ and the last two of the series could undoubtedly be obtained at a high mountain station. Thus the Sun, which is a yellow star, exhibits in certain parts of its atmosphere the characteristic radiation of the white stars. This result is important, for it confirms our present ideas on the evolution of the stars.

I have also obtained the line slightly less refrangible than α_1 (λ 388) of hydrogen, which was first discovered by Mr. Hale, and recently contested by Professor Young. But this line, always fainter than or at most equal to the line $H\alpha_1$, is not often present. The only permanent lines which I have observed in this region are those of hydrogen.

With this apparatus, which is of greater dispersive power than the former one, I have also photographed the spectra of spots and faculæ. The H and K lines of calcium often appear bright, and they are always longer and more intense than the lines of hydrogen;§ moreover, the great width of the dark bands which form their background is particularly favorable for the study of displacements and radial velocities. These photographs are thus suited, in a certain measure, to the regular study of the movements of the solar atmosphere in the part which is projected on the disc. The photographic spectroscope, movable around an axis, as described in the preceding note, will allow the forms and velocities of the incandescent masses at the surface of the Sun to be registered, not only in the annular region which surrounds the disc, but in the entire hemisphere turned toward the Earth.

---

* These photographs have been obtained with the aid of my assistant, M. Mittau.

† Mr. Hale has already announced that he has found five of these lines; Professor Young has obtained four.

‡ As is well-known, these ultra-violet hydrogen lines are missing in the spectrum of the disc, or appear very much widened.

§ These bright lines often have also a reversal in the center.

THE SUN-SPOTS, THE MAGNETIC STORM, AND THE AURORA.*

The abnormal condition of the Sun during the period 1892, Feb. 5-17, owing to the presence of a large group of Sun-spots, attracted the attention of all solar observers. With such tremendous disturbances in progress in the solar photosphere, some disturbance of the magnetic condition of the Earth was to be expected, and the magnetic storm of Feb. 13-14 was characterized by an intensity quite in keeping with the solar disturbance with which it was connected. The magnetic storm, which seriously disturbed the telegraph and telephone services throughout the world, was attended by one of the most brilliant auroral displays of recent years.

The group of Sun-spots to which these terrestrial disturbances are directly attributed appeared on the east limb of the Sun on 1892, Feb. 5, reached the central meridian on Feb. 11, and passed round the west limb on Feb. 17.

The total spotted area, measured on the photographs taken at Greenwich on Feb. 13, when the group reached its maximum, was no less than $\frac{1}{850}$ of the Sun's visible hemisphere. At Greenwich the area of spots is measured in millionths of the Sun's visible hemisphere, and this extensive group had an area of 2850 millionths, corresponding to 3360 millions of square miles. The center of the group was then at 260° long., and in latitude — 23°.

The group was a broad band extending over 22° of longitude in length and 10° of latitude in width, corresponding roughly to a greatest length of 150,000 miles and a width of 75,000 miles.

The large central spot of the group was 15° in length in longitude and 8° in width in latitude. The spot-group is the largest ever photographed at Greenwich, and is the largest which has appeared on the Sun since 1873. The large group of 1882, Nov. 18, was 2425 millionths of the Sun's visible hemisphere in area.

At Kew the magnetic disturbance commenced at about 5:45 A. M., on Feb. 13, the easterly declination slightly increasing until about 5:40 P. M., while both horizontal and vertical forces increased in intensity, especially between 4 and 6 P. M. They diminished after 10 P. M., but the changes became very rapid from 12 o'clock midnight to 2 A. M. (Feb. 14), the declination proceeding to its extreme westerly position. The disturbance gradually diminished and died out about 4 P. M. Feb. 14. So rapid were

---

* *Observatory*, March 1892.

the changes of force, and so great the extent of the vibrations of the free needles (over 2° in declination), that the Kew magnetometers could not record them.

At Potsdam the disturbance commenced on Feb. 13, about 6:30 P. M. (Berlin mean time), and enormous fluctuations of the needle were noticed. Changes of 2° in 2 minutes of time are recorded, and vibrations of over 3° were observed.

The records of the Greenwich magnetic instruments are fully dealt with in the notes of Mr. Ellis, published in this number.

The aurora of 1892, Feb. 14, was observed at Greenwich at 0^h 35^m to 0^h 45^m as a brilliant patch of crimson light extending from the N. N. W. to N., with streamers of a whitish color rising to an altitude of 50° or more, and converging to the right. Between 0^h 45^m and 0^h 50^m the crimson glow became more intense, afterwards dying away until at 0^h 55^m it disappeared, the streamers being visible to the last, but fluctuating in brightness. Light clouds formed to the North at 0^h 55^m, and at 1^h 15^m the sky was completely overcast.

At Ealing the aurora was first noticed at 0^h 30^m as a faint crimson light in the N. N. W., which rapidly increased in intensity. Streamers of a yellowish-white color were estimated to extend to an altitude of 60°, converging towards the north. Clouds immediately commenced to form to the N. N. W., and the contrast between the brilliant white clouds in the moonlight, the bright crimson sky, and the slightly yellowish streamers was very striking.

Attempts were made to observe the spectrum of the aurora with the star-spectroscopes used for the 5-foot reflector, but, except a faint brightening in the green, no details could be made out, owing to the bright moonlight.

The crimson glow at 0:50 A. M. extended round from N. W. N. to N. N. E., and a faint streamer arose from N. N. E. towards the north to an altitude of about 40°. The brightness of the streamers varied considerably, but they were visible until the sky was completely overcast at 1:10 A. M. The crimson glow was fainter after 1 A. M., but was visible through breaks until the clouds covered the sky.

MAGNETIC PERTURBATIONS OF FEBRUARY 13 AND 14, 1892.*

M. MOUREAUX.

An extraordinary magnetic perturbation, such as we have no observed for ten years, and even surpassing that of Novembe 1882, in intensity, was registered on the magnetograph of th Saint-Maur Observatory on February 13 and 14. It suddenl commenced on the 13th, about $5^h 42^m$ A. M., by a simultaneous ris in the declination and horizontal component, and a correspondin fall in the vertical component. The oscillations of the first tw elements were rapid, and of considerable amplitude all day o the 13th; after noon, the vertical component increased progre sively, and passed a considerable maximum between 4^h and 6 P. M. At this same moment the declination reached a minimu while the horizontal component exhibited nothing particularl remarkable.

The most important phase of the perturbation occurred b tween 11^h P. M. and 2^h A. M. The absolute maximum of declina tion was reached between midnight and 1^h, while the two com ponents passed an exceptional minimum: the vertical componen about 1^h, and the horizontal component between 1^h and 2^h A. The deflections were so great that the three images went out the field, a circumstance which prevents the accurate determina tion of the extreme values, as well as the exact time when thes values were attained.

After 3^h A. M., the oscillations, though still marked, were somewhat smaller extent, and after 6^h 30^m the three magnet were affected by vibratory movements until 9^h, at which time th sheet of sensitive paper had to be renewed. The perturbatio ceased at about 5^h P. M. on the 14th. The total deflection fo declination was more than 1° 25′; the horizontal and vertica components varied more than $\frac{1}{87}$ and $\frac{1}{88}$ of their normal value respectively.

According to the curves of the recording instruments at Pe pignan, Lyons and Nantes, communicated by Dr. Fines, M. A dre and M. Laroque, the phenomenon commenced at the sam instant, and the variations were so faithfully reproduced at th four stations that, with the exception of a few changes of inte sity in certain details, the tracings of the four instruments agre exactly, like copies of a single drawing.

This perturbation is sharply distinguished from all others o

---

[*] Translated from *Comptes rendus* (Paris), Feb. 15, 1892.

served here by the excessive variations in the vertical component. A very important group of Sun-spots, which first appeared on February 5, and which could be seen on the 12th with the naked eye, was passing near the center of the Sun's apparent disc on this same day. A very brilliant aurora borealis was seen at New York on the night of February 13-14.

THE REDUCTION OF SPECTROSCOPIC OBSERVATIONS OF MOTIONS IN THE LINE OF SIGHT.*

W. W. CAMPBELL.

The reduction of spectroscopic observations of motions in the line of sight is made exceedingly simple by the use of suitable tables. I herewith publish my tables with an explanation of their construction and use, in the hope that other observers will find them convenient. The results are expressed in English miles per mean solar second. They are convertible into German geographical miles by dividing them by 4.6038; or into kilometres by multiplying them by 1.6093. The remarkable accuracy of recent spectroscopic observations requires that the corrections be applied to the nearest tenth of a mile per second. The still greater accuracy which may reasonably be expected in the future will require that they be applied to the hundredth of a mile per second, and such is the limit of precision adopted in these tables. While the values of the variable quantities (e and Π only) have been taken for the epoch 1895, yet they vary so slowly that the errors do not amount to 0.01 miles per second for nearly thirty years.

According to Doppler's principle, the motion of a star in the direction of the observer, or from the observer, is indicated by a displacement of the lines in its spectrum from their normal positions; toward the red end if the star is receding from him, and toward the violet end if it is approaching him. The observation, whether visual or photographic, consists in the measurement of this displacement, which is generally expressed in terms of the unit of wave-length in Angström's scale. This unit is the *tenth-metre*, and denotes a change of one ten-millionth of a millimetre in the wave-length. A table giving the velocities of the star corresponding to a displacement of one tenth-metre in the different parts of the spectrum will enable us to obtain quickly the velocity corresponding to any observed displacement.

---

* Communicated by the author.

Let λ be the wave-length, expressed in tenth-metres of the line whose displacement is measured; V_s the velocity of a star in English miles per second corresponding to a displacement of one tenth-metre; v_s the velocity corresponding to any measured displacement $\Delta\lambda$; and let the velocity of light be assumed as 186,330 miles per second. Then

$$V_s = \frac{186,330}{\lambda} \qquad (1)$$

and

$$v_s = V_s \,.\, \Delta\lambda. \qquad (2)$$

$\Delta\lambda$ and therefore v_s are considered positive when the wave-length is increased, and denote a recession of the star; they are considered negative when the wave-length is decreased, and denote an approach of the star. Table I is constructed from equation (1), and gives the values of V_s for the principal Fraunhofer and other lines, and for each hundred units of wave-length in the photographic part of the spectrum.

The observed velocity is due both to the motion of the star and of the observer. The latter is made up of four components, all of which must be eliminated from the observation before the component of the star's velocity, with reference to the sidereal system, can be determined. The four components arise from

1. The rotation of the Earth on its axis. The elements of this diurnal component are well known, and it can be eliminated completely from the observed results.

2. The revolution of the Earth around the common center of gravity of the Earth and Moon. This monthly component is small and readily allowed for.

3. The revolution of the Earth around the Sun. The *form* of the Earth's orbit is well known, but there is at present an uncertainty of from one-half to three-fourths of one per cent in the assumed value of the solar parallax, or in the absolute value of the semi-major axis of the Earth's ellipse; which introduces a corresponding uncertainty in the Earth's orbital velocity of from 0.09 to 0.14 miles per second. By assuming the Earth's mean distance from the Sun to be 92,500,000 miles, which corresponds to a solar parallax of 8″.838, it is probable that the resulting orbital velocities will not be in error by more than 0.1 miles per second. There is reason to hope that the probable errors of spectroscopic observations will soon reach this low limit, in which case the problem will be reversed and the spectroscope will be used to *measure* the Earth's orbital motion and thus to determine the solar parallax.

4. The motion of the solar system as a whole. At present we have not sufficient data for estimating its direction and velocity, and this component can not now be eliminated from the observed velocities of the stars. Several astronomers are engaged in measuring the velocities of the brighter stars. When the velocities of several hundred stars distributed fairly uniformly over the celestial sphere have been well determined, we shall be able to obtain a fairly accurate knowledge of the motion of the solar system. The corrections for the solar motion can then be applied to the observations of the individual stars, and we shall be able to obtain their velocities in the line of sight with reference to our sidereal system.

When the corrections for the first three motions are applied the observations are said to be reduced to the Sun.

Let $e =$ the eccentricity of the Earth's orbit,
$= 0.016752$ for 1895,
$a =$ the semi-major axis of the Earth's orbit,
$= 92{,}500{,}000$ English miles,
$90^\circ - i =$ the angle which the tangent to the Earth's orbit makes with the radius vector drawn to the point of tangency,
$T =$ the number of mean solar seconds in a sidereal year,
$= 31{,}558{,}149$,
$\Pi =$ the longitude of the Sun at perigee,
$= 281^\circ\ 8'.0$ for 1895,
$\odot =$ the Sun's longitude at the time of observation,
☽ $=$ the Moon's longitude at the time of observation,
$\lambda =$ the longitude of the star observed,
$\beta =$ the latitude of the star observed,
$t =$ the hour angle of the star observed,
$\delta =$ the declination of the star observed,
$\varphi =$ the latitude of the observer,
$V_a =$ the Earth's velocity in miles per second in its orbit,
$v_a =$ the correction to the observed velocity of the star for this annual motion,
$V_m =$ the Earth's velocity in miles per second due to its revolution about the center of gravity of the Earth and Moon,
$v_m =$ the correction to the observed velocity of the star for this monthly motion,
$V_d =$ the velocity in miles per second of a point on the Earth's equator due to the diurnal rotation, and
$v_d =$ the correction to the observed velocity of the star for this daily motion.

The values of i and V_a are given by*

$$\tan i = \frac{e \sin(\odot - \Pi)}{1 + e \cos(\odot - \Pi)} \tag{3}$$

and
$$V_a = \frac{a}{\sqrt{1-e^2}} \cdot \frac{2\Pi}{T} \cdot [1 + e \cos(\odot - \Pi)] \sec i. \tag{4}$$

When the Sun's longitude is $\odot$ the Earth is approaching the point of the ecliptic whose longitude is $\odot + 270° - i$, with a velocity V_a. Projecting this motion upon the line joining the observer and the star (λ, β) we obtain

$$v_a = - V_a \sin(\lambda - \odot + i) \cos \beta. \tag{5}$$

In Table II the values of V_a and i are tabulated as functions of $\odot$; so that to find the value of the correction v_a it is only necessary to find $\odot$ in the Nautical Almanac for the instant of observation, take the values of V_a and i corresponding to this value of $\odot$ from Table II, and substitute them in equation (5). The maximum error introduced by neglecting i is 0.31 miles per second. If it is desired to use a value of the solar parallax different from that employed here, it is only necessary to multiply the values of V_a given by Table II, by a constant factor.

The value of the lunar correction v_m can usually be neglected. But its maximum value is nearly 0.01 miles per second, and the degree of precision adopted for these tables requires that it should be considered here. It is not necessary, however, to take into account the ellipticity of the orbit and its inclination to the ecliptic. The average value of V_m is nearly 0.01 miles per second, and the motion is toward the point of the ecliptic whose longitude is $\LEFTcircle + 270°$. Therefore, projecting this motion upon the line drawn to the star (λ, β), we have

$$v_m = - V_m \sin(\lambda - \LEFTcircle) \cos \beta = - 0.01 \sin(\lambda - \LEFTcircle) \cos \beta. \tag{6}$$

Owing to the diurnal rotation the observer is constantly approaching the east point of the horizon, with a velocity

$$V_d \cos \varphi = 0.29 \cos \varphi.$$

Projecting this motion upon the line drawn to the star (t, δ), we have

$$v_d = - V_d \sin t \cos \delta \cos \varphi = - 0.29 \sin t \cos \delta \cos \varphi. \tag{7}$$

---

* Equations similar to (3) and (4) are derived in *Chauvenet's Sph. and Prac. Astr.*, vol. I, § 391.

The values of this correction for the latitude of Mt. Hamilton (37° 20′) are tabulated in Table III with the arguments t and δ. The corresponding corrections at any other latitude φ' can be obtained from these by multiplying them by $\frac{\cos\varphi'}{\cos\varphi}$. v_d is negative if the star is observed west of the meridian, positive if the star is observed east of the meridian.

Example. At Mt. Hamilton, 1891, Nov. 24, $9^h\ 35^m$ Pacific standard time, measures of the position of D_3 in the third spectrum of Aldebaran showed a displacement of 0.908 tenth-metres toward the red. Required the velocity of the star with reference to the solar system.

For Aldebaran we have

$$\alpha = 4^h\ 29^m\ 40^s, \qquad \delta = +16^\circ\ 17'.4,$$
$$\lambda = 68^\circ\ 16'.0, \qquad \beta = -\ \ 5^\circ\ 28'.5.$$

The solution of (2) gives

$$\begin{aligned} \log V_s &= \log 31.63 = 1.5001 \\ \log \Delta\lambda &= \log\ \ 0.908 = 9.9581 \\ \log v_s &= 1.4582 \\ v_s &= +\,28.72 \text{ miles per second.} \end{aligned}$$

For the instant of observation the Nautical Almanac gives

$$\odot = 242^\circ\ 41'.5;$$

and for this argument Table II gives

$$\log V_a = 1.2709, \qquad i = -\,35'.5.$$

The solution of (5) is therefore

$$\begin{aligned} \log V_a &= \log 18.66 = 1.2709 \\ \sin(\lambda - \odot + i) &= \sin(184^\circ\ 59'.0) = 8.9388_n \\ \cos\beta &= \cos(-5^\circ\ 28'.5) = 9.9980 \\ \log v_a &= 0.2077 \\ v_a &= +\,1.61 \text{ miles per second.} \end{aligned}$$

The value of the Moon's longitude given by the Nautical Almanac is

$$\text{◑} = 173^\circ.$$

The solution of (6) is therefore

$$\begin{aligned} \log V_m &= \log 0.01 = 8.00 \\ \sin(\lambda - \text{◑}) &= \sin 255^\circ = 9.98_n \\ \cos\beta &= \cos(-\,5^\circ\ 28'.5) = 0.00 \\ \log v_m &= 7.98 \\ v_m &= +\,0.01 \text{ miles per second.} \end{aligned}$$

The hour angle of the star at the instant of observation was

$$t = 21^h\ 21^m;$$

and the value of v_d, equation (7), given by Table III is

$$v_d = +\,0.14 \text{ miles per second.}$$

Applying the three corrections v_a, v_m, and v_d to the observed velocity of the star v_s, we obtain the star's velocity with reference to the solar system,

+ 30.48 miles per second,

the positive sign indicating a recession.

TABLE I.

Velocities corresponding to Displacements of one tenth-metre.

Line.	V_s	log V_s	Wave-Length.	V_s	log V_s
C	28.39	1.4532	5300	35.16	1.5460
D_1	31.60	1.4996	5200	35.83	1.5543
D_2	31.63	1.5001	5100	36.54	1.5627
D_3	31.71	1.5012	5000	37.27	1.5713
1474	35.05	1.5446	4900	38.03	1.5801
E_1	35.35	1.5484	4800	38.82	1.5890
b_1	35.94	1.5556	4700	39.64	1.5982
b_4	36.06	1.5570	4600	40.51	1.6075
5005	37.23	1.5709	4500	41.41	1.6171
F	38.33	1.5835	4400	42.35	1.6268
Hγ	42.93	1.6327	4300	43.33	1.6368
G	43.25	1.6360	4200	44.36	1.6470
Hδ	45.42	1.6573	4100	45.45	1.6575
H	46.95	1.6716	4000	46.58	1.6682
K	47.37	1.6755	3900	47.78	1.6792

TABLE II.

The Earth's Orbital Velocity V_a and the Deviation i when the Sun's Longitude is ⊙.

⊙	V_a	log V_a	i ′	⊙	V_a	log V_a	i ′
0	18.48	1.2667	+ 56.5	180	18.36	1.2639	− 56.5
10	18.43	1.2655	+ 57.5	190	18.42	1.2652	− 57.5
20	18.37	1.2642	+ 57.0	200	18.47	1.2664	− 57.0
30	18.32	1.2630	+ 55.0	210	18.52	1.2677	− 54.0
40	18.27	1.2618	+ 50.5	220	18.57	1.2688	− 50.0
50	18.23	1.2607	+ 45.5	230	18.61	1.2698	− 44.5
60	18.19	1.2598	+ 38.5	240	18.65	1.2707	− 37.5
70	18.16	1.2590	+ 30.0	250	18.68	1.2715	− 29.5
80	18.13	1.2584	+ 21.0	260	18.71	1.2720	− 20.5
90	18.12	1.2581	+ 11.5	270	18.72	1.2724	− 11.0
100	18.11	1.2579	+ 1.0	280	18.73	1.2725	− 1.0
110	18.11	1.2580	− 9.0	290	18.72	1.2724	+ 8.5
120	18.13	1.2583	− 19.0	300	18.71	1.2721	+ 18.5
130	18.15	1.2589	− 28.0	310	18.69	1.2716	+ 27.5
140	18.18	1.2596	− 36.5	320	18.66	1.2709	+ 35.5
150	18.22	1.2605	− 44.0	330	18.62	1.2700	+ 43.0
160	18.26	1.2615	− 50.0	340	18.58	1.2690	+ 49.0
170	18.31	1.2627	− 54.0	350	18.53	1.2679	+ 53.5
180	18.36	1.2639	− 56.5	360	18.48	1.2667	+ 56.5

TABLE III.

$v_d = -0.29 \sin t \cos \delta \, (37° \, 20')$.

HOUR ANGLES.		DECLINATIONS.										HOUR ANGLES.	
t	*t*	0°	± 10°	± 20°	± 30°	± 40°	± 50°	± 60°	± 70°	± 80°	± 90°	*t*	*t*
h m	h m											h m	h m
0 0	12 0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12 0	24 0
0 30	11 30	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.00	12 30	23 30
1 0	11 0	0.06	0.06	0.06	0.05	0.05	0.04	0.03	0.02	0.01	0.00	13 0	23 0
1 30	10 30	0.09	0.09	0.08	0.08	0.07	0.06	0.04	0.03	0.02	0.00	13 30	22 30
2 0	10 0	0.12	0.11	0.10	0.10	0.09	0.07	0.06	0.04	0.02	0.00	14 0	22 0
2 30	9 30	0.14	0.14	0.13	0.12	0.11	0.09	0.07	0.05	0.02	0.00	14 30	21 30
3 0	9 0	0.16	0.16	0.15	0.14	0.13	0.10	0.08	0.06	0.03	0.00	15 0	21 0
3 30	8 30	0.18	0.18	0.17	0.16	0.14	0.12	0.09	0.06	0.03	0.00	15 30	20 30
4 0	8 0	0.20	0.20	0.19	0.17	0.15	0.13	0.10	0.07	0.03	0.00	16 0	20 0
4 30	7 30	0.21	0.21	0.20	0.18	0.16	0.14	0.11	0.07	0.04	0.00	16 30	19 30
5 0	7 0	0.22	0.22	0.21	0.19	0.17	0.14	0.11	0.08	0.04	0.00	17 0	19 0
5 30	6 30	0.23	0.23	0.22	0.20	0.18	0.15	0.11	0.08	0.04	0.00	17 30	18 30
6 0	6 0	0.23	0.23	0.22	0.20	0.18	0.15	0.12	0.08	0.04	0.00	18 0	18 0

$_d$ i + for stars observed east of the meridian. v_d is — for stars observed west of the meridian.

ON THE SPECTRA OF BINARY STARS.[*]

W. H. S. MONCK.

The following table may perhaps elucidate the questions relative to binary stars raised by Mr. Gore, Mr. Maunder and myself. It is the result of a comparison of Mr. Gore's Catalogue of Binary Stars with the Draper Catalogue, and, I think, contains all stars common to both catalogues. It shows, I think (1) The superior relative brightness of Sirian to Solar stars; (2) The numerical superiority of Solar stars among these binaries.

Name of Star.	Relative Brightness	Spectrum.
66 Piscium	9.77	A
14 (*i*) Orionis	4.09	A
12 Lyncis	14.01	A
Sirius	6.35	A ?
φ Ursæ Majoris	21.26	A
Castor	38.12	A
25 Canum Venaticum	7.28	A
γ Coronæ Borealis	20.83	A
λ Ophiuchi	28.16	A
δ Cygni	31.29	A
λ Cygni	11.01	A
Σ 3121	0.21	E
ω Leonis	4.06	E
OΣ 234	1.80	E ?
OΣ 215	2.08	E
σ Coronæ Borealis	1.77	E
Σ 3062	0.68	F
η Cassiopeiæ	0.51	F
Σ 1037	1.83	F
ζ Cancri	2.90	F
Σ 228	1.17	F
OΣ 235	2.11	F
γ Virginis	4.92	F
42 Comæ	2.46	F
44 (*i*) Bootis	2.07	F ?
η Coronae Borealis	1.40	F
μ Draconis	4.21	F
Σ 2173	0.88	F ?
ξ (51) Scorpii	5.70	F ?
99 Herculis	1.13	F
τ Ophiuchi	7.35	F
β Delphini	6.85	F
δ Equulei	2.12	F
τ Cygni	4.28	F
ζ Aquarii	9.21	F
ξ Ursæ Majoris	1.00	G
ξ Bootis	0.34	G
ζ Herculis	4.67	G
Σ 2107	1.74	H ?
61 Cygni	0.07	H
π Cephei	11.07	H ?
γ Leonis	92.99	K
70 (*p*) Ophiuchi	0.30	K
36 Andromedæ	6.23	M ?

Total: First type (Sirians) 11, second type (Solars) 32, third type 1.

A cursory examination leads me to think that in the case of double stars whose orbits cannot be computed in consequence of their very slow motion (whether owing to their great distances from us or their small masses) the proportion between Solar and Sirian stars is reversed.

THE SPECTRA OF STARS IN THE MILKY WAY.[†]

BY J. E. GORE F. R. A. S.

Professor Pickering finds that the majority of the stars in the Milky Way show spectra of the first or Sirian type. I have made

---

[*] Communicated by the author.

[†] The Journal of the British Astronomical Association, December, 1891.

a careful enumeration of the stars in the Draper Catalogue of Stellar Spectra which lie in the Milky Way and its branches, as drawn by Heis, and the following table shows the results I have found:—

Spectrum.	No. of Stars.	Total.	Type.	Remarks.
Sub-group A	1,893	1,940	I.	Sirian type
" B	44			
" C	3			
" D	—			
" E	237	1,100	II.	Solar type.
" F	315			
" G	14			
" H	454			
" I	45			
" K	34			
" L	1			
" M	15	15	III.	αHerculis type.
" Q	6	6		Spectra which differ from those of types I, II, III, and IV.
Grand Total	-	3,061		

The above result shows that of the stars in the Milky Way to about the 7th magnitude, 63.4 per cent are of the first type, and 36.6 per cent of the second and other types.

For the preceding half of the Milky Way visible in these latitudes (0^h to 9^h R. A.), I find that 1,078 stars are of type I. out of a total of 1,608, or a percentage of 67.

The richest region in stars of the first type lies between R. A. 3^h 16^m 8 and 3^h 25^m 5 (Epoch 1900) where out of 63 stars, no fewer than 52, or 82½ per cent are of type I.

It will be seen that there are no stars of Sub-group D in the Milky Way, and only one star of Sub-group L.

As Mr. Monck has pointed out, the fact of Stars of the Sirian type being probably brighter, surface for surface, than those of the second or solar type, would suggest that stars of the first type would be visible at greater distances than those of the second. I find that the great majority of stars with large proper motions,—generally supposed to indicate proximity to our system,—have spectra of the second type, and this is of course evidence in favor of Mr. Monck's view. The preponderance of first type stars in the Milky Way would therefore suggest that it lies further from us than the generality of the visible stars, a conclusion which has previously been arrived at from other considerations.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subject properly included in ASTRO-PHYSICS should be addressed to George E. Hale, Ken wood Astro-Physical Observatory, Chicago, U. S. A. Authors of papers are re quested to refer to page 352 for information in regard to illustrations, reprin copies, etc.

The New Star in Auriga.—Since the publication of our March number muc additional information has been received in regard to Nova Aurigae. Thoug shown by the Harvard photographs to have been visible to the naked eye fo weeks before the announcement of its discovery, the new star was not known t exist until Mr. T. D. Anderson, of Edinburgh, armed with a small pocket tel scope and Klein's Star Atlas, satisfied himself on January 31 that a stranger ha appeared in Auriga. Here is encouragement indeed for the amateur with sma instrumental equipment. It seems that there are cases in which the naked eye (fo the first glimpses of the Nova were obtained by Mr. Anderson without any aid t vision), or at best a telescope magnifying ten times, can outdo the largest an most searching instrument.

It is an interesting fact that as observed at Greenwich the Nova seemed t have a "slightly fuzzy" appearance, and its light was described as "not so pierc ing" as that of other stars in the same field. Dr. Common, observing at Ealin with his 5-foot reflector, did not note any "fuzziness." He found the spectrum t be crowded with bright lines, notable among which were C, F and G. "Ther was a bright line at or near D, one fairly bright between C and D (about 617 and several faint lines near both C and D. In the green between D and F thre very strong bright lines were visible. One of these was found by comparison t be practically coincident with the 517 hydrocarbon fluting, while another wa probably the 5005 nebula line. Several faint lines were observed in the gree Between G and F there were certainly three bright lines." (*Observatory*, Marc 1892). The dispersion employed is not stated. Mr. Lockyer saw no nebulosit about the star either in a 3-foot reflector or 10-inch refractor, nor was any show in a photograph taken by him with a 3½-inch Dallmeyer lens after three hours e posure. Father Denza, however, at the Observatory of the Vatican, notice certain peculiarities in the photographed images of the star. Two sets of phot graphs were made by him on the evening of Feb. 7, five images being obtained o each plate, which was moved a short distance in declination between each succe sive exposure. Five minutes, and twenty, fifteen, ten and five seconds, were th times given. As the star was shown with the shortest exposure, in spite of brigh moonlight, Father Denza concludes that it was of the 5th magnitude at that tim He remarks further: "In the two photographs the image of the star is not s sharp as the images of the other stars on the plate, which are perfectly round; i has a somewhat soft appearance, which gives reason to believe that this star ha recently experienced some disturbance." Father Denza has also determined th position of the Nova from the photographs (a *reseau* was imprinted on one of th plates), by micrometer measures, and with the meridian circle. The latter mea ures give: $\alpha = 5^h\,25^m\,3^s.4$, $\delta = +\,30°\,21'\,42''.0$. (*Comptes rendus*, Feb. 2 1892.)

At a meeting of the Royal Society on Feb. 11, Mr. Lockyer presented a pap on the photographic spectrum of the new star, in which he announced that "th bright lines K, H, h and G are accompanied by dark lines on their more refrang ble sides." As may be seen by referring to the photograph of the spectrum in the last number of ASTRONOMY AND ASTRO-PHYSICS, this interesting fact had already been discovered by Professor Pickering. In his communication Mr. Lockyer gave the following list of the wave-lengths of twenty bright lines in the photographic spectrum, determined by direct comparison with lines in α Cygni: 3933, 3968, 4101, 4128, 4172, 4202, 4226, 4264, 4291, 4310, 4340, 4383, 4412, 4434, 4469, 4518, 4555, 4587, 4625, 4860. He considers it probable that many of these lines are coincident with lines in the Orion nebula, Orion stars, and Wolf-Rayet stars. Other lines more refrangible than K, and probably including members of the ultra-violet hydrogen series, were also obtained on the plates. Mr. Lockyer refers to his "meteoritic hypothesis" for an explanation of the new star, and remarks that if subsequent photographs continue to show the dark lines displaced to the more refrangible side of the bright ones, "the spectrum of Nova Aurigae would suggest that a moderately dense swarm is now moving towards the Earth with a great velocity and is disturbed by a sparser one which is receding. The great agitations set up in the dense swarm would produce the dark-line spectrum, while the sparser swarm would give the bright lines." (*Nature*, Feb. 18, 1892.)

From the *Observatory* we learn that Professor Vogel has photographed the spectrum of the Nova with the Potsdam spectrograph, and finds that the hydrogen line used for comparison falls between the dark and bright lines in the star. The displacements for the two components are unequal, the bright lines indicating the greater velocity.

Dr. and Mrs. Huggins have continued their observations, and we add from the *Observatory* a communication presented by them to the Royal Society on Feb. 24.

"Perhaps the most noticeable feature to the eye in the star's spectrum was the great brilliancy of the hydrogen lines at C, F, and G; but the point of greatest interest was obviously that two of these lines, F and G—and we have since observed the same with C—were accompanied each by a strong absorption line on the side towards the blue. Comparison with the lines of terrestrial hydrogen, while confirming the obvious presumption that the star lines were really those of hydrogen, showed at once a large motion of recession of the bright lines and a motion of approach of a similar order of magnitude of the hydrogen which produced the absorption.

"A photograph which we have since taken gives the star's spectrum as far in the ultra-violet as about λ 3200. On this plate we see not only the other hydrogen lines at h and H, but also the series beyond, which is characteristic of the white stars—bright, with dark absorption lines on the blue side.

"Besides the hydrogen series there appear to be other lines doubled in a similar manner, including the sodium lines at D. The line K is strongly impressed upon the plate, but in our photograph it is not followed by an absorption so strong as in the case of H.

"In the green part of the spectrum three very brilliant green lines are seen on the red side of F. One of these falls not far from the position of the chief nebular line; but even when the shift of the spectrum is taken into account, we can scarcely regard this line as the true nebular line. In this connection it was a point of some importance to find that the strong and very characteristic line of the Orion nebula, which falls about λ 3725, is absent in our photograph of the Nova.

"The third line from F is rather broad and resolvable into lines. It falls partly upon the more refrangible pair of the magnesium triplet at b, but its character and position do not permit us to ascribe it to either magnesium or carbon.

"We wish to mention an early photograph of this star taken on the 3d instant by Father Sidgreaves, at Stonyhurst, which we had the privilege of examining. This successful photograph extends from h to near D, and shows the remarkable doubling of many of the bright lines by dark ones—a feature which was at once noticed by Father Sidgreaves and ourselves.

"In our photograph the spectrum of the star, which extends on the plate as far into the ultra-violet as our photographs of Sirius, is crowded throughout its entire length with dark and bright lines. In the visible region the number of bright lines and groups, including the double line of sodium and lines in the neighborhood of C, is also very great.

"We prefer in this preliminary note not to enter into any more detailed discussion of the star's spectrum, nor to refer to the probable phenomena which may now be in progress in this celestial body. We reserve these considerations for the present."

It will be remembered that in Professor Pickering's article in our last number mention was made of the fact that the dark hydrogen lines in the spectrum of Nova Aurigae are shown double in the photographs. This could even be seen in the half-tone cut which accompanied the paper. The interpretation of the duplicity as being the result of the relative motion of certain bodies in the complex system of the Nova was the most natural one to make in the light of data derived from other cases of a similar nature, and this conclusion is now greatly strengthened by the following important announcement, which we have just received from Professor Pickering.

A Change in the Spectrum of Nova Aurigæ.—From an examination of sixteen photographs of the spectrum of Nova Aurigae taken with the 11-inch Draper telescope between February 4 and February 16, 1892, Mrs. Fleming finds that a distinct change has taken place both in the width and distance apart of the components of the dark hydrogen lines. EDWARD C. PICKERING.

Harvard College Observatory,
Cambridge, Mass., March 11, 1892.

A letter received just as we go to press from Rev. A. L. Cortie informs us that Father Sidgreaves has obtained many photographs of the spectrum of the Nova in addition to the one mentioned by Dr. Huggins. They show over 100 bright and dark lines and bands, and also the doubling of the bright and dark lines. As orthochromatic plates were used the spectra extend from D to h. The most conspicuous lines are D_3, F, G and h, and strong bands are shown near λ 500 and near b. Photographs were secured on Feb. 4, 8, 11, 12, 13, 15, 16, and 18, and in this time the spectrum was found to have undergone certain changes. We have not yet learned the precise nature of these changes.

Magnetic Perturbations and the Great Sun-Spot.—That the great spot group which appeared at the Sun's eastern limb on Feb. 4, and was not far from the center of the disc on Feb. 13, should be in some way connected with the widespread magnetic storm and brilliant auroras of the latter date seems far from improbable, but we have nothing to warrant us in assuming a direct relation of cause and effect. As Dr. Veeder well puts it in a letter to the *New York Herald*, "If big Sun spots produce auroras, why did not this one continue to do so throughout the entire time that it remained visible?" It might be held that some great disturbance in the spot group occurred simultaneously with the magnetic storm, but nothing to parallel the classic observation of Carrington and Hodgson was recorded. It is true that observations made at Kenwood Observatory showed more activity, and greater distortion of the C line in the spot group on the date in question than at any other time of observation, but nothing of a very remarkable nature was seen. M. E. Marchand, however, thinks that Sun-spots produce an effect on terrestrial magnetism when they pass the center of the Sun's disc: "The very marked magnetic perturbation of Feb. 13-14, 1892, verifies in a very remarkable manner the general law which I deduced in 1887 from observations made at Lyons (France), on magnetism and the solar spots and faculae. (*Comptes rendus*, Jan. 8, 1887.) In fact solar observations on Feb. 10 and 11 show a very large spot group, *visible to the naked eye*, in latitude — 26°, followed by another group of small spots in latitude — 18°. The passages of these two groups over the central meridian took place on the following dates: Feb. 11.9 for the first; 13.1 for the second. Very extensive faculae connected these two groups, moreover, and extended far behind the second. Now the magnetic perturbation commenced on Feb. 13.2; that is to say, immediately after the passage of the second group of spots.

"Let us add that the *region of activity* in which these two groups occur, has long existed on the solar surface, but it has not always contained spots. In June, 1891, for example, it contained only faculæ; at other returns it was the seat of faculæ and pores. It has produced a magnetic perturbation at each of its passages over the central meridian; some of these perturbations have been comparatively strong, for example those of Jan. 17, 1892, Nov. 20, 1891, Oct. 24, 1891, Sept. 28, 1891, Aug. 29, 1891, Aug. 3, 1891." (*Comptes rendus*, Feb. 22, 1892.)

The "general law" referred to by M. Marchand is given in the *Comptes rendus*, Jan. 10, 1887, and may be translated as follows: "Each of the maxima (in a curve of magnetic declination) sensibly coincides with the passage of a group of spots or a group of faculæ at its shortest distance from the center of the solar disc." Diagrams are given which show the variation in the curve of intensity from December, 1885, to October, 1886, and the positions of spots or faculæ with reference to the central meridian of the Sun are noted above the maxima of the curve. In most cases the agreement is very good, but we cannot therefore assent that the *general* nature of the law has been proved, though we fully recognize that something more than chance coincidence is suggested. During the latter half of the period covered by the diagrams the Sun was frequently observed to be entirely free from spots, and the faculæ were therefore supposed to be responsible for most of the magnetic perturbations. "In this latter case, the faculæ have been generally observed up to quite a distance from the two limbs; it could be concluded that they must have persisted until they reached the center, although observation was rarely extended so far." But even taking it for granted that this assumption was a fair one, was it true that the passage of *every* facula across the central meridian was attended by a magnetic perturbation? Since we have been able at Kenwood Observatory to record faculae on all parts of the disc with equal ease by the aid of the spectroheliograph there has rarely been a time when at least one facula has not been crossing the central meridian. For the faculae are of great extent, and very irregular form, and they may require days to pass a fixed point. We therefore regard M. Marchand's theory with some hesitation.

Another theory which has been strongly advocated by Dr. M. A. Veeder and others, holds that solar disturbances do not as a rule produce any noticeable effect on terrestrial magnetism except when coming into view by rotation on the Sun's eastern limb. In the letter to the *New York Herald* from which we have

already quoted Dr. Veeder remarks: "It cannot be reiterated too often that
magnetic effect of solar disturbances is felt almost exclusively when they are
actly at the eastern limb. I have a record of numerous instances in which
most tremendous outbreaks located elsewhere have been attended by scarc
any auroral or magnetic effect whatever. On June 17, 1891, for example, th
was a disturbed area at the western limb of the Sun, in connection w
which enormous velocities of eruption were recorded. Nevertheless the c
was magnetically very quiet." (We may mention here that Mr. Whipple has
amined the magnetic records of the Kew Observatory for June 17, and fails
find even the slight disturbance shown by Mr. Turner in the diagrams given in
January number of ASTRONOMY AND ASTRO-PHYSICS.) "Compare this with wh
happened August 28, 1891, when a spot which was also in the same region wh
has recently been the seat of the great spot group above mentioned came i
view. Instead of almost perfect quiet the magnets were violently disturbed a
there was a brilliant aurora." In a letter from Dr. Veeder we learn t
there was a brilliant aurora on the night of Feb. 29, the date of the expected
turn of the disturbed section of the Sun which contained the great spot gro
In another letter dated March 13, Dr. Veeder writes: "Strong auroral stream
and patches were seen last evening from 8.07 to 8.30 through breaks in
clouds, and this morning there is upon the Sun's eastern limb a spot group
pearing by rotation. This is the recurrence of the Feb. 13-14 aurora and so
disturbance exactly on time. This periodicity and association of phenomena d
onstrates conclusively that the 'big Sun-spot' west of the meridian was not
sponsible for either of these auroral displays." Dr. Veeder is in perfect acc
with M. Marchand on one point at least; they agree in the belief that the siz
spots has nothing to do with their magnetic effect.

We are ourselves inclined to favor the "eastern limb" theory, but the time
not yet come to definitely accept any. The accumulation of data is now more
sirable than the formulation of theories, though these will play a very useful p
in guiding investigation.

Several notes on the magnetic storm and the great spots have been gathe
from various sources, and are given below.

A Magnetic Disturbance.—The following letter from the superintendent of
Kew Observatory appears in *Nature* for Feb. 18, 1891:

Our attention having been directed for some days past towards a spot of
usual size upon the Sun's disc we were not by any means surprised to observe
doubtless many of your readers elsewhere also did, an aurora of great beauty
Saturday night last; nor was our anticipation of seeing a magnetic disturba
portrayed upon the magnetograph records disappointed in the morning,
when the sheets were changed and the photographs developed, we saw that
turbations more violent than any which had been recorded at Kew for the p
ten years had been in progress since about 5.45 A. M. of Feb. 13.

The magnets were very quiet on Friday, but early on Saturday morning t
became disturbed. The easterly declination slightly increased until about 5.4
M., whilst both horizontal and vertical forces similarly increased in intensi
more especially between 4 and 6 P. M. They further diminished in force after
P. M., and their changes became very rapid from 12 midnight to 2 A. M., whilst
the same time the declination proceeded to its extreme westerly position. Sub
quently, the fluctuations in magnetism became much reduced in extent, and
whole disturbance gradually diminished and died out about 4 P. M. of Sund

The Kew magnetometers were not able to record the complete extent of the vibrations to which the needles were subjected, nor could the entire change of force be secured in the field of the instrument. The limits, however, clearly recorded were 2° of declination from .1760 to .1830 of horizontal force, and from .4350 to .4420 units of vertical force expressed in C. G. S. measure in absolute force.

G. M. WHIPPLE,
Kew Observatory, Richmond, Surrey, Feb. 16. Superintendent.

Great Magnetic Disturbance of 1892, February 13-14.—The magnetic disturbance commenced in all elements on February 13 at 5^h 30^m, Greenwich Civil Time, by a sudden increase of declination, horizontal force, and vertical force, accompanied by a strong manifestation of earth currents. Large motions continued to be registered throughout the day and following night; between February 13 14^h and February 14 5^h they were unusually large, amounting in declination to 1° and more, the trace having passed off the sheet for one hour shortly after midnight. In the horizontal force the disturbance exceeded 0.03 parts of the whole horizontal force, the trace having similarly passed off the sheet for nearly half an hour at about 22^h and for more than 1½ hours from shortly before 1^h to 2½^h. In vertical force the disturbance was also great, the trace going off the sheet on both sides, in the direction of increasing force from 14½^h to 19^h, and in the direction of decreasing force from 0½^h to 2^h; the range probably exceeded 0.02 parts of the whole vertical force. The disturbance ceased on the afternoon of February 14. An aurora was seen at Greenwich between 0^h and 1^h on February 14.

A preliminary sudden movement is a common feature of magnetic storms; sometimes the disturbance follows on at once, sometimes it is a premonitory sign of disturbance to follow in a lesser or greater number of hours. The latter was the case in the celebrated 1859 Sun-spot and the magnetic disturbance. Mr. Ellis has recently been making an examination of some peculiarities connected with the initial movements observed in magnetic storms, and expects to arrive at interesting information in regard to the question as to how closely these movements are simultaneous at different places, and also on other points.

The Magnetic Storm of Feb. 13-14.—M. Mascart has the following note in the *Comptes rendus* for Feb. 22:

The recording instruments of the Observatories of Nice, Toulouse, Clermont and Besancon uniformly imprinted this disturbance, with all the circumstances determined by the stations of Perpignan, Lyon, Nantes and Parc Saint-Maur; the details of the phenomena will form the object of a later investigation.

Moreover, the accompanying aurora borealis, first noted in the United States, was observed in Europe as well.

On Feb. 14, from 1^h to 1^h 10^m A. M. (Paris M. T.), M. A. Forel saw at Morges a very beautiful aurora borealis; the telegraph operator of the Morges–Rolle line was awakened about 12^h 25^m A. M, by the bell ringing of its own accord.

The same day, between midnight and 1^h A. M., M. P. Lefebre observed at Troyes "an aurora borealis of considerable intensity, since the phenomenon was easily visible in spite of the brilliancy of the full Moon. A faint purple light first appeared in the north; as it continued to rise higher, the center was sensibly displaced from east to west. At the moment of its greatest brightness, whiter and more brilliant vertical streamers were seen at intervals. Finally the phenomenon disappeared behind clouds, after having undergone a new displacement in a direction opposite to that of the first."

M. de Roquigny–Adanson informs me that the aurora was observed a Parc-de-Baleine by a gamekeeper. * * * * * The aurora was also seen in th Mediterranean, in the neighborhood of the coasts of Provence, at Rome, Bru sels, London, in Canada, in the United States above the 36th parallel, etc.

Note on a Sun-spot Observed at Meudon Observatory from Feb. 5 to Feb. 17, b M. J. Janssen.—(*Comptes rendus*, Feb. 22, 1892.) M. J. Janssen exhibited t the Academy the photographs of the Sun obtained on Feb. 5, 9, 12 and 1 on which is shown one of the largest spots observed during recent sola periods.

The fact which renders this spot particularly remarkable and allowed it to b easily seen with the naked eye, is the great extent of the surface disturbed (th diameter of which is about one-seventh the diameter of the solar disc), and th great number of nuclei distributed over this surface. Two of these nuclei unite in the same penumbra were from six-tenths to eight-tenths of a minute of a in diameter, which closely approximates the dimensions of the largest nuclei eve observed.

The large scale on which these photographs have been obtained permits of th study of the movements and changes which the nuclei underwent from the ap pearance of the spot on Feb. 5 to Feb. 19, at which date it was close to the lim This study is complicated by the fact that there enter into it as elements the va ation in time of rotation with the heliocentric latitude—a variation very perce tible in the present case, on account of the extent of the spot in the direction the solar meridian—together with certain proper motions, and finally the vari tion of the forces which produced this great photospheric disturbance If th results of this study are of sufficient interest the Academy will be informed them.

In regard to the question of a connection between the phenomena of Sun-spo and terrestrial magnetic disturbances, M. Janssen sees nothing in the facts so fa established which would as yet authorize us in admitting this correlation. Ho ever, as nothing should be rejected *a priori*, and as the study of this question ca not be otherwise than profitable in the advancement of science, it is desirable tha the number of meteorological and magnetic observatories be increased, principall in the Southern Hemisphere, in order that it may become possible to separate ou from a mass of electric and magnetic effects those which may have a general an simultaneous character over an entire terrestrial hemisphere, for it is eviden that only phenomena of this order can be attributed to solar action.

Photography of the Great Sun-Spot at the Lick Observatory.—We are indebte to the Lick Observatory for an excellent copy on glass of a photograph of the Su taken when the great spot was nearest the center of the disc. The photograp was accompanied by the following letter from Professor Campbell:

LICK OBSERVATORY, Mount Hamilton, March 8, 1892.

Dear Professor Hale:

I take pleasure in complying with your request for a copy of one of our photographs the great February Sun-spot. It is a positive contact copy of a negative taken by Profe sor Schaeberle and myself with the 40-foot photoheliograph on Thursday, Feb. 11, 189 10h 35m 48s Pac. St. Time. We have secured photographs of the spot every clear day tha it has been on the visible hemisphere of the Sun since Feb. 9, on which date it was detecte here by Professor Schaeberle by the naked eye. Unfortunately, however, the seeing ha usually been poor, and the definition is not as good as we should wish.

Yours very truly,
W. W. CAMPBELL.

Area and Position of the Great Sun-Spot as Determined at Greenwich.—In the Journal of the British Astronomical Association, Dec. 1891, Mr. E. Walter Maunder gives the following note on the great Sun-spot:

Although it is only two years and a half since the time of absolute minimum, the reviving energy of the Sun has already displayed itself in a group of spots which completely dwarfs any witnessed during the preceding cycle. A group appeared at the east limb on February 5, crossing the meridian on February 11, and disappearing at the west limb on February 13, which had an area on February 13 of more than 2850 millionths of the Sun's visible surface, the greatest area attained by the group of November 12-25, 1882, the largest group of the 1878–89 cycle, being 2425 millionths. As in the case of the 1882 spot, the giant group has been accompanied by violent and characteristic magnetic disturbances, and by brilliant aurorae. The center of the group on February lay in hel. long. 260°, and hel. lat. 23° S.

An Equatorial Group of Sun-Spots.—As is well known, Sun-spots vary not only in number, but in latitude as well during a Sun-spot cycle. Just after a minimum, at the beginning of a new cycle, the spots which have been frequenting lower and lower latitudes since the previous maximum soon disappear, and are replaced by new spots in higher latitudes. It is extremely rare that a spot is seen near the equator in the early part of a new cycle, and we are therefore interested in a note by Mr. J. S. Townsend in the Journal of the British Astronomical Association (Dec., 1891), in which he gives his observations of a small group of spots seen near the equator from Nov. 20 to Nov. 25, 1891. The heliocentric latitude of the group varied between + 1° and + 6°, and the longitude between 261° and 267°. As the last minimum occurred in 1889, the low latitude of the group in question is quite remarkable.

Observations of Eruptive Prominences by Mr. E. E. Read, Jr., at Camden, N. J.—On Feb. 18, from 10 to 12 A. M., Mr. Read observed a very bright prominence extending from P. A. 222° to 230°. The highest part was about 30″ above the photosphere, and the form changed so rapidly that it was not similar in any two consecutive quarters of an hour. The distortion of the C line was mostly toward the red. Reversals were observed as follows, the positions of lines being taken from Rowland's map: C, D_1, D_2, D_3, 5371.7, 5363., 5328.1, *1474 K*, 5276.2, 5269.5, 5234.8, 5227.4, 5226.6, 5208.6, 5206.2, 5204.7, 5188, b_1, b_2, b_3 b_4, 5018.6, 4957.7, 4924.1, F.

Bad air and haze made it necessary to stop observation at F. The b lines were (except C, D_3 and F) the highest and brightest, extending about half way up. The other lines were low down.

On Feb. 19 the prominence was again seen for a few moments, and found to be about 60″ high. C was considerably distorted in both directions.

On Saturday, March 6, Mr. Read observed a prominence at P. A. 232°, which was described in the note-book as follows: "bright, probably metallic, but definition too poor to see any reversals save hydrogen and D_3." The same day at 7:30 P. M. he saw a distinct, but not bright, aurora, which lasted for 30 minutes. On March 7, at 10:30 A. M., a prominence was seen at P. A. 234° which reached an elevation of 162″ and showed great activity. "The base was a perfect cyclone, the motion being in both directions. At 11 o'clock this prominence had risen to about 4′, the base having almost entirely vanished. By noon there was nothing visible at that point." Two drawings which accompany the letter show the form of the prominence at 10:15 and 11 A. M. At the latter hour the prominence seems to have been blown into fragments.

Comparative Photographic Spectra of the Sun and Metals, by Mr. F. McClean.- Though it is now many years since photography was first successfully er ployed in the registration of metallic spectra, the beautiful photographs recentl published by Mr. McClean form the first comprehensive series to be put into tl hands of spectroscopists for general use. The set of twelve large plates before u which we owe to the kind liberality o[illegible] Mr. McClean, contains the spectra of tl Sun and fifteen metals from λ 3800 (above H) to λ 5750 (near D) or more tha half the visible spectrum, on the scale of Angstrom's chart. They are divided int two Series; of these, Series I contains the spectra of the Sun, iron, platinur iridium, osmium, palladium, rhodium, ruthenium, gold and silver. The last eigl constitute the platinum group of metals. Series II contains the spectra of tl Sun, iron, manganese, cobalt, nickel, chromium, aluminum and copper; the seven metals constituting the iron-copper group. As in all cases the metall spectra were obtained from the spark discharge in air, the air spectrum is show in all the photographs. These are mounted in parallel sections, and the air lin consequently run uniformly across the entire series. Though somewhat ove exposed, owing to the fact that the metallic spectra require a longer exposure t bring out their lines properly, the air spectrum is quite sufficiently well shown t be included in the enumeration of the spectra contained in these maps.

Though every care was used to obtain metals in a pure state for the wor Mr. McClean remarks in the Note which accompanied the presentation of h photographs to the Royal Astronononomical Society that many further impuriti will have to be eliminated. Calcium, for example, is almost universally presen its principal lines appearing in nearly every spectrum, and coinciding wit marked groups in the solar spectrum. It appears most strongly in osmium ar cobalt. Iron and barium are also common to many spectra.

Everyone familiar with spectrum photography, knowing by experience tl amount of patient labor required in photographing the various regions whe specially prepared plates and absorbing solutions are essential to success, w unite in congratulating Mr. McClean on the advanced stage of his extensive i vestigations. With the completeness of his laboratory and apparatus, and tl excellent methods in use there in photographing and enlarging spectra, we are ou selves familiar from personal observation. In company with Mr. Ranyard, tl well-known Editor of *Knowledge*, the writer enjoyed last summer a most inte esting visit to Mr. McClean's home in Tunbridge Wells, England. The enti upper story of the house is fitted up as a laboratory, and a heliostat on the ro commands the horizon in almost every direction, thus making possible the ph tographic work on the high and low Sun spectrum which was carried on by i means. The light is reflected into a telescope fixed in the meridian at the angle the pole, and a total reflecting prism at the eye-end allows the image of the Su to be formed on the slit of the spectrograph. This instrument is provided wit a Rowland grating with 14,438 lines to the inch, and the observing telescope ha a focal length of about 36 inches. The photographs taken at the focus of tl spectrograph are subsequently enlarged about 8½ times. The electric apparatu is very complete. In the cellar of the house a gas engine is employed to charge large storage battery. The current from this is led to a motor in the laborator and this, in turn, drives an alternating dynamo. The alternating current su plies the primary of a specially constructed induction coil, and at the time of ou visit a battery of about forty Leyden jars was connected in parallel with the se ondary terminals. The extremely brilliant spark, perfectly adapted for spectr scopic work, was attended by a deafening rattle. We had the pleasure of exami ing some of the photographs of spectra under a microscope, but no testimony necessary as to the sharpness of the original negatives when such excellent definition is retained in the maps after a nearly nine-fold enlargement.

The photographs have been very creditably reproduced by the Direct Photo-Engraving Co., the Collotype process being employed.

Appointment of Sir Robert Ball as Professor Adams' Successor at Cambridge.—Though we are perhaps straying without our proper domain of astro-physics, we must allow ourselves the pleasure of congratulating Sir Robert Ball on the well-deserved honor conferred upon him. The Lowndean Professorship is for Astronomy and Geometry, but we unite with the Editors of the *Observatory* in the hope that the Cambridge Observatory will be put into the same efficient hands, that it may once more attain the important position which its relation with the University calls upon it to occupy.

Recent Publications.—We have received a number of important publications, some of which we should be glad to refer to more at length, but lack of space makes it impossible to mention more than the titles at present. They are as follows:

Washington Observations, 1887; Appendix 1, A Report upon some of the Magnetic Observatories of Europe; Appendix 2, Magnetic Observations at the U. S. Naval Observatory (1890); Appendix 3, Meteorological Observations and Results at the U. S. Naval Observatory (1883-1887).

Publications of the Lick Observatory, vol. I. (1887).

Lunar Radiant Heat, Measured at Birr Castle Observatory, During the Total Eclipse of Jan. 28, 1888. By Otto Bœddicker.

Transactions of the Astronomical and Physical Society of Toronto. (1891).

Publicationen des Astrophysikalischen Observatoriums zu Potsdam. (No. 28): Beobachtungen des Planeten Mars, von O. Lohse.

The Total Eclipse of the Sun, Jan. 1. 1889. A Report of the Observations made by the Washington University Eclipse Party.

A Mechanical Theory of the Solar Corona. By J. M. Schaeberle.

Exercises in Connection with the Presentation of the Ladd Observatory to Brown University.

CURRENT CELESTIAL PHENOMENA.

PLANET NOTES FOR MAY.

Mercury will be "morning star" during May. He will be at greatest elongation, 25° 39′ west from the Sun, on the morning of May 17; but as he rises then only 40^m earlier than the Sun there will be little opportunity for observation.

Venus will continue to increase in brilliancy during May and, also increasing in declination, will be better situated for observation than in the preceding month. The phase changes from gibbous to crescent, the illuminated portion of the disk being 0.498 on May 1 and 0.298 on May 30. During these two months of April and May, if ever, we ought to be able to see the markings of Venus' surface and decide the question of her rotation.

Venus will be in conjunction with the Moon, 1° 53′ south, May 29, 1 A. M.

Mars is a morning planet, visible in the south, almost on a parallel with, and a considerable distance east of, the red star Antares. The two are of almost the same brilliancy and color. The low altitude of Mars renders observations of his surface details difficult, yet under these unfavorable circumstances the principal markings can easily be seen. The phase of Mars is gibbous, 0.875 of the disk being illuminated on May 1. Mars will be in conjunction with the Moon, 3° 05′ north, May 17 at noon.

Jupiter is also a morning planet and may be seen in the east an hour before sunrise.

There is an interesting paper on "recent discoveries on Jupiter" by C. Flammarion, in the March number of *L'Astronomie*. It is illustrated by copies o drawings made during the past opposition by Messrs. Terby and Comas in France.

Saturn will be in excellent position for observation in the early evening during May. He is in the western part of the constellation Virgo, about half way between *Spica* and the familiar group of stars, The Sickle, in Leo (see chart p. 81). He is moving very slowly westward, will be stationary May 25, after which he will move eastward. Saturn will be in conjunction with the Moon, 2° south, on May 6 at 6 P. M. The rings are very nearly edgewise to us; the minimum apparent width will be reached during the latter part of May, when it will be only 0.25″.

Uranus is a little farther east than Saturn (see chart p. 81) in the eastern part of Virgo near the star λ. The month of May will be perhaps the best in the year for observations of this planet. There will be an occultation of Uranus by the Moon on the morning of May 10 which will be visible only in the western half of the United States.

We would call attention again to the occultation of Uranus on the night of April 12 between 10 P. M. and 1 A. M. central time, and hope that many observations of this rare phenomenon may be obtained.

Neptune will be in conjunction with the Sun May 29 and so cannot be seen during this month.

We have made many attempts during the past opposition to discern markings on the surface of this planet, using the 16-inch refractor of Goodsell Observatory, but have been unsuccessful. On each occasion of excellent seeing, the planet appeared at first look to be very slightly elongated, the direction of elongation being about 50° of position angle; but we never could be certain, after protracted examination, varying eye-pieces and position of eyes, of this elongation. It seemed also as if the planet were encircled by a whitish equatorial belt in the same position angle, which belt may have contributed to the impression of elongation.

MERCURY.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 5......	1 33.7	+ 7 10	4 06 A. M.	10 37.6 A. M.	5 09 P. M.
15......	1 56.0	+ 8 18	3 44 "	10 20.6 "	4 57 "
25......	2 38.7	+12 21	3 31 "	10 23.9 "	5 17 "

VENUS.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 5......	6 05.2	+26 54	7 05 A. M.	3 08.3 P. M.	11 12 P. M.
15......	6 44.2	+26 29	7 06 "	3 08.0 "	11 10 "
25......	7 17.0	+25 20	7 07 "	3 01.5 "	11 56 "

MARS.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 5......	20 07.2	−21 54	12 41 A. M.	5 12.0 A. M.	9 43 A. M.
15......	20 27.3	−21 17	12 19 "	4 52.7 "	9 27 "
25......	20 47.0	−20 40	11 52 P. M.	4 29.2 "	9 06 "

JUPITER.

Date 1892.	R. A. h m	Decl. °	Rises. h m	Transits. h m	Sets. h m
May 5......	0 44.4	+ 3 33	3 32 A. M.	9 49.0 A. M.	4 06 P. M.
15......	0 52.4	+ 4 23	2 57 "	9 17.5 "	3 38 "
25......	1 00.0	+ 5 09	2 22 "	8 45.8 "	3 10 "

SATURN.

Date 1892.	R. A. h m	Decl. °	Rises. h m	Transits. h m	Sets. h m
May 5......	11 40.5	+ 4 46	2 21 P. M.	8 42.8 P. M.	3 05 A. M.
15......	11 39.6	+ 4 50	1 40 "	8 02.5 "	2 25 "
25......	11 39.2	+ 4 50	1 00 "	7 22.8 "	1 45 "

URANUS.

Date 1892.	R. A. h m	Decl. °	Rises. h m	Transits. h m	Sets. h m
May 5......	14 05.9	−12 13	5 53 P. M.	11 07.8 P. M.	4 22 A. M.
15......	14 04.4	−12 05	5 12 "	10 26.9 "	3 42 "
25......	14 03.0	−11 58	4 31 "	9 46.2 "	3 02 "

NEPTUNE.

Date 1892.	R. A. h m	Decl. °	Rises. h m	Transits. h m	Sets. h m
May 5......	4 25.4	+20 8	6 01 A. M.	1 29.0 P. M.	8 57 P. M.
15......	4 27.0	+20 12	5 23 "	12 51.2 "	8 20 "
25......	4 28.5	+20 15	4 45 "	12 13.5 "	7 42 "

THE SUN.

Date 1892.	R. A. h m	Decl. °	Rises. h m	Transits. h m	Sets. h m
May 5......	2 52.8	+16 32	4 44 A. M.	11 56.5 A. M.	7 09 P. M.
15......	3 31.9	+19 06	4 32 "	11 56.2 "	7 20 "
25......	3 51.8	+20 11	4 27 "	11 56.8 "	7 26 "

Mr. Marth's Ephemerides of the Satellites of Saturn.

[From *Monthly Notices*, Nov. 1891.]

In this table the times have been changed from Greenwich Mean Time to Central Standard Time. The abbreviations *Rh.*, *Te.*, *Di.*, *En.*, and *Mi.*, stand for the names of the satellites Rhea, Tethys, Dione, Enceladus, and Mimas. The letters *a*, *b*, *c*, *d*, and *e*, stand for conjunctions of the satellites in order as follows: With the preceding end of the outer ring; with preceding end of planet's equatorial diameter; with center of planet; with following end of planet's diameter; with following end of ring. The letters *n* and *s* signify that the satellite at the time of conjunction is north or south of the point designated by the preceding letter; *Sh.* means that the shadow of a satellite is near the central meridian of the planet; *Ecl. D.* and *Ecl. R.*, the disappearance and reappearance of a satellite at beginning and end of an eclipse.

April 1892.		
16	12.1 a m	En es
	2.3	Di es
	3.0 p m	Te bs
	4 6	En an
	4.6	Mi en
	5.0	Te as
	10.0	Mi es
	10.9	En en
17	1.3	Di bn
	2.0	Te Ecl. R.
	3.2	Mi en
	3.2	Rh an
	3.3	En as
	3.7	Te en
	5.0	Di Ecl. R.
	5.7	Rh bn
	6.8	Di en
	8.6	Mi es
	10.3	Rh Ecl. R
18	12.2 a m	Rh en
	2.3 p m	Te as
	5.9	En es
	7.2	Mi es
	8.0	Di es
	10.2	Di ds
19	12.2 a m	En as
	1.1	Mi as
	1.4	Di bs
	4.7 p m	En en
	5.8	Mi es
	9.4	Rh es
	11.7	Mi as
	11.9	Rh ds
20	2.8 a m	En es
	3.8	Rh bs
20	3.3 p m	Titan bn
	4.4	Mi es
	7.2	En an
	9.2	Titan dn
	9.6	Titan middle of Ecl. of uncertain duration.
	10.3 p m	Mi as
21	1.0 a m	Titan
	1.5	En en
	1.6 p m	Di es
	3.0	Mi es
	3.8	Di ds
	6.0	En as
	7.1	Di bs
	8.9	Mi as
	9.3	Di as
22	2.0 a m	Te es
	7.5 p m	Mi as
	8.5	En es
	10.5	Di an
23	12.7 a m	Di bn
	12.7	Te an
	6.2 p m	Mi as
	7.3	En en
	11.3	Te es
	11.6	Mi an
24	1.3 a m	Te ds
	3.0 p m	Di as
	4.1	Rh bs
	4.8	Mi as
	6.7	Rh as
	9.8	En an
	10.0	Te an
	10.2	Mi an
	12.0 midn	Te bn
25	4.1 p m	Di an
	6.3	Di bn
	8.6	En as
	8.6	Te es
	8.8	Mi an
	10.2	Di Ecl. R.
	10.6	Te ds
	11.8	Di en
26	1.5 a m	Te bs
	3.9 p m	Rh am
	6.5	Rh bn
	7.3	Te an
	7.4	Mi an
	9.3	Te bn
	11.2	En es
	11 2	Rh. Ecl . R.
27	12.6 a m	Te Ecl. R.
	12.9	Rh en
	1.0	Di es
	5.9 p m	Te es
	6.0	Mi an
	7.9	Te dn
	9.9	En en
	10.8	Te bs
28	2.1	Titan bs'
	2.2	Axis of Titan's shadow cone just outside the ball.
	2.4	En as
	3.9	Di Ecl. R.
	4.6	Te an
	4.6	Mi an
	5.1	Titan as
28	5.5	Di en
	6.6	Te bn
	9.9	Te Ecl R
	10.1	Rh es
	10.6	Mi en
	11.5	Te en
29	3.2	Te es
	3.3	Mi an
	4.9	En es
	5.2	Te ds
	6.6	Di es
	8.1	Te bs
	8.8	Di ds
	9.2	Mi en
	10.1	Te as
	11.3	En as
30	12.1 a m	Di bs
	3.7 p m	En en
	3.9	Te bn
	7.2	Te. Ecl. R.
	7.8	Mi en
	8.8	Te en

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A................$0^h\ 52^m\ 32^s$
Decl.................+ 81° 17′
Period............$2d\ 11^h\ 50^m$

May	1	6 P. M.
	4	6 A. M.
	6	6 P. M.
	9	5 A. M.
	14	5 "
	19	5 "
	24	4 "
	29	4 "

S ANTLIÆ.

R. A...............$9^h\ 27^m\ 30^s$
Decl...............— 28° 09′
Period...........$0d\ 07^h\ 47^m$

May	5	8 P. M.
	6	8 "
	7	7 "
	8	7 "
	16	9 "
	17	8 "
	18	8 "
	19	7 "
	28	9 "
	29	8 "
	30	7 "
	31	8 "

δ LIBRÆ.

R. A...............$14^h\ 55^m\ 06^s$
Decl................— 8° 05′
Period............$2d\ 07^h\ 51^m$

May	6	10 P. M.
	13	10 "
	20	9 "
	27	9 "

U CORONÆ.

R. A...............$15^h\ 13^m\ 43^s$
Decl...............+ 32° 03′
Period............$3d\ 10^h\ 51^m$

May	6	7 P. M.
	10	6 A. M.
	17	4 "
	24	2 "

U OPHIUCHI.

R. A...............$17^h\ 10^m\ 56^s$
Decl...............+ 1° 20′
Period.......... $0d\ 20^h\ 08^m$

May	5	4 A. M.
	5	midn.
	6	8 P. M.
	10	5 A. M.
	11	1 "

U OPHIUCHI Cont.

May	11	9 P. M.
	15	5 A. M.
	16	1 "
	16	9 P. M.
	21	2 A. M.
	21	10 P. M.
	26	3 A. M.
	26	11 P. M.
	31	4 A. M.
	31	midn.

Y CYGNI.

R. A...............$20^h\ 47^m\ 40^s$
Decl...............+ 34° 15′
Period...........$1d\ 11^h\ 56^m$

May	3	5 A. M.
	6	5 "
	9	5 "
	12	5 "
	15	5 "
	18	4 "
	21	4 "
	24	4 "
	27	4 "
	30	4 "

Occultations of Stars by the Planets.

Date		Central Time of Conjunction.	Diff. of Decl.	Maximum Duration.	Magnitude of Star.
		STARS NEAR VENUS.			
		h m	″	m	
May	2	3 58 A. M.	+ 37	10.4	8.0
	3	4 20 P. M.	− 35	10.8	8.9
	4	6 46 A. M.	− 77	11.1	9.4
	5	5 56 "	− 28	11.3	9.3
	7	4 19 "	+ 9	11.6	9.2
	7	6 34 P. M.	− 42	11.9	9.0
	11	5 17 "	− 76	12.9	9.3
	12	10 15 A. M.	+ 15	13.2	9.3
	13	3 29 P. M.	− 46	13.6	9.4
	16	12 16 A. M.	− 7	14.4	9.4
	19	1 39 "	+ 32	15.7	9.4
	21	1 31 "	+ 80	16.8	7.0
	21	2 26 "	+ 68	16.8	7.7
	21	3 08 P. M.	+ 42	17.5	9.3
	24	9 56 "	+ 49	19.5	8.5
	26	8 38 A. M.	+ 58	21.0	8.6
		STARS NEAR MARS.			
May	10	2 46 P. M.	− 61	9.9	9.1
	12	5 18 A. M.	+ 1	10.3	9.5
	15	3 34 "	− 52	10.7	8.3
		STARS NEAR JUPITER.			
May	23	9.5 P. M.	− 16	1.2^h	6.0
		STARS NEAR SATURN.			
May	9	4.8 P. M.	+ 71	4.6^h	9.5

Occultations Visible at Washington.

Date 1892.		Star's Name.	Magnitude.	IMMERSION Washington M. T.		IMMERSION Angle f'm N pt.	EMERSION Washington M. T.		EMERSION Angle f'm N pt	Duration.	
				h	m	°	h	m	°	h	m
May	1	*c* Geminorum	6	10	22	47	10	50	346	0	28
	13	A Ophiuchi	5	9	22	149	10	16	253	0	54
	13	38 Ophiuchi	7	10	23	119	11	39	282	1	16
	29	λ Cancri	6	10	22	86	11	08	308	0	46

Phases and Aspects of the Moon.

		Central Time. d	h	m	
First Quarter	May	3	1	12	P. M.
Apogee	"	8	11	18	P. M.
Full Moon	"	11	4	59	P. M.
Last Quarter	"	19	8	53	A. M.
Perigee	"	24	10	30	A. M.
New Moon	"	25	11	49	P. M.

The Great Sun-Spot.—The great Sun-spot group of February reappeared on the east limb of the Sun about March 3. Our first photograph was obtained March 5. The group was so changed as to be unrecognizable, there being but four rather inconspicuous spots, surrounded by a large area of brilliant faculæ On subsequent dates one of these spots developed so that it was quite conspicuous. It had two umbræ somewhat like the principal ones in February. They changed considerably from day to day and it was impossible to identify them with certainty with the two spot centers whose positions we determined in February. The following are the measures of photographs taken at Goodsell Observatory:

		Central Time.		Spot Center A. Long.	Spot Center A. Lat.	Spot Center B. Long.	Spot Center B. Lat.
		h	m	°	°	°	°
March	5	12	29	251.4	— 26.8		
	7	2	50	251.5	— 27.6	250.4	— 29.0
	8	12	46	251.2	— 27.9	248.7	— 29.3
	10	12	54	251.8	— 28.2	251.2	— 27.5
	11	1	52	251.0	— 28.4	250.3	— 28.3
	12	4	53	251.7	— 28.3	250.0	— 28.1
	14	9	39	251.9	— 27.8	249.2	— 27.9
	15	2	05	251.9	— 28.5	249.4	— 29.1

Three New Asteroids, Nos. 324, 325 and 326. A planet of the 11th magnitude was discovered by Palisa at Vienna Feb. 25.5454 Gr. M. T.: R. A. 10^h 26^m 17.4^s; Decl. $+ 7° 40' 35''$.

A planet of the 12th magnitude was discovered by Wolf at Heidelberg March 18.4048: R. A. 11^h 06^m 40.6^s; Decl. $+ 4° 44' 49''$.

A planet of the 11th magnitude was discovered by Palisa at Vienna March 19.3900: R. A. 13^h 27^m 00.0^s; Decl. $+ 9° 55' 09''$. Daily motion west 16′, south 3′.

New Asteroid No. 327—A planet of the 13th magnitude or fainter was discovered by Charlois, at Nice, March 22.5190: R. A. 12^h 41^m 13.3^s; Decl. $- 7° 15' 26''$; Daily motion 15′ west, 5′ north.

Professor J. K. Rees' Astronomical Lectures.—Professor Rees of Columbia College, New York City has recently delivered a course of lectures on Astronomy, at Yonkers, N. Y., of which the daily papers of that city speak very favorably.

COMET NOTES.

March has been the banner month for discovery so far this year. Four new asteroids and two new comets have been discovered and Winnecke's periodic comet has been rediscovered at its sixth (observed) apparition.

Discovery of Comet b 1892 (Swift). On the morning of March 7, at 5^h 10^m, while seeking for comets with my 4½-inch telescope, I ran upon what at first sight, from its general appearance, I was sure was a comet. After some unusual delay, the 16-inch glass was turned on the object, but advancing daylight prevented the getting of its place with desired accuracy. Fortunately I had at 3 o'clock set my automatic R. A. circle to the R. A. of the meridian, and the following is the position read from it: 18^h 59^m, the Decl. circle recording — 30° 20′. It is possible that it is Brook's comet of 1886, though its great southern declination and its brightness both argue against the supposition. For a telescopic comet it exceeds in size and brilliancy any I have ever seen.—*Astronomical Journal No. 258.* LEWIS SWIFT.

Mr. Barnard writes that this comet is easily visible to the naked eye even in full moonlight. At Northfield we obtained observations of its position on the mornings of March 8, 14, 16, and 21 but did not try to see it without the telescope. There has been very little change in brightness. The nucleus became invisible each morning at almost exactly 6 o'clock central time or $5^h 47^m$ local time. The coma was brightest on the sunward side and there was a trace of a "fan." The tail was broad and about 1° in length.

The following observations are at hand:

	Greenwich M. T.	App. α			App. δ		
		h	m	s	°	′	″
Wilson,	1892 Mar. 8.0005	19	03	15.8	−30	34	48
Barnard,	8.0399	19	03	25.3	−30	32	53
Frisby,	11.9487	19	22	14.8	−27	18	48
Wilson,	13.9887	19	31	49.4	−25	26	33
Wilson,	15.9933	19	41	03.0	−23	34	45
Wilson,	20.9872	20	03	16.5	−18	41	00

Elements of Comet b 1892 (Swift)—Preliminary elements have been calculated by Rev. Geo. M. Searle, of the Catholic University at Washington, and by Miss F. E. Harpham and Mr. A. G. Sivaslian, students in Goodsell Observatory:

	Searle.		Harpham and Sivaslian.	
T =	1892, April 26.99 Gr. M. T.		1892, April 7.74 Gr. M. T.	
ω =	81° 33′	1892.0	26° 09′	1892.0
☊ =	237 34		240 55	
i =	64 29		38 54	
q =	0.5891		1.0185	

Mr. Searle's elements depend upon the observations of Barnard March 8, Frisby March 11, and one by himself, March 12; those by Miss Harpham and Mr. Sivaslian depend upon the observations by Barnard, March 8, and Wilson, March 13 and 15. These latter elements represent the observations fairly well.

Re-discovery of Winnecke's Periodic Comet.—This comet was observed at Vienna March 18.4041 in R. A. $12^h 43^m 27^s.5$; Decl. + 30° 35′ 38″. The corrections to the ephemeris given in the February number of ASTRONOMY AND ASTRO-PHYSICS are thus -4^s in R. A. and + 9.8′ in Decl. We have looked for this comet twice, since its discovery, with the 16-inch telescope but were unable to see it.

Discovery of Comet d 1892 (Denning).—A very faint comet was discovered by Denning in England, March 18.500 in R. A. 22h 44m; Decl. 59° 00′. Its daily motion was stated as north preceding, 50′. This comet was observed by Spitaler at Vienna, March 19.4338; R. A. 22h 46m 47.1s; Decl. + 59° 17′ 43″. Cloudy weather prevented us from looking for this comet until March 24, when we failed to find it.

Search Ephemeris for Comet 1867 II. (Tempel's Periodic Comet.)

[Continued from page 250.]

Perihelion = April 3.5.

1892	R. A. h m	Decl. ° ′	log *r*	log Δ
May 5	18 24.6	− 23 46.0		
10	18 25.9	24 22.4	0.3208	0.0984
15	18 26.4	25 01.8		
20	18 26.0	25 42.9	0.3231	0.0776
25	18 24.7	26 24.2		
30	18 22.7	27 06.2	0.3260	0.0634
June 4	18 20.0	27 47.7		
9	18 16.7	28 29.6	0.3294	0.0562
14	18 13.0	29 10.1		
19	18 09.0	29 50.8	0.3332	0.0575
24	18 04.9	30 32.0		
29	18 01.1	− 31 13.0	0.3375	0.0645

	Perihelion = March 24.5		Perihelion = Apr. 13.5	
	R. A. h m	Decl. ° ′	R. A. h m	Decl. ° ′
May 10	18 50.6	− 25 06	17 59.6	− 23 17
20	18 52.6	26 23	17 57.8	24 36
30	18 51.1	27 48	17 52.8	25 59
June 9	18 46.6	29 15	17 45.8	27 20
19	18 39.6	− 30 39	17 37.8	− 28 34

Search Ephemeris for Comet Brooks, 1886 IV.

[From Astr. Nach. 3064. continued from page 251.]

	Perihelion, March 1.			Perihelion, March 31.		
	R. A. h m	Decl. ° ′	Light.	R.A. h m	Decl. ° ′	Light.
May 10	21 56.5	− 25 26	0.17	20 42.4	− 29 44	0.53
20	22 16.3	− 25 38	0.17	21 03.8	− 31 42	0.52
30				21 20.1	− 33 46	0.50
	Perihelion, April 30.			Perihelion, May 30.		
May 10	17 20.8	− 27 19	2.45	12 16.9	+ 11 16	1.47
20	17 31.1	− 33 43	2.44	12 24.3	+ 4 52	1.45
30	17 36.8	− 39 23	2.16	12 36.5	− 1 56	1.35
	Perihelion, June 29.			Perihelion, July 29.		
May 10	10 24.7	+ 24 29	0.35	9 26.5	+ 28 53	0.13
20	10 39.8	+ 20 19	0.36	9 43.5	+ 25 58	0.13
30	10 57.6	+ 15 46	0.37	10 03.3	+ 22 49	0.14

Brorsen's Comet.—In reply to Dr. Lamp's request to forward the publications of the results of my work on the orbit of Brorsen's comet, I would say that, at present, my computations are not finished, but as soon as they are, I shall be pleased to forward them for publication. GEO. A. HILL.

Elements and Ephemeris of Comet b 1892 (Swift).—The following elements and ephemeris of Swift's comet were computed by Mr. A. G. Sivaslian and Miss F. E. Harpham. The observations used were those by Barnard, March 8, and Wilson, March 13 and 20.

ELEMENTS.

T = April 6.6868 Gr. M. T.

$$\left.\begin{array}{l} \pi = 265^\circ\ 29'\ 00'' \\ \omega = 24\ \ 35\ \ 20 \\ \Omega = 240\ \ 35\ \ 40 \\ i = 38\ \ 40\ \ 43 \end{array}\right\} \text{Mean equinox 1892.0}$$

$\log q = 0.011252$ $q = 1.02625$

Middle Place
$d\lambda \cos\beta = -5''$
$d\beta = -4''$

The equatorial co-ordinates are given by the following equations:

$$\begin{aligned} x &= r\,[9.923121]\sin(349^\circ\ 05'\ 41'' + v) \\ y &= r\,[9.999781]\sin(257\ \ 54\ \ 19\ \ + v) \\ z &= r\,[9.737957]\sin(345\ \ 06\ \ 41\ \ + v) \end{aligned}$$

The comet is moving north and east and will reach its maximum brilliancy early in April. It will continue to be visible, in the morning sky, through May and June.

EPHEMERIS.

Date		App. R. A.			App. Decl.			log Δ	log r	Br.
		h	m	s	°					
1892 Apr.	5	21	04	09.9	− 2	56	22	0.0274	0.0114	1.37
	6		07	55.3	1	53	50			
	7		11	38.8	0	51	45			
	8		15	20.3	+ 0	09	52			
	9		19	00.0	1	10	59	0.0336	0.0116	1.33
	10		22	37.8	2	11	36			
	11		26	13.8	3	11	39			
	12		29	48.0	4	11	05			
	13		33	20.3	5	9	53	0.0416	0.0136	1.27
	14		36	50.9	6	8	00			
	15		40	19.8	7	5	25			
	16		43	47.0	8	2	06			
	17		47	12.6	8	58	01	0.0512	0.0175	1.20
	18		50	36.5	9	53	10			
	19		53	58.7	10	47	31			
	20	21	57	19.3	11	41	03			
	21	22	00	38.3	12	33	46	0.0620	0.0230	1.11
	22		03	55.7	13	25	39			
	23		07	11.5	14	16	42			
	24		10	25.7	15	06	53			
	25		13	38.3	15	56	13	0.0735	0.0302	1.02
	26		16	49.3	16	44	42			
	27		19	58.7	17	32	19			
	28		23	06.6	18	19	05			
	29		26	12.9	19	05	01	0.0856	0.0387	0.93
	30		29	17.6	19	50	05			
May	1		32	20.8	20	34	18			
	2		35	22.4	21	17	41			
	3		38	22.5	22	00	15	0.0978	0.0484	0.84
	4		41	21.0	22	41	59			
	5		44	18.0	23	22	54			
	6		47	13.4	24	03	01			
	7		50	07.3	24	42	21	0.1102	0.0591	0.75
	8		52	59.6	25	20	54			
	9		55	50.4	25	58	41			
	10	22	58	39.7	26	35	43			
	11	23	01	27.4	27	12	00	0.1223	0.0706	0.67
	12		04	13.6	27	47	34			
	13		06	58.2	28	22	26			
	14		09	41.2	28	56	35			
	15	23	12	22.7	+ 29	30	04	0.1341	0.0828	0.60

NEWS AND NOTES.

The pressure upon us for space, this month, has led to an additional form of 16 pages in the present number. The four plates accompanying important articles are fine and helpful illustrations.

Subscribers and correspondents are requested to notice especially the announcements that are made on the last page of these notes. Careful attention to the directions there found will materially aid all interested.

United States Naval Observatory.—We have been much interested in the steps of progress taken during the last sixty days, pertaining to a change in the management of the United States Naval Observatory. To this end bills have been introduced into both branches of Congress, urging that the name of the Observatory be changed, and that the superintendency of it be placed in the hands of a skilled practical Astronomer. In support of this movement other useful, general work, in scientific circles, is going forward with perfect unanimity.

The Harvard College Observatory Time Service.—Not long ago, Professor E. C. Pickering, Director of Harvard College Observatory, published a brief historical statement of the Time Service of the Observatory which has been in operation since 1856. From this review of the work of that Observatory an extract is taken to show how other Observatories have suffered in a much greater degree, at the hands of ambitious Government officers aided by a single commercial corporation:

"One of the greatest advantages of the time-service to the Observatory has been that it kept before the public the practical value of astronomical work. Many thousands of persons who take no interest in work of a purely scientific character recognize the great financial value to the public of an accurate system of time. The Observatory desires to confer this benefit on the public, and it would be ready to do so even at a financial loss. But recently the time-signals of the United States Naval Observatory have been offered to the public at very low rates, through the Western Union Telegraph Company. This can the more readily be done since the expense of furnishing the time is borne by the people through a government appropriation, while the company has the largest facilities for the maintenance of telegraphic connections. The Harvard College Observatory is therefore relieved of this duty. If the public is to be the gainer, signals of equal accuracy and continuity must be furnished. Unfortunately, signals sent to a great distance are liable to frequent interruptions from trouble with the telegraph lines, and therefore secondary clocks must be used in each large city if continuous signals are to be distributed. These clocks must be constantly compared and corrected if great accuracy is to be attained, and it is still a question whether satisfactory results can be secured outside of an Astronomical Observatory. If the results prove unsatisfactory, however, the responsibility for trying the experiment will not rest upon this Observatory."

"In view of the facts stated above, it has been decided to discontinue the time-signals furnished by this Observatory after March 31, 1892. An earlier date would have been selected, but for the desire to give our subscribers sufficient time to make other arrangements for securing signals."

If one of the most able and judicious astronomers in America, who stands at the head of one of the greatest Astronomical Observatories, speaks out thu frankly and forcibly for *cause*, what could others say who are in charge of smalle Observatories and who have depended chiefly on local support for their scientif work, if they cared to make their views known?

The New Star in Auriga Disappearing.—The new star is going the way of a temporary stars. It is invisible with an opera-glass or small telescope. On photograph taken at Goodsell Observatory, March 23, with a camera and 2 inch Darlot lens, exposure 30 minutes, the star made no impression whatever.

Mr. Thomas D. Anderson, the discoverer of this star, has written the follov ing letter which was published in *Nature*, Feb. 18, 1892:

"Prof. Copeland has suggested to me that, as I am the writer of the anony mous postcard mentioned by you a fortnight ago, I should tell your reade what I know about the Nova.

"It was visible as a star of the fifth magnitude certainly for two or three day very probably even for a week, before Prof. Copeland received my postcard. I a almost certain that at 2 o'clock on the morning of Sunday, the 24th ult., I sav a fifth magnitude star making a very large obtuse angle with β Tauri and χ A rigæ, and I am positive that I saw it at least twice subsequently during tha week. Unfortunately, I mistook it on each occasion for 26 Aurigæ, merely r marking to myself that 26 was a much brighter star than I used to think i It was only on the morning of Sunday, the 31st ult., that I satisfied myself tha it was a strange body. On each occasion of my seeing it, it was slightly bright than χ. How long before the 24th ult., it was visible to the naked eye I canno tell, as it was many months since I had looked minutely at that region of th heavens.

"You might also allow me to state for the benefit of your readers that m case is one that can afford encouragement to even the humblest of amateur My knowledge of technicalities of astronomy is, unfortunately, of the meagere description; and all the means at my disposal on the morning of the 31st ult when I made sure that a strange body was present in the sky, were Klein's "Sta Atlas," and a small pocket telescope which magnifies ten times." H. C. W.

Astronomical and Physical Society of Toronto.—A copy of the Transactions this Society for the year 1891, has recently been sent us through the kindness of th corresponding Secretary, Mr. Lumsden. This is a neatly printed volume of 8 pages, with a lithographed drawing of Jupiter as frontispiece. The list of paper read at the meetings, abstracts of which are given for the most part, shows tha the people of Toronto are very much interested in astronomy and physics and ar doing creditable work. At the end of the volume is a list of the principal sidere phenomena for the year 1892. H. C. W.

On the Possibility of seeing Meteors from Comet 1882 I.—Permit me to call at tention to the fact that the Earth passes near the ascending node of comet 188 I on April 15, the approach being a rather unusually close one. The Earth passe outside the comets' node by 0.03 of the Astronomical unit, or about 3 millio miles. This comet was a bright and large one, and, allowing for the latera spreading of meteors in their orbits, it is quite possible that the Earth might at tract some of them into its atmosphere. The radiant point is 356.9° in R. A and —14.°4 in Decl. O. C. WENDELL.

Harvard College Observatory, March 21, 1892.

Distribution of the Moon's Heat.—The February number of the Monthly Notices of the Royal Astronomical Society is an excellent one. It gives this favorable summary to Professor Very's recent researches on the distribution of heat on the Moon's surface: "The maximum for light is more pronounced than that of heat, so that the visible rays form a much larger proportion of the total radiation at the full than at the partial phase. Next, the heat areas are eccentric, having their greatest extension towards the west; the diminution of the heat in the third quarter of the lunation is slower than its increase in the second, and, lastly, there is a fair agreement between Mr. Very's results and those of Lord Rosse, although so differently obtained. Thus the result of Dr. Copeland obtained in 1870, that the greatest heat was attained before the full, is confirmed by the present series of observations."

"Mr. Very's researches open a new field, as previous investigations have dealt with the radiation of the Moon as a whole, whereas his method deals with that from numerous small portions of its disc under various conditions of phase, thus affording much additional information of a kind entirely new."

Strassmaier and Epping's Researches on Babylonian Astronomy.—In the last number of *Monthly Notices* will be found an account of the labors of Strassmaier and Epping in deciphering the Assyrian texts pertaining to Babylonian Astronomy. The labors began more than ten years ago, and the results already reached have established in great measure the system of astronomy of the Babylonians regarding their method of calculating and predicting the new Moon, the determination of the dates of the era of the Seleucidæ in Julian style, the explanation of the lunar and planetary calendars, the mode of prediction used therein and the publication of several lunar and planetary tables of observation. Under the head of chronological results the following facts are given:

"The commencement of the eras of the Seleucidæ (S. E.), and of the Arsacidæ have been fixed with a certainty which is based upon the calculation of eclipses contained in the Lunar Calendars. The years of the Seleucidæan eras were luni-solar; their months lunar, sometimes of thirty, at others of twenty-nine, days. They employed intercalary months, but according to what law is yet unknown. The year commenced with the month Nisan, which fell about the spring equinox. The five following dates have been determined by Epping:

1 Nisan 188 S. E = April 4 — 123 J. E.
" 189 " = March 25 — 122 "
" 190 " = April 12 — 121 "
" 201 " = " 10 — 110 "
" 202 " = March 30 — 709 "

Hence the Seleucidæan era began in the year — 310 of the Julian era, and that of Arsacidæ in the year — 246. The civil day of the Babylonians began at sunset, and the division of the day into twenty-four hours was in use among them. But their astronomers, as is evident from the calculating tables, besides using a division of the day into 360 time-degrees, referred its commencement to the midnight following the beginning of the civil day."

The entire account indicates that these men are engaged in the successful prosecution of a most useful piece of scientific work.

M. Camille Flammarion's Popular Lectures in Paris.—By kindness of American friends, resident in Paris, we have been favored with copies of the *New York Herald* (Paris edition) containing brief accounts of the popular lectures on Astronomy recently given by the distinguished M. Camille Flammarion in that ci Two themes of his latest lectures were "Among the Stars" and "The End of t World." The Herald's account of the last is graphic indeed, and would be peated here somewhat at length, if we could be sure that the reporter had c rectly stated Flammarion's views. His references to Christ's sayings about t end of the world are noteworthy. There is but one quoted passage in this view. It is as follows: "I believe," said Flammarion, "that life is eternal, a as the world had a commencement so I expect that it will have an end. T transformation may come from any quarter. It may as likely begin in the mid of the great American continent, as in the middle of the Atlantic Ocean, or Egypt, amid the Pyramids, as the center of England; but we scientists are for to arrive at the conclusion that it will come about in the manner above d cribed."

Note on the Lick Observatory Lunar Photographs.—In number 16 of the Pul cations of the Astronomical Society of the Pacific, a letter from Professor Wein of Prague, was inserted because it afforded an "interesting proof of the va of the Lick Observatory Moon negatives when studied by an eminently com tent eye." Professor Weinek said: "Neison has erroneously drawn the sm crater which lies N. W. on the crater Thebit A on the outer wall. According the negative (of Aug. 27, 1888) it lies on the inner wall." That is, Profess Weinek means Neison has drawn the small crater on the N. W. outer wall of t crater Thebit A.

As I possess excellent silver prints from the negatives of Aug. 15 and 1888, I have examined them and also Neison's map for this small crater a have found that it doesn't exist. Neison certainly shows no such formation; E dently Professor Weinek's "eminently competent eye" was somewhat at fa this time. But N. W. of Thebit A Neison has drawn a small crater on the ou wall of Thebit. According to the photograph of Aug. 15, this lies on the in wall and in such a manner that it also must be considered as a feature of t floor of the crater (Thebit). The photograph of Aug. 27 does not show t small crater at all.

I wish to call attention to the erroneous way in which Neison, in his M VI, has drawn the crater Pico D with reference to the three-peaked mounta Pico B. The photograph of Aug. 15, 1888, also shows a very distinct cra N. E. of Pico D which Neison does not show on this map. Yet, in Map IX, though these features are only introduced on the margin, they are all shown a shown nearly in their correct relative positions. A glance at the photograph Aug. 15 suffices to show that Neison's representation of the ridge, a portion which lies between Pico D and B, is utterly worthless as regards detail.

In Map IX, Neison draws two small craters south of the bright mounta Piton. Both of these are shown in the photograph of Aug. 27, and to the rig of one of them (Piton *a*) by about that crater's diameter, I think I dete another crater. If so, it is not shown by Neison.

Another new feature seen in the photograph of August 27, is a fine crook white line crossing Plato from N. E. to S. W., a very delicate object to the nak eye. It might be a fault in the lunar surface, perhaps. I also see a narrow wh line beginning at the mountain Plato Pi and extending N. E. until it just ski the north side of the crater Condamine B and passes beyond. The nature of th I am unable to guess, unless it is a defect in the photograph. These features a only referred to here in order that they may receive proper attention and stu from some person with an "eminently competent eye." ROGER SPRAGUE.

Berkeley, California, Feb. 26, 1892.

Note on Double Stars.

δ Auriga = OΣ 545 is undoubtedly binary.

The following are recent measures:

A and B

1892.164	349°.0	2″.59	3 — 8
.167	349 .1	2 .35	3 — 8

A and C

1892.167	292 .9	46 .11	9
.184	293 .4	46 .59	9

The following are previous measures:

A and B

1871.42	5°.6	2″.15	OΣ	7 *n*
76.45	1 .9	2 .17	De.	4 *n*
78.86	5 .8	2 .17	β	2 *n*

A and C

1852.12	290.9	43.27	OΣ
76.24	292.6	45.17	De
79.41	293.3	45.51	β

The Greenwich 10 year Cat. 1880 gives the proper motion A. R. = + 0ˢ.0037 N. P. D. = + 0″.078.

The companion of Σ 3002 was found to be a delicate double.

A and B

	1890.909	203°.4	4″.11	8 — 10
	.964	204 .2	3 .83	
Mean	1890.94	203 .8	3 .97	

B and C

	1890.909	213 .1	0 .60	10 — 11
	.964	218 .8	0 .75	
Mean	1890.94	215 .9	0 .67	

Prof. S. W. Burnham has communicated the following measures:

A and B

	1891.540	201 .3	3 .77	7.8
	.562	202 .9	3 .80	8
	.575	202 .1	3 .83	8
Mean	1891.56	202 .1	3 .80	

B and C

	1891.540	205 .2	0 .75	11 — 11.5
	.562	214 .0	0 .75	11 — 11.3
	.575	215 .6	0 .90	10 — 10.8
Mean	1891.56	214 .9	0 .80	10.7 — 11.2

G. W. HOUGH.

Archenhold's Bibliography.—In answer to your letter of Jan. 13, I reply that the astronomical bibliography was already begun in 1889, and that 1889 and 1890 are almost complete except a few English periodicals which were not accessible to me at that time in the Berlin libraries.

The plan is extensive. Throughout, there is regard for what is of interest to astronomers. With this purpose, there are four main divisions: general, astronometric, astro-physics and astro-mechanics. These main divisions fall into subdivisions, as follows: general, in 40; astronometrie, in 82; astro-physics, in 98; astro-mechanics, in 32. In accordance with your wish, the manuscript of the plan lies subject to your order.

The celebrated publisher, Engelmann, in Leipzig, after mature considerat has declared that there is absolutely no profit in publishing the work, and tl fore declines to undertake it. In consequence, I negotiated through the astr omical Gesellschaft with Professor Bruns in Leipzig for the printing, and Gesellschaft will be prepared, as soon as the edition of the zone-observatio somewhat farther advanced, to undertake the edition of the Bibliography. case it should be necessary, I would willingly publish the Bibliography q terly instead of yearly, and it appears to me not improbable that it will perh appear as a supplement to your publication, ASTRONOMY AND ASTRO-PHYSICS would also in any case, be prepared to furnish an abstract for your journal.

My farther purpose is to complete the Bibliography backward until it jo the Houzeau-Lancaster, although the latter would be brought out later than first.

F. S. ARCHENHOLD.

Wolsingham Observatary.—From the report of 1891, by T. E. Espin, Direc of Wolsingham Observatory the following paragraph is taken:

"The work of the Observatory has been much the same as in former ye As the Science of Astronomy widens, the greater the need of taking up one spe line and working steadily at it. The sweeps for stars of the Third and Fou Types have, therefore, been continued, and also the re-observation of Red St published in the Red Star catalogue. During the year, 120 new Third T Stars have been discovered, and one Fourth Type Star, bringing the total to 6 many of them are faint and difficult objects even with the large light-grasp power of the telescope and some doubt exists as to whether some of them n not be really of the Second Type. The year has been an interesting one in records of the Observatory through the discovery of five variable stars. On particularly interesting as discovering a star of Burton's, which has long b missing. Seven nights in the Autumn were given up to the observation of th stars on Dr. Wolf's photos of Cygnus, which showed much discrepancy in m nitude as compared with Argelander. In all, 171 stars were thus observed. some doubt appears as to the number of Red Stars in the Perseus Cluster, it v carefully examined in December, and another Red Star added to the recei number, making, in all, nine. The work of the Observatory has been much fac tated by the generous gift of Argelander's Charts by Mr. T. W. Backhouse. T has allowed of systematic zone work, and seven hours of zone + 55° had been amined by the close of the year. The charts were directly compared with the s and the stars which had anything remarkable in their spectra pencil marked the Charts, thus saving the labor of circle readings, and assuring certain ident cation."

National Observatory at Athens—I have the honor to inform you that Royal Government has placed me in charge of the National Astronomical a Meteorological Observatory of Athens.

The period of re-organization which we are experiencing does not permit us present to take the active part which we desire in the great scientific movem in which your celebrated journal occupies so distinguished a place. But we ho that by means of the improvements which we are constantly seeking in our s vice, we will soon be in a position to contribute as much as possible by utilizi the beautiful sky of Athens, to the advancement of our science.

A regular publication of our astronomical and meteorological work is fou in the plan which we hope to realize, and which will enable us to establish sci tific communications and to follow the great progress of our science.

I hope that you are willing to materially aid us in our labor by sending us your journal. Our Observatory will be greatly favored if you are willing to enrich our library by a complete collection of the works issued by you, and your celebrated journal.

DEMETRITS EGINITIS, Director.

Dr. Bœddicker's Drawing of the Milky Way.—We have just received a beautifully executed lithographic copy of a drawing of the Milky Way made by Dr. Otto Bœddicker, astronomer at the Earl of Rosse's Observatory at Birr Castle, Parsontown, Ireland. This drawing shows the Milky Way from the north pole to 10° of south declination, as it appeared to Dr. Bœddicker's eye, and shows a wonderful amount of detail. It was begun in Oct., 1884, and required five years of very careful and difficult observation. The drawing could only be made in small sections, but the sections were drawn repeatedly, and varied in such a way that each overlapped several others, thus enabling the observer to compare the scales of light intensity of different nights. After the whole visible galaxy had been gone over thus in small sections, these were combined into a composite picture of the whole.

We congratulate Dr. Bœddicker on having completed so successfully his long and arduous task and upon having his work so skilfully reproduced, as it has been done by Mr. Wesley. It will be very interesting to compare this work with the photographic pictures of the Milky Way which are being obtained. H. C. W.

The Mexican Meteorites by J. R. Eastman.—We have only lately seen Profesors J. R. Eastman's paper on "The "Mexican Meteorites" which was read before the Philosophical Society of Washington, D. C., Jan. 2, 1892. It was published last month. In that paper is a brief description of twenty-four of these meteorites. A table showing the designation of these masses and their respective weights is given below:

	Tabulated Weights of the Mexican Iron Meteorites.	*Kilograms,*
1.	The Bonanza masses (estimated at least 15 tons)	13,600
2.	The Butcher masses	1,699
3.	The Santa Rosa mass	63
4.	The "Couch" meteorite	114.3
5.	The Fort Duncan mass	44.1
6.	The Potosi mass (estimated)	91
7.	The Cerralvo mass (estimated)	136
8.	The Casas Grandes mass (estimated at 5,000 pounds).	
9.	The Centennial Exhibition mass, probably same as No. 8 (estimated)	1,134
10.	The Presidio del Principe masses, no weight known.	
11.	The Huejuquillo masses, San Gregorio	11,560
	" " Concepcion	3,130
	" " Chupaderos	15,600
	" " "	9,290
12.	The Ranchito mass, measures 3.65×20×1,5 meters.	
	" " (estimated)	40,800
13.	The La Plata mass	124.7
14.	The Guadalupe masses	46.4
15.	The Cacria mass	41.4
16.	The Mezquital mass	7
17.	The Bella Roca mass	33
18.	The Catorce masses, 576, 4.5, 41.7 kilograms	622.2
19.	The Charcas mass	780
20.	The Zacatecas mass	907
21.	The Toluca mass (estimated)	275
22.	Specimens from Los Amutes and Cuernavaca (no weight given)..	
23.	The Yanhuitlan mass	421
24.	The Caparrosa mass, 341 grams	0.3
	Total	100,519.4

Queries for Brief Answers.

7. I read in Steele's Astronomy, "It has been recently shown that equator is not a perfect circle, but is somewhat flattened, since the diam which pierces the meridian 14° east of Greenwich is two miles longer than one at right angles to it." How is this explained? What is the cause? M. H.

8. What units of time and distance are used in applying Kepler's Third L to the motion of the Moon? E. L. E.

9. How can Newton's method of discovering the law of gravitation be ex ited to a class of unprofessional persons? E. L. E.

Answers to Queries.

Query No. 3 (p. 255).—In reply to the question of G. I. H., "how far ahead h eclipses been predicted, and where can I obtain a list," I would call his attent to the 52nd vol. of the Memoirs of the Imperial Academy of Sciences of Vie which is the late Professor Appolzer's great work upon the past and fu eclipses of the Sun and Moon.

The volume contains the necessary data for predicting 8,000 Solar and 5, Lunar eclipses, and covers the intervals from — 1207 to + 2161 or 3368 ye As this volume is very valuable, I doubt if it will be found in many of the lib ries in the country.

We have it in our library, and if G. I. H. will address me stating what ecli he desires, I will be pleased, with the permission of the superintendent, to him the dates of such future eclipses as he may desire. GEO. A. HILL.

Naval Observatory, Washington, D. C.

Query No. 4 (p. 255).—The belief that Mercury rotates on his axis in the sa time that he completes a revolution around the Sun rests almost wholly on observations of Schiaparelli at Milan. Observations of Mercury's surface ma ings are so extremely difficult that no one has yet satisfactorily verified Schia relli's conclusions. The answer, therefore, to this query must be non-committ

Query No. 6 (p. 255).—Answers have been received from Rev. Edward Bro of Yankton, S. D., and F. Bradbury, St. Augustine, Fla. The expression, " undevout astronomer is mad," is found in Young's "Night Thoughts," Night about line 500.

PUBLISHER'S NOTICES.

The subscription price to Astronomy and Astro-Physics in the United Sta and Canada is $4.00 per year, in advance. For foreign countries it is $4.40 year which is the uniform price. Messrs. Wesley & Son, 28 Essex Street, Stra London, are authorized to receive subscriptions. Payment should be mad postal notes or orders or bank drafts. Personal checks for subscribers in United States may be used.

Currency should *always* be sent by registered letter.

Foreign post-office orders should be drawn on the post-office in St. Paul Northfield is not a foreign money order office.

All communications pertaining to Astro-Physics or kindred branches Physics should be sent to George E. Hale, Kenwood Astro-Physical Observato Chicago, Ill.

All matter or correspondence relating to General Astronomy, remittances, s scriptions and advertising should be sent to Wm. W. Payne, Publisher of tronomy and Astro-Physics, Goodsell Observatory of Carleton College, Nor field, Minn.

Manuscript for publication should be written on one side of the paper o and *special care should be taken to write proper names and all foreign na plainly*. All drawings for publication should be *smoothly* and *carefully* made *India ink* with lettering well done, because such figures are copied exactly by process of engraving now used. If drawings are made about double the size tended for the printed page, better effect will be secured in engraving than if copy is less in size. As a rule the publishers have had to re-draw the figures s during the last year at considerable expense. We hope to avoid this in the ture. It is requested that manuscript in French or German be type-written. requested by the authors *when articles are sent for publication*, ***twenty-five*** print copies, in covers, will be furnished free of charge. A greater number of prints of articles can be had, if desired, at reasonable rates.

Rates for advertising and rates to news agents can be had on applicatio the publisher of this magazine.

PLATE XIV.

Astronomy and Ast

NEW SERIES No. 5. MAY 1893.

GENERAL ASTR

THE MOUNTAIN STATION OF THE HA TORY

WILLIAM H.

The Boyden Department of H
founded in the spring of 18
siderable sum of money was left
an Observatory "at such an eleva
practicable, from the impedim
which occur in the Observatorie
pheric influences." Evidently the
the fund was to find a suitable
cordingly the following summer
to Colorado, well-equipped with
successively secured in three
springs, altitude 6,035 feet
tude, 10,964 feet, and Pike's Pe
of these stations a 12-inch Clark
portable mounting especially con
Peak is probably the greatest
strument has ever been used. A
with two 60° prisms was also em
eral hundred photographs secur
eral of these spectra showed a line
to be the shortest wave-length yet
spectrum. The negative which sho
vantage, however, was one taken fr

An examination of the other p
perceptible advantage was gain
altitude, and it was, therefore, conclu
lengths which the Sun, in all pr
space, were absorbed before pass
In regard to the steadiness of seei

Communicated by the author.

PLATE XIV.

Astronomy and Astro-Physics.

NEW SERIES No. 5. MAY, 1892. WHOLE No. 105

GENERAL ASTRONOMY.

THE MOUNTAIN STATION OF THE HARVARD COLLEGE OBSERVATORY.*

WILLIAM H. PICKERING.

The Boyden Department of Harvard College Observatory was founded in the spring of 1887. By the will of Mr. Boyden a considerable sum of money was left to aid in the establishment of an Observatory "at such an elevation as to be free, so far as practicable, from the impediments to accurate observations which occur in the Observatories now existing, owing to atmospheric influences." Evidently the first duty of those in charge of the fund was to find a suitable locality for the Observatory. Accordingly the following summer, an expedition was undertaken to Colorado, well-equipped with instruments, and observations successively secured in three localities, namely:—Colorado Springs, altitude 6,035 feet; Leven Lakes (near Pike's Peak) altitude, 10,964 feet, and Pike's Peak, altitude 14,147 feet. At each of these stations a 12-inch Clark refractor was set up, with a portable mounting especially contrived for the purpose. Pike's Peak is probably the greatest altitude at which so large an instrument has ever been used. A quartz spectroscope furnished with two 60° prisms was also employed at each station, and several hundred photographs secured of the solar spectrum. Several of these spectra showed a line at w. l. 292, which is believed to be the shortest wave-length yet photographed in any celestial spectrum. The negative which showed this line to the best advantage, however, was one taken from the lowest station.

An examination of the other photographs showed that no perceptible advantage was gained by an increase of 8000 feet in altitude, and it was, therefore, concluded that the shorter wave-lengths which the Sun, in all probability, gives out from his surface, were absorbed before passing through his atmosphere. With regard to the steadiness of seeing, no appreciable advan-

---

* Communicated by the author.

tage over Cambridge was shown at any of the stations. T stars were undoubtedly somewhat clearer than at sea level, b this difference only amounted to a fraction of a magnitude. As final result of the summer's work, it was concluded that the s lection of a proper site for an Observatory was by no mea merely a question of elevation.

The next expedition sent out by the Department was in t winter of 1888-89. Observations with a 13-inch Clark refract were made at Willows in northern California, and later, on W son's Peak, altitude 6000 feet, in the southern part of the sta The telescope was kept at the latter point for over a year, a continuous observations made every clear night. During t rainless season scarcely a cloud obscured the sky, and the defi tion was extraordinarily fine. Altogether the station was a d cided improvement over Colorado. Nevertheless, there were o jections to the location, one being that it was found almost i possible to secure a clear title to any land near the summit of t mountain. For this and other reasons it was decided to seek fa ther.

In the mean time Messrs. S. I. and M. H. Bailey had unde taken an expedition to the west coast of South America, and ha established a station upon Mt. Harvard, altitude 6600 feet, n far from Lima, Peru. This station was occupied for over a yea and very satisfactory results were obtained at it. It was co cluded from theoretical considerations, largely meteorologica into which it is not necessary to go at present, that a desirab location ought to be found near the tropics. The Messrs. Bail explored the coast as far south as Valparaiso, with this point mind, visiting also several inland cities. Especial attention w directed to Arequipa, and this city was so favorably reported c that it was decided to send the next expedition to that point.

The present expedition left the United States in Decembe 1890, arriving in Arequipa the middle of the following Januar It was then in the height of the cloudy season, which lasts abo four months, and little direct astronomical work could be acco plished. Nevertheless a map of the valley was undertaken, a si for the Observatory selected, the land purchased, and the erectio of buildings commenced. The clear season opened in April, a soon it was found that the favorable reports given us had reality far understated the truth. The transparency of the sk was such, that it was a common occurrence to see third magnitu stars set below the horizon where it was on a level with the ey while at home, as is well known, to see any star set, unless b hind some elevation, is an unusual event.

But with the 13-inch telescope the most interesting results were obtained. Ten and twelve diffraction rings have been counted, under favorable circumstances, around the brighter stars, each ring being nearly if not absolutely motionless. It is well known that in general to see the rings at all with a telescope as large as the 13-inch is a rare occurrence, and that the few there seen are nearly always wavering and broken. At first a power of 475 was used exclusively for all observations, saving those requiring a large field, this being the highest power with which we came provided. The definition under these circumstances upon the Moon and planets was absolutely sharp, and without a blur or waver. Since then higher powers have been sent from home, and 1140 diameters have been used upon Venus in the day-time, that power showing the planet to decidedly better advantage than 812. The phases of Jupiter's satellites are readily observed as they enter into the shadow of the planet, a phenomenon which it is thought but few astronomers have ever seen, even with much larger telescopes than the 13-inch.

This telescope, though small compared to the modern giant refractors, is nevertheless the largest visual refractor in use south of 35° north latitude, although there are about thirty larger ones north of this parallel. This fact has therefore enabled us to study all of the more interesting southern objects for the first time with an instrument of this power. As a result many new double stars have already been discovered, together with several faint clusters and nebulæ which are probably new. Some of our most interesting observations, however, pertain to the bodies of the solar system, which the high magnifications that we are able to employ enable us to study to great advantage. Descriptions of some of these observations we hope shortly to be able to send to ASTRONOMY AND ASTRO-PHYSICS. This telescope, as has been mentioned upon former occasions, has the valuable peculiarity that by reversing the crown lens, and shifting the flint, we may convert it from a visual, into a photographic telescope, of high excellence, Notwithstanding the great interest attaching to the visual work which may be accomplished here, the photographic results which may be obtained by an instrument of this size, so unusually located, are so much more important, that it is very doubtful if many more visual observations can be made with it, and this year its time will be largely devoted to securing spectra of the brighter southern stars.

The city of Arequipa, though the third in size in Peru, having a population of about 29,000, is not well known to the outside world. The visitor arriving at the Port of Mollendo, passes through a rougher surf than he has probably ever seen upon the Atlantic Coast, and takes the cars of the Southern Railway o Peru one hundred and seven miles across the desert, to his destination. The city itself is situated in a little green oasis containing perhaps sixty square miles, through which runs the River Chile. The Observatory is built upon the crest of a hill overlooking the valley, and about four hundred feet above the city. To the eastward lies the extinct volcano of Pichu pichu, 18,600 feet in height, northeast and but ten miles distant lies the quiescent volcano of the Misti, 19,200 feet in altitude, and to the north and twelve miles distant, lies Charchaui 20,000 feet in elevation Although these mountains are so near at hand, yet in no case do they rise over 12° above the true horizon.

The true geographical position of the Observatory has not a yet been accurately determined, but it is, roughly speaking, i latitude 16° 24′ south, and longitude 4^h 45^m 30^s west from Greenwich. It is consequently about 4,000 miles south of Harvard Observatory, and about 18 miles west of it. Its altitude i 8055 feet above the sea, and it is therefore considerably highe than any other Observatory in the world having so extensive a equipment.

Owing to our location within the torrid zone, our meteorologica conditions are very regular. As we have been here but one yea we cannot as yet generalize, but we may say that the clear season is expected to begin the latter part of March or first of Apri and to continue with scarcely an interruption from cloud until th first of November. November is the beginning of the cloudy season, and during this month this last year 0.02 of an inch of rai fell. December was fairly clear, while January and Februar were cloudy and rainy. Nearly all the rain falls in January an March, amounting in general, to two or three inches in all. Th mornings, with few exceptions, are bright and sunny throughou the year, most of the rain falling in the afternoon and evenin Excepting during the rainy season the climate is exceedingly dr With some persons the skin becomes rough, and the lips crac from the excessive drouth. All vegetation is maintained by constant irrigation, for an evaporation of 0.59 of an inch in one da has been recorded in the rainy season. No observations have a yet been made when the weather was really dry. The win reaches its maximum in the middle of the day, and it is unusuall calm at night. The highest velocity noted was December 2 when it reached a velocity of 17.2 miles an hour, but a sligh addition must be made to this figure on account of our rarefied atmosphere.

The barometric pressure and temperature are very uniform throughout the year. Tri-daily observations are maintained and during the clear season a fourth observation is taken in the middle of the night. The highest barometer reading recorded was 22.676 on Aug. 17, and the lowest 22.472 on January 19. The maximum thermometer reading was 79°.0 on June 3, but this was unusually high, the second highest being 74°.3 in October. The minimum thermometer reading of the year occurred eight days after the maximum upon June 11, and was 38°.5. Although the temperature of the air never gets down to freezing, not only do we have occasional frosts, but standing water is known to skim over with ice during the clear season, such is the excessive radiation. The power of the Sun is at times tremendous, and a blackened bulb thermometer exposed to its rays in vacuum has been known to reach 164°. We have sometimes had difficulty in our tool room in the afternoon, when the Sun shone in, as the tools become so hot, that we could not handle them, without first putting them in the shade to cool. It is not pleasant to be out in the middle of the day during the clear season, but in the shade, upon our verandah it is never uncomfortably warm and the middle of the day there is always a cool breeze blowing. I have gone into considerable detail in describing our meteorological conditions, as I am inclined to think that they have more to do with our favorable seeing, than has our elevation of 8,000 feet *per se*. Of course they may be said to depend upon it, more or less, but still, we might have the same elevation elsewhere, and be very differently circumstanced meteorologically. From my experience with large refractors in different parts of the world, I am inclined to attribute our exceptionally steady seeing more to the excessive dryness of our climate than to any other one cause.

AREQUIPA, Peru, March 1, 1892.

THE BOYDEN STATION OF THE HARVARD COLLEGE OBSERVATORY.*

WILLIAM H. PICKERING.

In the foregoing paper I gave an account of the situation and the meteorological conditions prevalent at the Peruvian station

---

* Communicated by the author.

of this Observatory. In the present paper I shall describe its equipment, and the class of work to which it will be especially devoted. A general idea of its situation may be obtained from the plate* accompanying this article. The great mountain mass in the background is Charchaui, an extinct volcano, 20,000 feet in altitude, whose crater was probably originally some six miles across, and whose summit is twelve miles distant from the Observatory in an air line.

At the bottom of the snow line in this picture, and almost exactly under the deep *cal* situated to the left of the main summit, lies a plateau, rather less than half a mile square. Near the front edge of this plateau, where it drops off in a precipice several hundred feet deep, stands the upper meteorological station of the Observatory—the highest observing station in the world. A more detailed account of our various meteorological stations, and of our topographical and barometrical determinations of their altitudes, will be reserved for a later paper, where they can be discussed to more advantage.

The accompanying photograph was taken in a direction nearly due north, as may be seen by the orientation of the sides of the buildings. To the west and south the land slopes away gradually, but on the east, it descends sharply some two hundred feet to the river valley. On the opposite side it rises, at first gradually, and later, more and more steeply, to the summit of the Misti, some ten miles distant. As the land had not been purchased one year, when this negative was taken, February 11, 1892, much still remains to be done,—such as clearing the grounds, laying out paths, etc. The erection of the house itself consumed considerable time and thought, as very little building is done in this place, and the party had to be its own architects. The house is now completed, however, and has proved to be very satisfactory.

On the left of the house is seen the dome of the 13-inch telescope. The walls of the building are constructed of wood, being a single thickness of board, in order that they may take the temperature of the outside air as rapidly as possible. The revolving portion is built in the form of a drum, and consists of a wooden frame and boarded roof, covered with canvass. Its walls are framed upon three wooden rings, one at the top, one at the bottom, and one in the middle. The bottom ring is complete, but the middle one is broken on the side where the shutter opens. The upper ring is also broken, on the side turned away in the picture, and here a smaller opening is made, closed by two shutters, one in the side

---

* See Frontispiece.

and one in the roof. By this plan, the chief objection to the drum form of dome is avoided, and any portion of the sky can be observed at any time, through one or the other of the two openings. A ladder permanently attached to the outside of the drum, but not shown in the picture, leads onto the roof and has been found extremely convenient on several occasions. The main side and roof shutters are made in separate pieces, any one of which can be opened independently of the rest. This is especially important when carrying on photographic work upon windy nights. It is less important in this locality, however, as the nights are almost invariably calm. All of the shutters open outward upon hinges, as shown in the photograph and are managed by cords from the floor of the dome. Indeed, it seems to me that this form of dome, if so modified as to be adapted to the climate of the temperate zones, would be generally found not only very much cheaper, but very much more convenient than the ordinary hemispherical form. The height from the floor to the bottom of the cross ties inside the roof is twenty-four feet, which is also the diameter of the drum. The drum revolves upon independent iron wheels, and can be readily turned without mechanical aid, with one hand.

The telescope contains no unusual features save the reversible lens, previously referred to, and a device for reading the right ascension directly without computation, as one does the declination. A 12-inch prism is attached in front of the object-glass, and is so counterpoised that it may be pushed to one side without altering the adjustment of the instrument. It is proposed to employ this telescope for photographing the brighter stellar spectra, for the charting of clusters, the measurement of close double stars, and the study of planetary and lunar detail. To the telescope is attached an 8-inch, and a 1¼-inch finder, the latter having a field of about nine degrees in diameter.

In front of the dome and to the left of it is the laboratory, containing the offices, work-room, tool-room and photographic rooms of the Observatory. These rooms are fitted up in the manner that experience has shown to be most convenient, and need no farther comment.

Between the laboratory and dome is the shed covering the 20-inch reflector. It is of only 42 inches focus, and is one of the pair made by Mr. Common for use during the second solar eclipse of 1889. This instrument is especially adapted on account of its great aperture and short focus to the study of faint nebular detail. The shed covering it slides forward upon a track, leaving the instrument entirely exposed to the sky. To the east of this instrument, but hidden behind the house, is the meteorological shelter, made in the customary form, and carrying upon its roof a Robinson anemometer, wind-vane and a pair of sunshine recorders of the form adopted by Harvard College Observatory.

North of the meteorological shelter are the transit pier and clock room, the latter a small stone structure with a stone roof, supported upon iron rails. From the pier a view of the sidereal clock may be obtained through a glazed window. Notwithstanding the intensity of the sunlight, it is found best to open the clock room slightly in the middle of the day, otherwise its inside temperature will be lower at mid-day than at midnight. This is due to the slow conduction of heat by the stone walls and roof. The clock room is connected by wire with the laboratory and dome. Four wires lead to the former and may be faintly traced in the picture, although photographed from a distance of over nine hundred feet.

In the clock room are placed the earthquake recorders. This arrangement is only temporary, however, and a separate building will be constructed for them later. Whenever an earthquake occurs, it is announced automatically upon a bell in the laboratory, and a clock is stopped at the same time by electricity. Many of these earthquakes occur in the course of a year, but they are usually so slight that they would pass unnoticed if one were standing, save for the rattling of the doors and windows which is sometimes heard. Usually the pen of the siesmograph merely makes a little hole in the lampblacked surface of the glass plate on which it rests, but in two instances thus far, a distinct and complicated curve has been drawn.

Several severe earthquakes have, at different times, been felt in this locality, and accordingly every precaution has been taken in the erection of buildings and instruments, to render them perfectly secure. The base of the iron pier of the telescope is buried five feet deep, in a mass of solid masonry, eight feet square, whilst the dome is built as lightly as possible. This is the most approved form of construction for buildings in earthquake countries, because in case of a severe shock, being very light, they merely shake about, but do not come down. In the case of the dwelling house, on the other hand, where warmth was a *desideratum*, it was necessary to construct it of stone, but the pillars are pierced in each case from end to end by an iron bar, and they and the walls are all bound together by railroad iron, passing under the floor of the rooms. No plastering is employed upon the ceilings, but all are made either of wood, or of stone, securely supported upon iron rails, the latter being the customary construction here among the better class of houses. The walls of the upper story are of bamboo, small stones, and stucco. Thus the house, while it is in outward respect quite similar to northern dwellings, is, in its internal structure, quite unlike them. We have been often asked if the frequent earthquakes would not throw our instruments out of adjustment. So far, however, we have had no more trouble than we would have had at home, where after the frosts, the ground always settles somewhat under the piers. If the earthquakes shake the instruments, they apparently let them settle back again into their original positions.

To the east of the meteorological shelter, and also behind the house, is the 5-inch visual telescope. It is intended to use this instrument later for solar work. To the left of the laboratory is seen the shed covering the 8-inch Bache telescope. Over thirteen hundred 8 × 10 photographs have been secured with this instrument during the past year, some of them being star charts and others stellar spectra. Between the Bache shed and the laboratory is seen the somewhat pyramidal prime vertical pier. Its summit furnishes our bench mark for altitude, and is exactly on a level with the floor of our upper piazza. It has been used hitherto chiefly for surveying purposes.

To the left and below the Bache shed lie the stable and servants' quarters, and just above them, with its white canvas cover thrown back is found the 2½-inch camera. This instrument is of exceptionally short focus, and it is with it that the great outer spiral of the Orion nebula was discovered two years ago at the Boyden station in California. The mounting, however, which is new, is not yet satisfactory, and we hope to improve upon it shortly. We have, nevertheless, already found with it that the Greater Magellanic Cloud is also a spiral structure, similar to the Orion nebula, but with the center less condensed, and the outer regions much more so. The great nebula of 30 in Dorado is near, but not coincident with the center. This wonderful object, second only in the whole heavens to the Orion nebula, is, however, unlike it in being very non-actinic, and we have only succeeded in photographing the very highest portions of it hitherto with the large telescope. Its spectrum is also probably gaseous.

It is expected that in a year or so, we shall receive from the United States a 5-inch photographic meridian photometer, for determining the photographic magnitudes of all the brighter stars south of the equator. Also later the 24-inch photographic doublet, known as the Bruce telescope, modeled after the Bache, but constructed upon three times the scale, with which it is intended to make a complete chart of the heavens. In fact, our equipment will be excellent in many respects, and the chief instrument which we are at present lacking is that which many would consider the most important of all, and which we do, undoubtedly, very much need, and that is a first-class large visual refracting telescope. It has been often said that the chief obstruction at present to astronomical advance was our own atmosphere. But this obstruction has now, at this station, been practically overcome, and what we see here depends not as elsewhere upon the condition of the air, but only upon the size and quality of the telescope employed.

AREQUIPA, Peru, March 7, 1892.

RADIANT ENERGY AS A PROBABLE CAUSE OF THE SOLAR CORONA, THE COMÆ AND TAILS OF COMETS AND THE AURORA BOREALIS.*

SEVERINUS J. CORRIGAN.

According to the hypothesis advanced in my paper entitled "The Transmission of Radiant Energy through Gaseous Media," and published in Nos. 101 and 102 of ASTRONOMY AND ASTRO-PHYSICS, the component atoms of each molecule of any gas are regarded as being in incessant and exceedingly rapid revolution around a focus situate within the molecule. If this be true, it is, I think, reasonable to assume that these rapidly moving atoms can, and do, take up an indefinite number of finely divided, or exceedingly minute particles of any solid, liquid or gaseous matter against which they may impinge, and that, from their own inherent store of energy they can, and do, impart motion to such assumed particles. We can conceive that such matter is transferred from molecule to molecule, as if by a train of revolving wheels in intimate contact with each other, and that it is thereby diffused, more or less rapidly, throughout any gaseous mass which is in any way in contact with the solid, liquid or gaseous matter aforesaid. The diffusion of gases is a well-known phenomenon of Physics, and it is clearly explicable under this hypothesis, as is also the phenomenon known as evaporation.

---

* Communicated by the author.

According to this view, when the particles of a liquid mass, water, for instance, are sufficiently separated by the impulses emanating from the vibrating, *i. e.*, heated atoms of a containing vessel, or, in other words, by the action of applied heat, which occurs when the water has reached the temperature of ebullition, they are, by the energy of the applied heat, forced in amongst the revolving atoms of the occluded and the superincumbent gas, against the pressure of such gas, and are endowed with a portion of the energy of motion possessed by these moving atoms.

Since the quantity of energy resident in any moving body depends not only upon the linear velocity, but also upon the mass of the body moved (being equal to one half the mass into the square of the velocity), the greater the quantity of aqueous particles taken up and set in motion by the rapidly revolving atoms of the gas, the greater will be the tension or pressure of the resulting vapor, or, in other words, the greater will be the ability of such vapor to perform work. It is a well-known fact that the weight of any given volume of steam increases with the pressure of the latter, being greater on account of the greater number of watery particles assumed and set in motion by the rapidly revolving atoms of the sustaining air. I hold, therefore, that without an occluded or a superincumbent gas there can be no evaporation. This statement may seem to run counter to observed facts relative to evaporation *in vacuo*, but it should be noted that according to the hypothesis which I have advanced in No. 101 of ASTRONOMY AND ASTRO-PHYSICS, what is called a vacuum, ordinarily, is very far from being one in so far as inherent energy is concerned.

The above enunciated hypothesis enables us to clearly define the difference between a *gas* and a *vapor*; viz.: that the latter consists of solid or liquid particles sustained in rapid motion by the revolving atoms of a true or permanent gas.

Strong observational proof can be adduced in corroboration of said hypothesis. It is a matter of common observation that when an incandescent electric lamp has been in use for a considerable length of time, the inner surface of the glass bulb becomes blackened; this blackening is found to be due to carbon particles which have been forced against the glass with considerable violence, since they adhere quite firmly thereto. The only source from which these particles can come, being the carbon filament, which is found to have undergone an appreciable waste, the question arises, how have they been transported across the highly vacuous space between the filament and the inner surface of t glass globe? The hypothesis above stated furnishes a ration answer, viz.: that the particles of carbon are transported by t revolving atoms of the remanent gases, namely, nitrogen and ca bonic acid gas, included by the glass bulb, and which, as stat above, act like a train of revolving wheels in contact with ea other, the particles being taken from the filament by the revo ing atoms in contact therewith, passed along by the intermedia molecules, and finally deposited upon the glass by the revolvi atoms impinging against it; in other words, the transportati of the particles is a result of evaporation or of diffusion.

If the truth of the hypothesis advanced above be admitte a probable cause of the phenomena mentioned in the title of tl paper can be proposed. The first mentioned is the solar coror that luminous apparition surrounding the Sun, and visible the naked eye at time of total solar eclipse. We know that t surface matter of the solar globe is composed of gases and t vapors of many kinds of matter, and that the Sun is constant emitting intense, thermal, luminous, and electrical radiatio which are transmitted throughout surrounding space. Now, the hypothesis above set forth in regard to the cause of diffusi and of evaporation be true, the vapors surrounding the sol globe should be urged outward into space, by the Sun's radia energy, as if impelled by a force acting in opposition to sol gravity, and luminous vaporous matter so radiated, would a pear as the corona, and possibly, as the zodiacal light. I wou here adduce collateral evidence to support the hypothesis of t existence of a force, or *quasi* force, naar the Sun's surface, acti in opposition to solar gravity. In No. 75 of THE SIDERE MESSENGER, I called attention to the remarkable fact that t time of rotation of any planet of the solar system appears to a function of the density of the planet the Earth's time of rot tion and density being each taken as unity. In each case, t time of rotation is very nearly proportional to the square ro of the density and I endeavored, in my paper published in t above mentioned number of the MESSENGER, to demonstrat mathematically, the cause of this peculiar relation. I also call attention to the fact that it exists in the case of every one of t eight planets of our system, but *not* in that of the Sun, and showed that this exception could be well accounted forunder t hypothesis that there is an apparent force emanating from t Sun, and acting in opposition to solar gravity, driving off t vaporous surface matter of the Sun to form the corona.

As a result of the demonstration above referred to, I found, and published, in the paper aforesaid, the following equations:

$$T = \frac{D}{\sqrt{\frac{k}{r^3}}} = \frac{D}{\sqrt{\frac{M}{r^3}}} = \sqrt{D}$$

in which D represents the density, T the time of rotation, k the unit of attractive force, and M the mass of the body under consideration, all of these quantities being relative to the corresponding ones proper to the Earth, and which are taken as the units. Now the density, time of rotation, radius, and mass of the Sun are quite accurately known, so that the only quantity that can be regarded as undetermined is k, or the unit of attractive force; it is true that in so far as the action of the Sun upon the planets is concerned, k is proportional to M, and is therefore known, but the mass, M, of the Sun, is derived from the motion of the Earth around that body, and if there be in action against the surface matter of the Sun a force directly opposed to gravity, but whose influence does not extend to, or, at least, has no effect upon the planetary bodies whose motions are dependent upon M, the quantity, k, in so far as it affects the Sun's surface matter, will not be proportional to M, and although the values of the mass and radius, and, therefore, of the density, be accurately known, they will not give the true relative time of rotation of the surface matter, through the equations above set forth; a repellant force would lessen k, and therefore increase the time of rotation of the surface matter, which is the time observed, and this is what happens in the case of the Sun, the time observed being much greater than that given by the hypothesis.

The existence of such a force renders comprehensible the observed fact of the extreme mobility of the surface matter of the Sun, which mobility is indicated by the opening and closing of spots or cavities covering millions of square miles of the Sun's surface, and the upheaval of vast quantities of solar matter to the height of several hundred thousand miles, often in a space of time so short that a force capable of producing the observed effects is, judging from terrestrial analogies, almost inconceivable.

If the formation of the solar corona be due to the cause above stated, the nature of the operation which forms the coma and the tail of a comet becomes, I think, at once apparent. Radiant energy proceeding from the nucleus, or the central portion of the comet, drives outward the vapors which constitute a great part of the cometary mass, and as the comet approaches the Sun, these vapors are impelled in a direction away from the latter

body by the radiant energy emanating therefrom and form
tail of the comet. Since it is known that evaporation takes pl
more quickly as the atmospheric pressure decreases, and since
diffusion of vaporous matter, above referred to, is akin to eva
ration, the rapidity of formation of the tail of a comet as th
body, moving in the highly vacuous regions of space, approac
the Sun, is clearly explicable.

Auroral phenomena are so peculiar that they may, at fi
sight, seem to be inexplicable by the hypothesis above
forth, but if we accept as most probable, that view wh
regards the aurora as due to electrified matter in the form
aqueous vapor, or ice particles such as constitute the cir
cloud, and that this electrified matter is in motion at a very gr
altitude in the Earth's atmosphere, I think that it can be sho
that the aurora can be properly classed, in so far as its ca
is concerned, with the phenomena above regarded as resu
of radiation. We know that the frequency of the aur
varies with that of the Sunspots and that these spots indic
abnormally great disturbance of the solar matter and therefo
abnormally great emission of radiant energy. This excess
radiant energy produces excessive evaporation, and drives
matter so evaporated, and electrified, (probably by the act
evaporation) into a region of the atmosphere much higher th
that in which such matter could be normally sustained. The r
tion of such electrified matter, suspended, probably, above
stratum of rare, dry, non-conducting air, must cause it to act
induction upon the Earth, and thus to generate those dist
bances of the magnetic needle, and the other electrical phenome
which are known to accompany the aurora. The format
of the latter is, therefore, analogous to that of the tail o
comet, but there is this important difference, viz.: that the
porous matter of the aurora is not driven off in a direction
actly away from the Sun, as is the cometary matter, but be
electrified, it is acted upon by the Earth's magnetism (which
itself probably a result of solar radiation), and is forced there
to assume a peculiar conformation, or to set itself along
magnetic lines of force, or parallel to the magnetic meridian.

In this conection reference may be made to the fact that
roræ and the tails of comets both display phenomena wh
seem to be electrical, and which point to the same or a simi
origin for both.

It should be noted that what I have called the *force* produc
the effects above mentioned, *i.e.*, the repulsion of matter from

surfaces of the Sun, Earth, and comets, is not of the same nature as gravity, and, strictly speaking, is not a repellent force at all (although in so far as its effect upon vaporous matter is concerned it acts like such a force), for if it were, the motions of the planets and other bodies of the solar system would be different from what they are well known to be.

The vaporous matter at the surface of the Sun, and the other bodies aforesaid, is simply taken up by the rapidly revolving atoms of each molecule of gaseous matter by which these bodies are surrounded, and carried outward, passing from molecule to molecule with great rapidity in highly vacuous space, while the only effects produced upon the planets are thermal, electrical and luminous. Only vaporous matter, or matter so finely divided that it can be assumed by, and intimately connected with, the revolving atoms, is subject to the action of this *quasi* force, and, therefore, the objections that can be urged against the existence of a force of repulsion, as it is generally understood do not apply in this case.

The action is, probably, the same as that which operates in the case of the incandescent electric lamp, in which particles of the heated carbon filament are carried outward to the sides of the glass bulb by "radiant energy," *i. e.*, by the action of the rapidly revolving atoms of the molecules of the gaseous matter which constitutes the transmitting medium.

In fine, setting aside all theoretical considerations, it is, I think, reasonable to assume that, if radiation from the heated filament of the electric lamp aforesaid, can produce the effects noted, radiation from the heated bodies of the solar system must produce similar effects, upon a scale proportionate to the magnitude of the radiating masses.

ST. PAUL, March 25, 1892.

GEORGE BASSETT CLARK.[*]

J. A. BRASHEAR.

> "Great truths are the simplest
> So are the greatest men."—ANON.

It would seem almost like a work of supererogation to write a biography of such a man as George B. Clark.

If a man's work is to live after him, surely, he who by his life work has left his "footprints among the stars" so that they

---

[*] Communicated by the author.

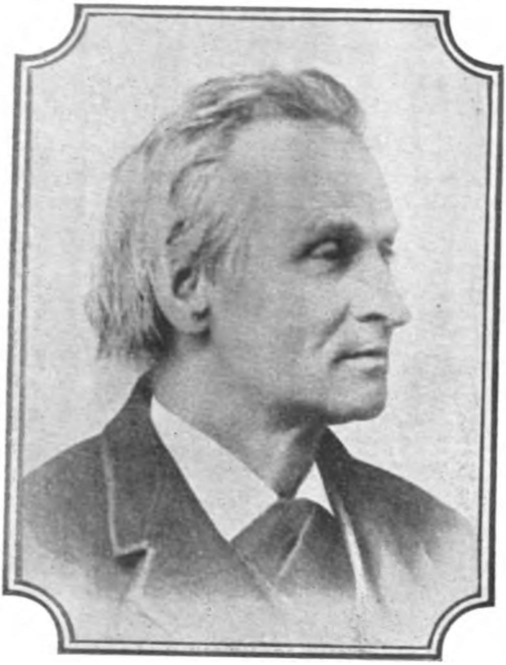
as
genius
oped.

George Bass
his early education
Whitman's private
Academy, Andover, in 184

---

* As Mr. Clark's parents desired
amined by Professor Benjamin O. Pierce,
more class, except perhaps in Greek, which
with credit; but instead of that he chose to

PLATE XV.



GEORGE BASSETT CLARK.

Feb. 27, 1827-Dec. 30, 1891.

may be traced in the ages to come, needs no better, no grand panegyric.

It is not, therefore, to praise his life work that these lines a written, and, indeed, few men of his great worth had such innate shrinking from publicity as did Mr. Clark; but when such man has laid down his armor, and has gone to his rest those w knew of his great work in "pushing outward the borders human knowledge," treasure the incidents in the life history th led to such remarkable results.

In a most interesting article written by Professor Newcomb 1874, on the Washington telescope, these words occur:

"When we trace back the chain of causes which led to the co struction of the great Washington telescope we find it to co mence with so small a matter as the accidental breaking of dinner bell in the year 1843 at the Phillips Academy, Andov Mass.

One of the scholars of the Academy, George B. Clark by nam gathered up the fragments of the bell, took them to his home Cambridgeport, put them into a crucible with some tin, and pr ceeded to melt them in the kitchen fire. His mother very na urally inquired the cause of such an interference with the culina arrangements, to which he replied that he was going to make telescope. Having melted his metals he cast them into a disc an commenced grinding them into a concave mirror.

His father, learning what be was doing, lent a helping han and the combined skill of father and son was soon rewarded the completion of a five-inch reflecting telescope which wou show the satellites of Jupiter, the rings of Saturn and other te scopic objects. Such was the origin of the now well-known fir of Alvan Clark & Sons."

Years ago the writer asked Father Clark what became of th first mirror, but he could not remember. Thus it was, that, wh the great work that Alvan Clark & Sons began in so small a wa as the making of that five-inch mirror, there was evidently genius for the work only waiting for an opportunity to be dev oped.

George Bassett Clark was born Feb. 14, 1827. He receiv his early education at a grammar school, high school and at M Whitman's private school in Cambridge. He entered Philli Academy, Andover, in 1844.* After leaving the Academy he wa

---

* As Mr. Clark's parents desired him to go to Harvard College, he was e amined by Professor Benjamin O. Pierce, who pronounced him fit for the Soph more class, except perhaps in Greek, which he could master sufficiently to pa with credit; but instead of that he chose to go at once into active life.

s, May, 1892.

tt Clark.

needs no better, no grander

his life work that these lines are of his great worth had such an as did Mr. Clark, but when such a and has gone to his rest those who pushing outward the borders of the incidents in the life history that

written by Professor Newcomb in scope, these words occur:

the chain of causes which led to the con- Washington telescope we find it to com- matter as the accidental breaking of a at the Phillips Academy, Andover

the Academy, George B. Clark by name, of the bell, took them to his home in into a crucible with some tin, and pro- in the kitchen fire. His mother very nat- of such an interference with the culinary which he replied that he was going to make a ds he cast them into a disc and concave mirror.

was doing, lent a helping hand, and son was soon rewarded by reflecting telescope which would the rings of Saturn and other tele- origin of the now well-known firm

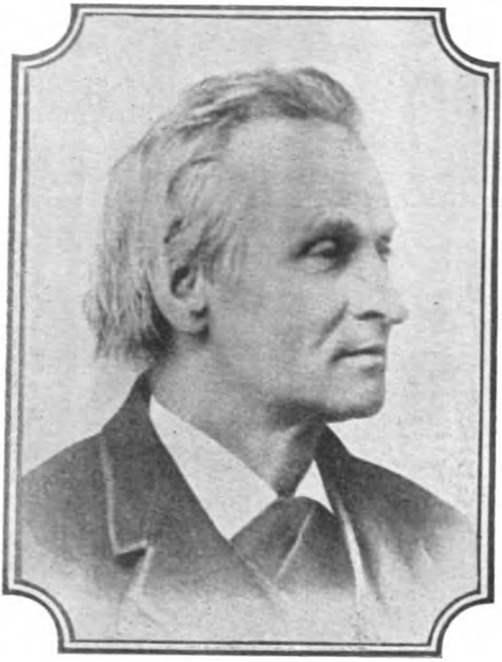
asked Father Clark what became of that not remember. Thus it was, that, while van Clark & Sons began in so small a way that five inch mirror, there was evidently a only waiting for an opportunity to be devel-

Clark was born Feb. 14, 1827. He received at a grammar school, high school and at Mr. private school in Cambridge. He entered Phillips Andover, in 1844.* After leaving the Academy he was

---

lark's parents desired him to go to Harvard College, he was ex- Peirce, who pronounced him fit for the Sophomore class, except perhaps in Greek, which he had mastered sufficiently to pass with credit; but instead of that he chose to into active life.

PLATE XV.



GEORGE BASSETT CLARK.

Feb. 27, 1827–Dec. 30, 1891.

employed in civil engineering on the Boston and Main Railroad, and the Ogdensburg and Lake Champlain Railroad. He went to California in 1848 but soon returned. After his return he started business as a maker and repairer of instruments in east Cambridge, and was subsequently joined by his father and brother.

In 1857 he was married to Jennie M. Mosely. In 1860 the place of business was removed to Cambridge where it still continues.

The early work of the Clarks was confined to reflecting telescopes; but soon developed into that class of instruments—the refractor—upon which they have achieved a success second to none in the world. Indeed, so intimately has the name of Clark been associated with the progress and development of the achromatic telescope and the discoveries made with them during the past half century, that, if we were to blot out that record, it would take from the pages of scientific discovery, in the domain of astronomical research, the grandest part of that record.

The history of the great objectives made by Alvan Clark & Sons, from the memorable one sent to Dawes of England to the culmination of their great work on the 36-inch glass of the Lick Observatory, is so well known to the readers of this journal that it were useless to repeat it; but it is not known, perhaps, so widely that Geo. Clark was the master mechanician of the firm, and none knew this better than the astronomers of Harvard Observatory whose confidence in him as an accomplished mechanician was unlimited; and the discoveries made at this famous Observatory are very closely related to the life work of George B. Clark. Much of his time and genius as a mechanician was devoted of late years to the development of the instrumental equipment of the Draper memorial work, in which such signal and valuable results have been obtained, and it was with profound regret that he was compelled to give it up when he was attacked with the illness that ended his useful life.

Mr. Clark was a member of Professor Winlock's eclipse party at Shelbyville, Kentucky, in 1869. He was urged to join the party that went to Spain as well as Dr. Draper's party in 1878, but these invitations he had to decline because of the pressure of occupation at home. His services were always in demand and were eagerly sought after by the astronomers of eclipse expeditions.

On the 9th of January, 1878, Mr. Clark was unanimously elected a member of the American Academy of Arts and Sciences, his special department being that of Practical Astronomy and Geodesy.

This honor was entirely unsought, as far as is known, knew nothing about his being proposed as a member until he cieved notice of his election.

In 1882 he was elected a member of the Count Rumford co mittee on which his name was continued year after year. Ho ors were thrust upon him from time to time, but they never ha more effect upon him than that which is felt by every man of re worth, *i. e.*, an incentive to nobler and better efforts, if such we possible.

The writer has spent many a delightful hour with Mr. Cla in the old Cambridge workshop. He never cared to work wh a friend dropped in to see him, and many a noted personage ma the old workshop a frequent stopping place, and these pag could be filled with the reminiscences gathered on my visits Cambridgeport. The poet Longfellow was one of the welcom visitors, and liberty is here taken to tell of one of those charmi reminiscences as told me by Father Clark. A telescope had be finished and set up in the shops; Longfellow dropped in and aft looking it over with interest, he remarked: "Clark, that loo like a cannon." He immediately added: "How much bett for the peace of our loved country than a cannon."

George Clark was one of the most unpretentious men, kind in disposition, unselfish, generous; so like his father that write of one includes both. Friend of nature the song of t bird was ever sweet to him, and it was one of his great regre during his illness that the song of the birds—aye, even of t frogs in the pond near his summer home was lost to his ear. tender was his nature that he never would take a gun with hi to the woods. I quote the words of one who knew and lov him best. "He had a great love of nature, the woods were perpetual delight to him; to hear a bird sing, to watch its flutte ing wings, to hear the winds through the trees, to find the wi flowers of the wood, to him was purest delight, but he did n enjoy gunning or *injuring any living creature*."

He was never frivolous, but loved to chat upon his favori themes—which were always of an elevated character.

He loved poetry and among all poems, he loved "Thanato sis" perhaps the best of all. Gray's Elegy was also a favorit Friday, before his death, he desired Gray's Elegy read to him a on Saturday night, asked for Thanatopsis, after the reading which he remarked, "No one ever wrote anything better tha parts of that poem."

"He loved truth, and duty was ever the key note of his life far as intercourse with others was concerned—and it was only his own good that was too often uncared for." I quoted those words from one who knew him better than all others.

Like too many of the world's great workmen, Mr. Clark overtaxed his powers—and on the 14th of April, 1889, he had an attack of aphasia. Surgeon General Holt pronounced his case a very serions one, and said he must rest at once; that only a long rest would give him a lease of life. He gained in strength so rapidly that in a few weeks he was enabled to go back to the works, and he thought by applying himself less closely, he might be able to finish the Draper work then well under way. It seemed he could not rest content away from the work he loved so well, but as he was a sufferer from insomnia, he could not build up—and in March of last year he was taken worse and the physician pronounced the trouble as lesion of the nerve centres. He was again compelled to relinquish work and spent a few weeks at Vineland, New Jersey; then took a cottage at Bedford Springs, Mass. His hold on life seemed to be most wonderful and he kept up until tired nature refused to respond to the demands of his indomitable will, although the physicians thought at one time he would rally and be restored to health and usefulness again; but on Thursday, Dec. 24, he overtaxed his strength, and although he was evidently worse, he had the pleasure of the company of his dear old mother and another valued friend to dine with him and his companion on the following day—which was Christmas.

But the summons had come, and his life was fast ebbing away. After a drive to Park Square in Boston, still holding on to the slender thread—as he would hold on to a problem in astronomical engineering, he returned home, soon became uncouscious,—never regaining that which had made him a man among men, and at two o'clock in the afternoon of December 30, 1891—without fear of the grim monster that will claim us all, he fell asleep—with a fond hope that he might be permitted to solve some of the unsolved problems of his loved study in the great beyond.

Thus has passed away one who has devoted a life to the advancement of human knowledge—who has contributed a large share in the advanced researches of the latter half of the eighteenth century—a man whose name need not be engraved upon a marble tablet—nor upon the lasting bronze, for it is already written among the stars—where it shall be read as long as men point the mighty tube towards the stellar depths.

The portrait of Mr. George B. Clark that faces page 368 of this number of "Our" Journal is a very faithful likeness of him as the writer knew him in the later years of his life. A loving wife, an aged mother and his brother, Alvan G. Clark survive him.

"He has loved the stars too fondly
To be fearful of the night."

HISTORY OF THE COLOR OF SIRIUS.*

T. J. J. SEE.

GEMINUS.

This astronomer was probably a contemporary and associate of Hipparchus. In the "Elements of Astronomy" (the edition of J. P. Migne, Paris, 1857, is the best) he argues logically and at great length against the belief that the conjunction of the Sun with Sirius causes the intense heat of summer; and in the course of his remarks says:—

> "*ὑ γὰρ ἀστὴρ (κύων) οὗτος τῆς αὐτῆς οὐσίας κεκοινώνεκε πᾶσι τοῖς ἄστροις. Εἴτε γὰρ πύρινά ἐστε, εἴτε καὶ αἰθέρια τὰ ἄστρα, τὴν αὐτὴν ἔχει δύναμιν πάντα, καὶ ὑφείλει κατακρατεῖσθαι ὑπὸ τοῦ πλήθους τῶν ἄστρων ἢ ἀπὸ τοῦ κυνὸς ἀποφορά.*"
>
> (p. 849 of Migne's edition).

[For this star (Sirius) is of the same nature as all the rest of the stars. And whether the stars are fiery (*πύρινα*) or clear (*αἰθέρια*), all have the same power, and exhalations ought to proceed from the multitude of the stars rather than from Sirius].

It is evident that *πύρινα* refers to the red stars and *αἰθέρια* to the white (or "clear") ones. Geminus, therefore, affirms indirectly, but emphatically, that Sirius is *πύρινος*, while the multitude of stars are *αἰθέρια*. But "all stars have the same power," and he rightly concludes that a red star such as Sirius exercises no more influence upon the earth than a white one. The contrast between the color of Sirius and that of the multitude is perfectly distinct, and since the language above quoted is that of a professional astronomer its truthworthiness can not be questioned. To my mind the above passage alone is a conclusive proof of the ancient redness of Sirius, the more so since Geminus shows himself unfettered by popular belief, and argues logically against the palpable fallacy that "Sirius causes the intense heat of the Dog Days."

---

* Communicated by the author. (Continued from page 274.)

ERATOSTHENES.

An edition of the "Catasterisms" was published at Frankfort in 1817 by F. C. Marthiae. On examining it I find, strange to say, no color assigned to any star except Vega, which is called white (λευκός). In the notes on the planets (evidently derived from an astrological source) Mars is called "πυροειδής" and Venus "λευκός." Concerning the constellation κύων, Eratosthenes says:

"Ἔχει δ' ἀστέρας ἐπὶ μὲν τῆς κεφαλῆς (ά, ὃς Ἶσις λέγεται) ἐπὶ τῆς γλώττης ά, ὃν καὶ Σείριον καλοῦσι μέγας δ' ἐστὲ καὶ λαμπρός (τοὺς δὲ τοιούτους ἀστέρας οἱ ἀστρολόγοι Σειρίους καλοῦσι, διὰ τὴν τῆς φλογὸς κίνησιν)." (p. 67.)

We shall presently see that the "two stars," Isis and Sirius, are only *two names* for the same star, but the error is faithfully copied by Hyginus. In saying that "Astrologers call such stars Sirians on account of the motion of the flame," Eratosthenes commits another error, which Hyginus has likewise copied. For we have seen that the name Σείριος was used by Hesiod five centuries earlier to denote Sirius alone and that it means the "burning one," as is evident from the language of Hesiod and Aratus. The very uncritical "Catasterisms" of Eratosthenes, therefore, throw no light upon the color of Sirius.

HYGINUS.

The author of the "Poeticon Astronomicon Libri IV" (edition of Dr. B. Bunte, Leipsic, 1875), was a native of Spain and freedman of the Emperor Augustus, by whom he was made chief of the Palatine Library. From the "tyro-like" mistakes in the works of Hyginus critics have generally agreed that they were composed before he had fully mastered the Latin language. The name of Eratosthenes is often mentioned, and a very superficial examination will show that the work is merely a disitillation of Eratosthenes' Catasterisms, to which are added some notes on the planets evidently derived from some work on Astrology, of which nothing is now known. The authority of Hyginus is certainly not original. Concerning Sirius he says:

"Sed canis habet in lingua stellam unam, quæ ipsa canis appellatur, in capite autem alteram, quam Isis suo nomine statuisse existimatur et Sirion appellasse propter flammæ candorem, quod ejusmodi sit, ut præ ceteris lucere videatur. Itaque quo magis eam cognoscerent, Sirion appellasse." (Lib. II, XXXV, p. 74).

Again:

"Hic canis habet in lingua stel quæ Stellæ Canis appellatur, in capite autem alteram, quam nonnulli Sirion appellant, de quo prius diximus." (Lib. III, XXXIV, p. 95).

It is to be observed that Hyginus says the star in the tongue is called Canis, whereas Eratosthenes says it is called Sirius; and the star in the head, called by Eratosthenes Isis, is called Isis or Sirius by Hyginus. The confusion is therefore extreme, but we shall presently see that there was only one star with two names (or rather three—Canis, Isis and Sirius) which was spoken of sometimes as "in the tongue" and sometimes merely as "in the head." If in Hyginus' rendering of Eratosthenes' "*διὰ τὴν τῆς φλογὸς κίνησιν*" by "propter flammæ candorem," "candor" has any definite meaning at all, it is "light" or "brightness," not "whiteness." Cicero uses "candor" in this sense:

> "Solis candor illustrior quam ullus ignis."
> (De. Nat. Deor. II, 15.)
>
> "Ut cum videmus speciem primum, candoromque cœli."
> (Tusc. Quæst. I, 28.)

Hyginus' remarks are, however, in no case to be taken as the result of observation, but merely of book-work, as is shown by the way he copies Eratosthenes, and by the astrological sources of his information implied in the use of "figura" for "color:"

Mars: "figura est similis flammæ."

Jupiter: "figura autem similis Lyræ"—meaning apparently that Jupiter is of the same color as Vega.

Saturn: "Colore autem igneo, similis ejus stellæ quæ est in humero dextro Orionis."

M. Georges Lafaye in the "Mélanges d'Archéologie et Histoire de l'Ecole Francaise de Rome," 1881, has a very interesting paper entitled "Un Monument Romain de l'Etoile d'Isis." In this paper the author shows clearly that Isis was a general name for Sirius among the Egyptians. The star was also called (in the Decree of Canopus) Sopet; elsewhere sometimes Sepet, Sept, Set and finally Sot, Soti, or Sothi, which, when given the Greek ending, becomes Sothis, the Egyptian word for Sirius in common use among classic authors. It has also been suggested that Thoth the first month of the Egyptian calendar, is named from Sothis the heliacal rising of which marked the beginning of the fixed year (of 365¼ days) and also of the "wandering" year (of 365 days) at the beginning of a Sothic period. M. Lafaye mentions a Temple at Assouan especially dedicated to the worship of Isis Sothis, and shows that the Egyptians regarded Sirius as the sou of the goddess Isis transferred to the heavens; wherefore special ritual honors were accorded her spirit, and the worship of Isis-Sothis afterwards even imported into Italy. We ought here to note that the Egyptian religion was older than Babylonian Astrology, and since Sirius rose heliacally about the time of the inundation of the Nile, this star was especially venerated in Egypt from the earliest times; therefore when astrology came west it does not appear to have inspired among the Egyptians (except the Alexandrians) that dread of Sirius, which was spread throughout the Greek and Roman world. The conditions in Egypt were unfavorable to the growth of the idea that Sirius exercised an evil influence, and hence we find astrological doctrines (especially that which assigned the heat of the "Dog Days" to the "influence" of the "burning Sirius") more firmly implanted in the minds of the people north of the Mediterranean, where the climatic conditions favored their propagation.

Some of the authorities cited by M. Lafaye seem worth quoting:

Horapollo: "*Ἶσις δὲ παρ' αὐτοῖς (τοῖς Αἰγυπτίοις) ἐστιν ἀστήρ, Αἰγυπτιστὶ καλούμενος Σῶθις.*"

Also "*Αἰγυπτιστὶ καλούμενος Σῶθις, Ἑλληνιστὶ δὲ Ἀστροκύων.*"

Plutarch: "*οἱ(δὲ) ἱερεῖς λέγουσιν...τῶν θεῶν...τὰς ψυχὰς ἐν οὐρανῷ λάμπειν ἄστρα, καὶ καλεῖσθαι κύνα μὲν τὴν Ἴσιδος ὑφ' Ἑλλήνων, ὑπ' Αἰγυπτίων δὲ Σῶθιν, Ὠρίωνα δὲ τὴν Ὥρου, τὴν δὲ Τυφῶνος Ἄρκτον.*"

And "*Λίβυες δ' Αἰγυπτίων καταγελῶσι μυθολογούντων περὶ τοῦ ὄρυγος, ὡς φωνὴν ἀφιέντος ἡμέρας ἐκείνης καὶ ὥρας ᾗς ἐπιτέλλει τὸ ἄστρον, ὃ Σώθην αὐτοί, Κύνα δέ καὶ Σείριον ἡμεῖς καλοῦμεν.*

Also "*τὸν μὲν Ὠρίωνα Ὥρου, τοῦ δὲ Κύνα Ἴσιδος ἱερὸν Αἰγύπτιοι νομίζουσιν.*"

Library of Photius: "*τὴν Σῶθιν Αἰγύπτιοι τὴν Ἶσιν εἶναι θεολογοῦσιν, οἱ δὲ Ἕλληνες εἰς τὸν Σείριον ἀνάγουσι τοῦτο τὸ ἄστρον, καὶ ὡς Κύνα τὸν Σείριον, οπαδὸν Ὠρίωνος ὄντα κυνηγετοῦντος, οὕτω διαζωγραφοῦσιν.*"

In the Decree of Canopus (relative to the reform of the calendar) issued in the ninth year of the reign of Ptolemy III, Buergetes I, (B. C. 238) the Greek translation of the Egyptian text reads:

"*τὸ ἄστρον τὸ τῆς Ἴσιδος, ἣ νομίζεται διὰ τῶν ἱερῶν γραμμάτων νέον ἔτεος εἶναι.*"

In a hieroglyphic inscription engraved upon a column dedicated to Isis at Nysa in Arabia, the goddess herself is made to affirm her identity with the Dog star:

"*Ἐγὼ Ἶσίς εἰμι...ἡ ἐν τῷ ἄστρῳ τῷ Κυνὶ ἐπιτέλλουσα.*"

Therefore it is evident that Isis and Sirius are only different names for the same star, and hence we perceive that the inconsistencies of Eratosthenes and Hyginus have arisen from mere confusion of names.

HORACE.

This poet has left us several allusions to the "Dog Star," but only one of these positively affirms that Sirius was red; the others have reference mainly to the intense heat attending the heliacal rising of the star, but they also imply a fiery appearance.

"Hic in reducta valle Caniculæ
Vitabis æstus." (Ode, XVIII, 17, Bk. I.)

"Te flagrantis atrox hora Caniculæ
Nescit tangere." (Ode. XIII, 9, Bk. III.)

"Seu rubra Canicula findet
Infantes statuas." (Sat. V, 39, Bk. II.)

"Flagrans" implies "burning," but "rubra" makes the redness of the star definite. Horace, it is true, is not an astronomical authority, as has been suggested by those who seek to disbelieve the testimony of the ancients; but can anyone suppose that a poet who enjoyed the learning of Rome in the time of Augustus was ignorant of the appearance of so conspicuous and famous a body as the Dog Star, which he had repeatedly spoken of in his own writings? The manner in which "rubra Canicula" is introduced seems to imply not only that the star was red, but that the color was a matter of universal knowledge.

VIRGIL.

In the Georgics we read:

"Jam rapidus, torrens sitientes Sirius Indos,
Ardebat in cœlo, et medium sol igneus orbem."
(Lib. IV, verse 324-6.)

In speaking of the Scorpion Virgil says:

"Ipsi tibi jam brachia contrahit ardens scorpios."
(Georgics, Lib. I, verse 34.)

We have seen that Germanicus used "ardenti cum pectore" when alluding to Antares; Virgil's "ardens" certainly refers to the same star. "Ardebat in cœlo" then seems to imply that Sirius presented the appearance of Antares: there is also an illusion to drought in the above passage, and Virgil makes a similar reference in another place (Georgics, Lib. II, verse 353), but no color can be inferred.

Now it seems to me that if Sirius had been white, the ancients would much more naturally have attributed the droughts and other evil "influences" of summer to the great ruddy Antares, which was visible during the hottest months.

MANILLIUS.

The author of the "Poeticon Astronomicon" has left us two references to Sirius which imply a fiery appearance:

> "Canis in totum portans incendia mundum."
> (verse 17, Lib. V.)
>
> "Canis rabit suo igne." (verse 208, Lib. V.

The only other allusion in Manillius implying a ruddy color of any other star is that made to Antares in speaking of the Scorpion:

> "Attrahit ardenti fulgentem Scorpion astro."
> (verse 268, Lib. I.)

SENECA.

After speaking of fire, lightning, evaporation, and other natural phenomena, Seneca says:

> "Nec mirum est, si terræ omnis generis et varia evaporatio est; quum in cœlo quoque non unus appareat color rerum, sed acrior sit Caniculæ rubor, Nartis remissior, Jovis nullus, in lucem puram nitore perducto." (Quaest. Nat. Lib. I, cap. I, § 6.)

This is the deliberate statement, and no accidental allusion, of one of the greatest philosophers of antiquity. Seneca's remarks on the colors of Mars and Jupiter show conclusively that he was well acquainted with the appearance of the planets. This may also be inferred from the attention which he gave to comets and meteors, to solar and lunar halos, and other remarkable phenomena. It is, therefore, practically certain that he had observed Sirius hundreds of times, as any natural philosopher at Rome must necessarily have done.

There is absolutely no reason for supposing Seneca's original language to have been other than what we have quoted. The suggestion that the reading should be "fulgor" instead of "rubor" is too absurd to need refutation. We have, therefore, no alternative but to accept the testimony of Seneca as a fact; and the direct and positive manner in which he says Sirius was redder than Mars certainly entitles his evidence to the very hig est consideration.

COLUMELLA.

In speaking of roses Columella compares their hues to Tyria purple, the rising sun, Sirius, Mars and Venus (when setting wit the evening glow or rising with the dawn):

"Jamque Dionæ is redimitur floribus hortus
Jam rosa mitescit Sarrano clarior astro.
Nec tam nubifugi Borea Latonia Phœbe
Purpureo radiat voltu, nec Sirius ardor
Sic micat, aut rutilus Pyrois aut ore corusco
Hesperus, Eoo remeat cum Lucifer ortu."
(De Cultu, Hortorum Lib. X, verse 286

The reference to Venus evidently is more concerned with t ruddy glow of the sky at sunset and sunrise than with the col of the planet when high in the heavens; for it is absurd to su pose Columella would compare a rose to a body which is mere bright without any color. The language seems to imply that a the objects enumerated were of about the same color, and th the comparison was suggested by the brilliant colors of roses.

PLINY.

In the *Natural History* a good many astronomical allusio occur, but only three bodies are in any case called "ardens," "igneus," and these are Sirius, Mars and the rising Sun:

> "Suus quidem cuique color est, Saturno candidus, Jovi clarus, Marte igneus, Lucifero candens, Vesperi refulgens, Mercurio radians, Lunæ blandus, Soli, cum oritur, ardens, po radians." (Nat. Hist. Lib. II., cap. XVIII.)

In speaking of the Etesias, a wind which blew from the Nor about the rising of the Dog Star, "ardentissimo tempore," Pli says:

> "Mollire eos creditur, solis vapor geminatus ardore sideris, n ulli ventorum magis stati sunt." (Nat. Hist. Lib. II, cap. XLVII

The following allusion to rabies in dogs is of great importanc

> "Rabies canum Sirio ardente homini pestifera, ut diximus, i morsis letali aquæ metu." (Nat. Hist. Lib. VIII, cap. LXIII.)

It is worth noting that Pliny in speaking of Canopus does n call it "ardens," but "Sidus ingens et clarum." (Lib. VI, ca XXIV.)

We now come to some very remarkable evidence confirming the ancient redness of Sirius. Pliny (Nat. Hist. Lib. XVIII, cap. XXIX) mentions the Roman agricultural festivals known as the Robigalia (to avert the rust of the corn), the Floralia (that the blooming fruits might mature) and the Vinalia (a festival consecrated to the vine). All of these festivals were held in May, at which time the Sun began to enter the sign of Taurus, and consequently to approach Sirius. Pliny says the Floralia was instituted in the year of the city 516 (238 B. C.), at the bidding of the oracle of the Sibyl, and it is certain that it continued down to the time of the Christian Emperors.

Now, Ovid speaks of the sacrifice of dogs to the Dog Star made at these festivals:

"Est canis, Icarium dicunt, quo sidere moto
Tosta sitit tellus, praecipiturque seges.
Pro cane sidero canis hic imponitur aræ:
Et, quare pereat, nil nisi nomen habet."
(Fastorum, Lib. IV, 939.)

But the most trustworthy evidence regarding the sacrifices attending the celebration of the Floralia is to be obtained from the grammarian Festus, who probably flourished in the time of the Antonines.

SEXTUS POMPEIUS FESTUS.

The title of this author's work is "Sexti Pompei Festi de Verborum Significatu quæ supersunt cum Pauli Epitomæ," (edition of Æmilius Thewrewk, Berlin, 1890.)

Under the word "Catularia" we read:

"Catularia porta Romæ dicta est, quia non longe ab ea ad placendum Caniculæ sidus frugibus inimicum rufæ canes immolabantur, ut fruges florescentes ad maturitatem perducerentur."
(Word, Catularia p. 31.)

In the "Fragmenta" Festus says:

"Rutilæ canes, id est non procul a rubro colore, immolantur, ut ait Ateius Capito Canario Sacrificio pro frugibus deprecandæ servitæ causa sideris Caniculæ." (p. 396.)

Thus it is clear that at the Floralia ruddy dogs were sacrificed "ad placandum Caniculæ sidus;" why ruddy dogs rather than dogs of any other color? There is, I think, only one explanation of this remarkable pagan rite, and that is that the star was red and that dogs of the same color (non procul a rubro colore) were demanded to satisfy the ruddy Dog Star, and ward off its evil "influences," so that the blooming fruits might not suffer blight when the fiery Sirius came into conjunction with the Sun, but (the "angry" star being appeased) be brought to full maturity. It must be remembered that it was a very common belief among the ancients that stars were deities demanding special propitiation. It is difficult to imagine a more incontestible proof of the ancient redness of Sirius than that furnished by a wide-spread pagan rite extending over centuries and celebrated annually with the greatest hilarity and splendor. The annual sacrifice of ruddy dogs to Sirius must have made the Dog Star very well known to everybody at Rome, and this is what we should infer to have been the fact from the frequency with which the star is mentioned by classic authors. The existence of such a religious rite also makes it impossible that learned men like Cicero, Seneca, Horace, and Pliny can have been ignorant of the color of Sirius.

PTOLEMY.

In the Catalogue (7th and 8th books of the Almagest) Ptolemy calls Arcturus, Aldebaran, Pollux, Betelgeux, Antares and Sirius *ὑπόκιῤῥος*, "fiery red." All of these stars except Sirius are still red or reddish, and there are no other conspicuous stars so highly colored as these. Ptolemy therefore did not overlook the red color of the most conspicuous stars, and on this account, as well as on account of the genius displayed in his immortal Almagest, he is by far the greatest authority of antiquity for the appearance of a heavenly body. His note on Sirius in enumerating the stars in the constellation *Κύων* is this:

"*ὁ ἐν τῷ στόματι λαμπρότατος Καλούμενος Κυων καὶ ὑπόκιῤῥος*"
(edition of Halme and Delambre, Vol. II. p. 72).

The Basel manuscript reads "*Κύων ὑπόκιῤῥος* instead of "*Κύων καὶ ὑπόκιῤῥος*," and this reading has been adopted by Mr. Frances Baily in his edition of Ptolemy's Catalogue, published in the Memoirs of the Royal Astronomical Society, vol. XIII. Since, however, the meaning remains unchanged, it is not a matter of any importance which reading we accept. It has been asserted by Mr. W. T. Lynn (*Observatory*, vol. X, p. 104) that the note on Sirius is "somewhat peculiar;" but after comparing it with Ptolemy's notes on other red and bright stars I fail to discover anything suspicious about the record he has left us. There is only one other convenient form in which the note could have been written:—

"ὁ ἐν τῷ στόματι λαμπρότατος καὶ ὑπόκιρρος καλούμενος Κύων."

Adopting, however, the reading given by Baily, the language of Ptolemy in regard to Sirius is exactly similar to that used for Arcturus. Professor Schjellerup in the introduction to his admirable translation of Al Sûfi's "Description of the Fixed Stars," was the first to question the genuineness of the language of the Almagest in regard to Sirius; Mr. Lynn and Miss A. M. Clerke ("System of the Stars," p. 146) have followed Professor Schjellerup in explaining Ptolemy's "Κύων καὶ ὑπόκιρρος" as a transcriber's error for "Κύων καὶ Σείριος," an explanation *a priori* very improbable on account of the magnitude of the error postulated, and in fact without the slightest foundation, as we shall now proceed to show.

Professor Schjellerup believed he had discovered in Albategnius' "*De numero Stellarum*"—usually known as "*De Scientia Stellarum Fixarum*"—a statement that Ptolemy mentioned only five red stars, and from this he concluded that Sirius was not classed as a red star in the Arabian versions of Ptolemy's Almagest. Plato Tibertinus published in one volume at Nuremberg in 1537, a Latin translation (which is so bad that Delambre calls it "semi-barbaric") of a part of Alfraganus' "*Elementa Astronomica*" and Albategnius' "*De numero Stellarum*" under the name of "*De motu Stellarum*," but the work is usually known as "*De Scientia Stellarum*." Now, in the part of this work taken from Alfraganus where the stars catalogued by Ptolemy are enumerated, we read "5 rubeæ," but the reading should be "5 nebulosæ," as we see by referring to the good edition of Alfraganus published at Frankfort (in 1590 and 1618) by Jacob Christmann, and to the still better translation (with Latin and Arabic text) published by the illustrious Arabic scholar, Jacob Golius, at Amsterdam, in 1668. In Tibertinus' work the chapter in which the passage occurs is numbered XIX, and likewise in Golius' translation, but in Christmann's the number is XXII.

The correct reading is therefore "5 nebulosæ," which agrees with what Ptolemy has given at the end of his catalogue, where he sums up the number of stars of the different magnitudes and also those classed as "nebulous" and "obscure," but gives no summary of those classed as ὑπόκιρρος. Now this summary of Ptolemy is copied by both Alfraganus and Albategnius *verbatim et literatim* without any addition or change whatever. Therefore I do not hesitate to venture the opinion that no Arabian Astronomer ever went to the trouble to count up Ptolemy's red stars. This servile repetition of Ptolemy's summary witho adding to it the number of stars classed as red is another pro of the proverbial sterility of the Arabian genius.

I have very carefully examined Albategnius' "*De numero St larum*" (both Tibertinus' edition, and that of Ugullottus, whi appeared at Bologne in 1645), as well as Alfragenus' "*Elemen Astronomica*" (editions of Christmann and Golius), with the f lowing results:—

(1). Albategnius and Alfraganus are both absolutely sile concerning Ptolemy's observations of red stars. (And the sa is true of Al Sûfi and Ulugh Beigh, as we shall presently see).

(2). Albategnius himself does not note the color of any sta but Alfraganus speaks incidentally of the color of Antares, P lux and Aldebaran.

Therefore it is evident that Professor Schjellerup was misled l the false translation of Plato Tibertinus, and there is no a thority for the statement that Albategnius gave the number Ptolemy's red stars as five. Alfraganus and Albategnius bo flourished about the end of the 9th century, and are among t most important authorities dating from the era of Sarac splendor. As respects the colors of the stars, however, the a thority of Al Sûfi, who flourished abont the middle of the 10 century, is greater, and indeed the greatest of all the Arabian A tronomers. His "Description of the Fixed Stars" is found upon the catalogue of Ptolemy, and the name of Ptolemy often mentioned in locating the stars of a constellation in the respective places, *but Sufi never, in a single instance, alludes Ptolemy's observations of the colors of the stars.* Al Sûfi not as red the following stars: Aldebaran, Arcturus, Antares, Bet geux, Pollux, α Hydræ, and —*mirabile dictu*—Algol! Nothing said of the color of Sirius, and after calling it "very brilliant and locating it in the mouth of the Dog, Sûfi proceeds to rela an Arabian fable in which Sirius and Canopus are spoken of sisters. This fable would seem to imply that Sirius and Ca opus could not have had conspicuously different colors in t 10th century; they appear now to be exactly the same colo as near as I couid determine by naked-eye observation at Cair Egypt (March 15th, 1891.)

Al Sûfi therefore noted the colors of all of Ptolemy's red sta except Sirius, and added to the list α Hydræ, which is now re dish, and Algol which is perfectly white. Sûfi and Schmidt (o one occasion at Athens in 1841) are the sole authorities for t redness of Algol; it remains, therefore, uncertain whether Alg has changed its color, or is subject to temporary suffusion of redness, or whether the two observers have in some way been deceived. The fact that Sûfi says nothing of Ptolemy's observations of red stars, and that he noted the color of α Hydræ and Algol, would lead one to conclude that Sûfi's notes were the result of his own incidental observations; there is no reason to suppose he devoted especial attention to the colors of the stars.

Ulugh Beigh in his catalogue (edition of Baily, Mem. Roy. Ast. Soc., vol. XIII) notes the colors of Antares, Aldeberan, Betelegeux and Pollux; but overlooks the color of Arcturus and α Hydræ, and says nothing of the color of Algol or Sirius. In Tycho Brahe's catalogue Antares alone is noted as ruddy; Sirius is called "splendidissimo." Alfraganus, Albategnius, Al Sûfi and Ulugh Beigh are the only important Arabian authorities on the appearance of the fixed stars. Therefore, since all of these are silent concerning the color of Sirius, it is very unlikely that any information will ever be obtained from lesser Saracen authorities.

We see therefore that the Arabians throw no light whatever upon Ptolemy's record of the color of Sirius; and we have also seen that there is absolutely no ground for supposing an error to have crept into our copies of the Almagest. Therefore there is every reason to suppose that Ptolemy himself classed Sirius as fiery red. That he can have mistaken the color of this star in the steady atmosphere of Egypt is quite incredible. For Sirius attained a high elevation in passing the meridian, and Ptolemy was not deceived by atmospheric scintillation, as is proved by the fact that he assigned no colors to bright stars lying much further south, such as α Centauri and Canopus. Moreover the present scintillation of Sirius (as I have found by careful observation) is exceedingly blue with scarcely a trace of red; and this is a *general reason* why the ancients can not have been deceived by atmospheric effects upon the light of the star; for had they assigned the color from scintiliation such as it now shows, the star would certainly have been classed as blue.

CONCLUSION.

We have seen that the highest authorities of antiquity affirm the redness of Sirius, and that there is no authority who affirms that the star was white. We have also seen that the ancients distinguished between the red and white stars and that the distinctions were correctly made. It has been shown that the whole ancient world ascribed the intense heat of the "Dog Days" to the "influence" of the "burning Dog Star," and that evil "influences" were usually supposed to proceed from bodies pr senting a fiery ("angry") appearance, and "salutary" influenc from those which shine with a clear brilliant light. Moreover, the celebration of the Floralia, when the Sun was drawing ne to Sirius, we have seen that ruddy dogs were sacrificed "ad pl candum Caniculæ sidus." Wherefore, from this many-sided ar overwhelming testimony it incontestibly follows that in the b ginning of our era (and perhaps during countless centuries ant cedent thereto) Sirius shone with a ruddy light; and since Sene says explicitly that the star was redder than Mars, and there every reason to believe his statement, we may conclude th the Dog Star was then the reddest body in the sky, not even e cepting the ruddy Antares.

The following is the comparative evidence for the ancient re ness of the two stars:

	Author.	Sirius.	Antares.
1.	Ptolemy	"ὑπόκιῤῥος"	"ὑπόκιῤῥος."
2.	Geminus	"πύρινος" (multitude αἰθέρια)	
3.	Seneca	"Acrior sit Caniculae rubor, Martis remissior."	
4.	Pliny	"Ardore Sideris" and "Sirio ardente" (like Mars and rising Sun).	
5.	Cicero	"rutilo cum lumine."	
6.	Germanicus	"Cursu rutili"	"ardenti cum pectore"
7.	Aratus	"ποικίλος."	
8.	Horace	"rubra Canicula."	
9.	Festus	"Rutilæ Canes immolabantur ad placandum Caniculæ Sidus."	
10.	Columella	"Sirius ardor."	
11.	Hesoid	"Σείριος ἄζει."	
12.	Virgil	"Ardebat in cœlo."	"ardens"
13.	Manilus	"rabit suo igne."	"ardenti astro"
14.	Theon	"ποικίλος."	
15.	Ap. Rhodius.	"Σείριος ἔφλεγε."	
16.	Euripides	"πυρὸς φλογέας."	
17.	Avienus	"multus rubor."	
18.	Homer	"φέρει πολλὸν πυρετὸν," and "χαλκός," also "ἀκάματον πῦρ, ἀστέρ ὀπωρινῷ ἐναλίγκιον."	

From this investigation it follows that Sirius has become white since the time of the Roman emperors, and, if we may trust Theon and Avienus, perhaps since the end of the fourth century. That the star was not conspicuously red in the tenth century may be inferred from the silence of Al Sûfi; but farther than that can not at present be determined. The star may have changed color very suddenly, or its redness may have gradually faded with the centuries and disappeared slowly like the ancient civilization. There is practically no record of the heavens from the time of Theon to Al Sûfi; and therefore the rapidity of the change can not be ascertained. In modern times the star has always been seen white, and therefore there is no suspicion that the color changes periodically. The redness of a star's light depends without doubt mainly upon the selective absorption in its own atmosphere; therefore the natural explanation of this change of color would seem to be a change in the atmosphere by which Sirius is surrounded. This might take place solely from the secular contraction of the mass, and when we remember the enormous rate at which Sirius is losing radiant energy, an explanation of this kind seems very likely to be correct. The emission of heat and light is at least one hundred fold that of our Sun, and therefore two hundred thousand years of solar radiation will scarcely equal a radiation of two thousand years in Sirius. And we are certainly far from being able to affirm that our Sun was not red two thousand centuries ago. The change in the color of Sirius during the last 2,000 years is not then so very remarkable, as it could result from purely natural causes; but we shall not in this paper attempt to assign the cause of the change. It is sufficient for the present to establish the fact.

It only remains to add that in the foregoing investigation the authorities cited have been examined with the most scrupulous care, and therefore I do not think anything of any importance can have been overlooked. From Censorinus, Varro, Cato, Aristotle (Treatise on the Heavens), Plato, Sophocles, Æschylus, Pindar, Tacitus, Polybius, Livy, Manetho and Empedocles, I have not been able to obtain any information of any value. There are some other classic authors from whom information might be obtained, and it would also be interesting to extend the inquiry to the Egyptian, Chaldean, Assyrian, Indian and Chinese writers, but it is doubtful whether much would be gained. The foregoing testimony of the Greeks and Romans seems to have settled the question already, and time employed in this manner would perhaps be largely wasted.

Since, therefore, Sirius was formerly red, and is now whit follows that some of the red stars become white in the co of ages, and this we may perhaps infer to be the general la color in celestial evolution. Whilst, therefore, I think we conclude that red stars in time become white, it does not fol that all white stars have formerly been red; for if this were case the sidereal system at some past time must perhaps b been as red as it is now white, which is very improbable. would be a matter of great scientific interest to determine the act shade of all the important colored stars now visible, so t changes which might hereafter take place could easily be re nized, and thus the order of color evolution determined v greater certainty. It is always possible (though very impr able) that an individual change of color may result from s exceptional circumstance, and therefore it is desirable to estab as early as possible a considerable number of changes, so that effects of chance may be eliminated, and the phenomena refe to their true physical cause.

ROYAL OBSERVATORY, Berlin, Jan. 28, 1892.

OBSERVATIONS AND PHOTOGRAPHS OF SWIFT'S COMET MARCH 6, 1892.[*]

E. E. BARNARD.

I have observed Swift's new comet on every available occas since March 7.

Unfortunately a prolonged cloudy spell prevented many ob vations during March and especially during the latter half of month; no opportunity occurring to observe the comet until morning of April 4 when the sky cleared after midnight.

At this observation, on the morning of the 4th, the remarka growth of the comet was at once apparent. At the previous servations, March 7, 8, 9 and 15th, though distinctly visibl the naked eye as a large, hazy star of the 5th or 6th ma tude, no tail whatever was visible, and only an incipient could be seen with the telescope.

On the morning of April 4 the head was slightly less than 3d magnitude. The tail was fully twenty degrees long straight and slender. Careful sketches were made of the p tion of the tail as seen by the naked eye and of the head and

---

[*] Communicated by the author.

as seen in the 12-inch. The head was undeveloped and round with a bright nucleus which showed indications of fans on the sunward side. The telescopic view of the tail showed it to consist of two branches, well defined on their outside edges. Scarcely any nebulosity was visible between these two tails. The northern tail prolonged would have passed through the nucleus. There was positively no trace of a third branch.

On the morning of the 5th, I made a photograph of the comet with the 6-inch Willard lens strapped on to the 6½-inch equatorial. The nucleus was followed, and an exposure of one hour was given. During about three-fourths of the exposure, the comet was covered with haze and clouds.

This photograph showed a remarkable state of affairs. There were now three main branches to the tail—a new one having sprung out between the two which were seen on the previous morning. Each of these branches was, in turn, separated into several others until at least a dozen could be counted. The comet's head was about 19′ in diameter and the width of the tails where they joined the head, about 13′. The north tail—a narrow ray—was 2° long. The middle tail ran off the plate at a distance of 8° from the nucleus.

At a distance of two degrees from the head, along the northern side of the middle tail, a sudden bend southward occurs, from whence the tail continues. Springing from the north preceding portion of the head, two fine, dark thread-like lines are shown. These appear to be darker than the sky anywhere on the plate, though they may be simply due to contrast, as there is a faint strip of nebulosity between them. Some thread-like strips of nebulosity emanate from the head on both sides and stream back in the direction of the tail.

On the morning of the 6th, the eastern sky was densely clouded and the comet did not get out of the clouds until after 4 hours. An exposure of half an hour was given through a hazy sky and dawn. This plate is defective, but enough is shown to mark a great change in the tail. The short northern branch had wholly disappeared and the two others had blended together more or less to form a single flat train very narrow where it joined the head. There are brushes of matter extending on both sides of the head in a preceding direction for a few minutes of arc. The tail was much broken by longitudinal stripes.

On the morning of the 7th perhaps the most successful picture of the series was made. This exposure extended from $3^h\ 30^m$ to $4^h\ 35^m$. The sky was free from clouds, but moonlight and dawn interfered. The most remarkable changes are shown on this plate. The southern component, which was the brightest on the

5th, had become diffused and fainter, while the middle tail w very bright and broad. Its southern side, which was the best fined, was wavy in numerous places—the tail appearing as if c turbing currents were flowing at right angles to it. At 42′ fr the head the tail made an abrupt bend towards the south as if current was deflected by some obstacle. In the densest porti of the tail at the point of deflection, is a couple of dark ho —similar to those seen in some of the nebulæ. The middle p tion of the tail is brighter and looks like crumpled silk in plac The width of the tail at 2° from the head is 54′.

On the morning of the 8th in moonlight and dawn, an expos of one hour was given. This plate was developed with difficu as the strong moonlight and dawn had fogged it somewhat, a the resulting image is necessarily weak but clearly defin The tail is traceable for upwards of 10°, where it leaves the pla The most remarkable changes had occurred since the precedi morning. Near the head the tail was split up into six differ branches. The northern being no longer the main branch; seems to have faided out while the southern branch is the m prominent and shows a remarkable and unique phenomenon. 1° 42′ back of the head there is a projecting lump-like mass fr the south side of the tail. This leaves the tail at an angle about 115°, and extending out for a space of about 15′. Fr this the tail again continues its course. A lesser projection seen on the north side of this same branch. At one degree ba of the head there is a sharp bend in this tail towards the nor exactly similar to the bend which was visible in the north tail the 7th.

Some of these remarkable changes in the relative brightness the component parts of the tail, etc., as shown on the pho graphs of different mornings, would almost suggest a rotatio the tail on an axis through the nucleus. Unfortunately clou weather and moonlight have prevented anything definite in planation of these changes.

This comet, with a head of the 3rd magnitude, and a rat strongly marked tail twenty degrees in length, is the larg comet visible in the northern hemisphere since the great comet 1882. It is the first large comet that the photographic plate h been applied to successfully since that of 1882, and the pheno ena shown and the exceedingly rapid changes recorded, wo seem to show that this is one of the most remarkable comets have yet had.

I secured a number of sketches of the position of the tail amo the stars which will be valuable in connection with the pho graphs, in a study of the physical structure of this remarka comet.

For the inspection of the editor of this journal I send two gl positives from the negatives of April 4 and 6. From a lack of t proper transparency plates, these are not as good positives a would wish, and therefore are not suitable for reproduction he It is proposed later to make a thorough discussion of these p tographs.

MT. HAMILTON 1892, April 12.

ASTRO-PHYSICS.

ON THE SPECTRA AND PROPER MOTIONS OF STARS.*

W. H. S. MONCK.

I have more than once called attention to the relation between the spectra of stars and their proper motions, and in the February No. of ASTRONOMY AND ASTRO-PHYSICS, I suggested that the broad distinction between Sirian and Solar stars was insufficient for the purpose, and that it would be necessary to take into consideration the minuter distinctions given in the *Draper Catalogue*. I now send the result of applying this distinction to stars of the types designated B and F in the *Draper Catalogue*, and I think the difference will be found rather startling. I did not carry the comparison below the 5th magnitude (according to the *Harvard Photometry*) because Professor Pickering admits that the classification of the spectra of the fainter stars in the *Draper Catalogue* is not to be relied on in its full details. The sub-classes B and F stand nearly at opposite extremities of the scale as regards proper motion, and the average motion for the latter sub-class is so large as to suggest that the Sun forms one of a cluster of stars belonging chiefly to this sub-class or to the sub-class E which, in many respects, resembles it. Other grounds might be urged in support of this hypothesis, but in the present article, I confine myself to facts. The magnitudes are taken from the *Harvard Photometry*, and the Proper Motions from Mr. Main's Catalogue.

STARS WITH SPECTRUM B.

Star.	Magn.	Proper Motion. Parallel.	Proper Motion. N. P. D.	Star.	Magn.	Proper Motion. Parallel.	Proper Motion. N. P. D.
γ Orionis	1.86	0.03	0.04	54 Andromedæ	4.24	— 0.01	0.03
β Canis Majoris	2.01	0.01	0.02	μ^1 Bootis	4.38	— 0.17	— 0.09
σ Sagittarii	2.30	0.00	0.08	τ Tauri	4.40	0.00	0.02
δ Orionis	2.36	0.02	0.04	ν Andromedæ	4.42	— 0.03	0.01
η Canis Majoris	2.41	— 0.05	— 0.01	υ Cygni	4.44	0.00	0.01
δ Scorpii	2.52	— 0.01	0.01	π^2 Cygni	4.44	0.00	0.02
β Scorpii	2.91	— 0.03	0.02	ω Orionis	4.50	0.03	0.00
ι Orionis	2.97	0.02	0.01	ξ Ophiuchi	4 51	0.24	0.21
ζ Canis Majoris	3.01	0.03	— 0.02	λ Persei	4.54	— 0.02	0.05
κ Scorpii	3.08	— 0.04	0.04	6 Lacertæ	4.57	— 0.04	0.00
θ Ophiuchi	3.44	— 0.04	— 0.02	57 Cygni	4.59	— 0.01	0.00
λ Tauri	3.59	— 0.03	0.02	ο Orionis	4.65	0.02	0.02
ι Herculis	3.92	0.15	— 0.01	48 Libræ	4.80	— 0.03	0.10
π^2 Orionis	3.98	0.03	0.01	ο Tauri	4.82	— 0.01	0.01
67 Ophiuchi	4.02	0.00	0.03	π^1 Cygni	4.87	— 0.05	0.01
δ Ceti	4.13	0.05	0.03	υ Herculis	4.91	— 0.04	0.00
ν^2 Scorpii	4.17	— 0.03	0.03	2 Cygni	4.93	0.01	— 0.05
κ Cassiopeiæ	4.18	— 0.01	— 0.01				

---

* Communicated by the author.

STARS WITH SPECTRUM F.

Star.	Magn.	Proper Motion. Parallel. ″	Proper Motion. N. P. D. ″
Capella	0 18	0.08	0.43
Rigel	0.32	−0.02	0.02
Procyon	0.46	−0.72	1.08
α Persei	1.94	0.02	0.05
Polaris	2.15	0.03	0.00
β Cassiopeiæ	2.42	0 50	0.19
α Leporis	2.67	0.01	0.00
γ Virginis	2 84	−0.56	0.05
π Sagittarii	3.11	−0.06	0.03
π Orionis	3.33	0.49	0 01
ξ Geminorum	3.36	−0.10	0.22
α Trianguli	3.59	0.00	0.23
η Cassiopeiæ	3.64	1.08	0.49
β Delphini	3.74	0.07	0.04
η Leporis	3.74	−0.03	−0.14
γ Leporis	3.76	−0.32	0.37
12 Eridani	3.77	0.33	−0.62
ζ Aquarii	3.81	0.14	−0.03
τ Cygni	3.94	0.16	−0.47
ι Pegasi	3.99	0.29	−0.02
δ² Cephei	4.00	0.02	0.02
μ Sagittarii	4.08	−0.06	0.01
o¹ Eridani	4.10	−0.03	−0.07
ω Piscium	4.16	0.15	0.13
10 Ursæ Majoris	4.19	−0.44	0.27
ι Virginis	4.23	0.02	0.41
50 Andromedæ	4.24	−0.18	−0.39
θ Bootis	4.25	−0.26	0.41
ι Piscium	4.28	0.37	0.45
8 Canum Ven.	4.30	−0.77	−0.30.
ψ Capricorni	4.30	−0.09	0.17
λ Serpentis	4.35	−0.19	0.04
42 Comæ	4.38	−0.44	−0.13
43 Comæ	4.38	−0.79	−0.89
μ Cygni	4.39	0.21	0.26
π¹ Pegasi	4.41	−0.04	0.05
π² Pegasi	4.41	−0.01	0.00
τ Bootis	4.50	−0.48	0.05
ψ Draconis	4.52	0.00	0.27
93 Leonis	4.55	−0.20	0.00
f¹ Cygni	4.57	−0.05	0.01
υ Pegasi	4.57	0.18	−0.03
π Aquarii	4.59	0.00	0.01
ν Herculis	4.63	−0.03	−0.01
χ¹ Orionis	4.65	−0.23	0.10
θ Cygni	4.65	−0.02	−0.15
υ Sagittarii	4.67	−0.03	0.05
20 Ophiuchi	4.68	0.06	0.08
ζ¹ Cancri	4.72	0.06	0.11
χ Leonis	4.74	−0.36	0.08
A Scorpii	4.74	−0.04	0 01
b Scorpii	4.79	−0.07	0.02
σ² Ursæ Majoris	4.79	−0.03	0.11
ω Andromedæ	4.80	0.33	0.11
ν Aquilæ	4.80	0.00	−0.04
d Bootis	4.84	0 00	0 05
36 Ursæ Majoris	4.89	−0.11	−0.01
ι Bootis	4.90	−0.45	0.02
τ¹ Hydræ	4.94	0.11	0.03
40 Leonis	4.95	−0.27	0 20
λ Aurigæ	4.95	0.49	0.70
36 Draconis	4.98	0.34	−0.01
58 Ophiuchi	4.98	−0.14	−0.04

This list will, I think, be found to be pretty nearly complete, and, at all events, it has been impartially selected. The high proper motions of the stars of the F type continue below the fifth magnitude as far as the *Draper Catalogue* continues to distinguish them. Several of the stars in the above list have their spectrum marked with a (?), and I suspect that a more accurate determination of their spectra would remove them from the F class to some other; for it is often with the slow-moving stars that the query occurs. There are, however, some bright stars of this class whose spectra do not appear to be open to doubt, but whose proper motions are notwithstanding very small. Whether these stars are really distant, or whether their proper motions are neutralized by the motion of the solar system in space remains to be ascertained. It is not probable that stars with any particular class of spectrum are to be found near the Sun *only*, but there is no improbability in supposing that a particular type preponderates among our own nearest neighbors. In any case I think the necessity of considering the spectrum in all questions connected with the proper motions of stars (such as the determination of the Sun's motion in space), will clearly appear.

DUBLIN, Ireland.

THE MOTION OF NOVA AURIGÆ IN THE LINE OF SIGHT.*

H. C. VOGEL.

Although the spectroscopic observations of the Nova in Auriga are not yet concluded—since the star will probably continue visible for some time—I consider it of importance, in the interest of the subject, to communicate my observations made hitherto, and the conclusions drawn therefrom, even though the latter should not in the future be confirmed in all points.

Concerning, first, the direct spectroscopic observations, I have, on February 20, observed the Nova with a compound spectroscope of a dispersion sufficient just to show the nickel line between the D lines. The hydrogen lines C, F, and Hγ appeared bright. Their identification was easy by means of a hydrogen tube in front of the slit. These three lines did not exactly coincide with the lines of the comparison spectrum, but were displaced considerably toward the red, without, however, separating completely from the artificial lines since they were very broad. The continuous spectrum appeared faint, owing to the comparatively high dispersion; and with certainty only the dark broad F line was recognizable, situated toward the more refrangible side, distinctly separated from the bright line in the spectrum.

Between C and F a large number of bright lines could be seen, but most of them were too faint to be fixed with certainty. In the case of two brighter lines near F, Mr. Frost, who assisted in the observations, and myself, succeeded in making very certain wave-length determinations; we found 492.5μμ for the fainter of the two lines, which appeared broad and fuzzy on both edges, and 501.6μμ for the brighter line. The limit of error is to be taken at about ± .3μμ, and it results from the observation with certainty that the brighter line is *not* identical with the double line of the air spectrum or with the brightest line of the nebulæ, and still less the other with the second nebular line. From Young's list of lines most frequent in the chromosphere, it follows that near F only the two groups of lines, 501.87, 501.59, and

---

* *Nature*, March 24, 1892.

493.44, 492.43, 492.24, 491.92, frequently appear bright. The
is no doubt that both lines in the spectrum of the Nova are chr
mosphere lines, and this result appears to me of great importanc
in so far as it is made probable that the line observed in No
Cygni (1876)—W. L. $500\mu\mu \pm 1\mu\mu$—which, during the gradu
fading of the star, alone remained, was a chromosphere line, a
not the nebular line.

Further both Mr. Frost and myself probably saw the magn
sium lines, certainly the sodium lines bright, as also two lin
between *b* and D, one of which was probably the well-know
chromosphere line W. L. 531.72, also observed in Nova Cygn
By direct comparison with the hydrocarbon spectrum, t
brightest band of which nearly coincides with the *b* group, a
with the sodium flame, *b* and D were identified. Mr. Frost cou
see a displacement of the D lines in the star spectrum with respe
to the comparison spectrum. There was no indication of hydr
carbon bands in the spectrum of the Nova.

Up to the present eleven mostly very good spectrographic ph
tographs have been taken; they were obtained by means of
small spectrograph connected to the photographic refractor
34 cm. aperture. The dispersion is only small, but in the sma
spectrum of 10 mm. length, extending from F to H, much deta
is discernible. The illuminating power of the apparatus is
great, in spite of the narrow slit employed, that even now an e
posure of forty minutes is sufficient to obtain an image suitab
for measurement. The bright hydrogen lines F, $H\gamma$, *h*, H, a
the calcium line, H_2, are very broad; and, as already announce
the corresponding dark lines of a second spectrum are displac
with respect to the bright lines toward the violet, and in spite
the breadth of the latter, are almost entirely separated. The
are also some of the hydrogen lines in the ultra-violet visible, b
they are too faint for any approximately certain observation.

In the last few days the spectrum has changed, inasmuch as
the broad bright lines $H\gamma$, *h*, H, and H_2 (F is only traced on plat
which are over-exposed for the middle of the photographic sp
trum), two maxima of intensity are plainly discernible, and, as
each of the corresponding dark lines, a narrow bright line h
appeared. From the measurements, a connection between the
and the hydrogen lines appears beyond doubt, and it is not i
probable that these linear brightenings in the broad dark lin
indicate eruptions of gases from the interior of the body posses
ing the continuous spectrum with the dark absorption line
Such brightenings are occasionally seen in the spectra of Su

spots. On this supposition, the fine bright lines would indicate very nearly the middle of the dark lines.

The appearance of two maxima of intensity in the broad bright lines admits of the conclusion that two bodies with different motions possess spectra with bright lines, and that therefore the spectrum of the Nova consists of at least three spectra superposed, from the measurement of which, in connection with the comparison spectra of β Aurigæ or β Tauri on the same plate, the relative motions of the three supposed bodies, as well as their motions with respect to the earth, can be determined. Denoting the body with the dark-line spectrum by a, the two others with bright-line spectra by b and c, measurements by Dr. Scheiner and myself have given the following results:

$$a - \tfrac{1}{2}(b + c) = 120 \text{ miles,}^{*}$$
$$b - c = 70 \text{ miles;}$$

and further with respect to the earth—

$$a = -\ 90 \text{ miles, } b = -\ 5, c = +\ 65 \text{ miles.}$$

This result is still very uncertain, and must be regarded as quite preliminary, for it is evident that with the small size of the spectra the accuracy cannot be pushed very far—a displacement of .01 mm. corresponds, for instance, to a motion of 8 to 12 miles, according to the situation of the line in the spectrum—and that the size of the silver grain in the photographs can exert a very marked influence on the measurements.

In the photographic spectrum of the Nova, besides the broad lines mentioned, several more bright and mostly very broad lines can be seen, whose wave-lengths I intend to communicate later on.

ROYAL OBSERVATORY, Potsdam, Germany.

SOME RECENT STUDIES ON THE SOLAR SPECTRUM.†

A. L. CORTIE.

Until the middle of this century the term Physical Astronomy, as distinguished from Observational Astronomy, was usually applied to those investigations of the mathematicians of the mechanics of the celestial sphere, by which they triumphantly vindicated the truth of Newton's theory of gravitation, as giving the only sufficient explanation of the motions of the heavenly bodies. It then came to be used of all such observations and

---

[*] = about 540 English miles.—*Tr.*

[†] *The Month*, August 1891.

deductions therefrom, as depend upon or are explainable by the principles of chemistry and physics. And now this latter branch of astronomy, sometimes called the New Astronomy, which has made gigantic strides since the invention of the spectroscope and our greater knowledge of the action of light, has almost entirely usurped to itself the title of Physical Astronomy, leaving to the older science the name of Mathematical Astronomy. In the following pages it will be our endeavor to give a brief sketch of the recent progress which has been made in but one line of research in this newer science, and to record the successes of the last few years. We have prefaced and interspersed our review with such remarks as are deemed necessary for the clearer understanding of a technical subject by those whose reading has mostly lain in other directions.

The first map of the solar spectrum, which could pretend to give a picture of the chief dark lines, or images of the slit of the spectroscope caused by the absorption of the solar atmosphere, was drawn in the year 1814-15 by the celebrated Fraunhofer. He also proved, by observing the spectra of the brighter stars and noting their discrepancies from the solar spectrum, that these dark lines, whatever might be their true explanation, were not solely due to the action on the rays of the Sun of the Earth's atmosphere. But he went no further. In 1849, Foucault, while experimenting with the spectrum formed by the carbon points of the voltaic arc, observed the coincidence of two bright yellow lines due to the metal sodium, with the black double of the solar spectrum called D by Fraunhofer. And not only this; for he was struck by the appearance of the D lines when the spectrum of the glowing vapors was superposed upon them, which, instead of becoming less dark as would have been naturally expected, were seen to be darker than usual. The observation of this seeming anomaly was a second great step in advance. The theoretical explanation of this appearance was first enunciated, though not published, in 1852 by Professor, now Sir George, Stokes, arguing from the analogy of the absorption of sound waves by a suitable medium. If the explanation was correct, it followed that the spectroscope had, despite the oft-quoted dictum of Comte uttered barely a decade before, proved beyond doubt the existence of sodium in the Sun. In 1859 a German physicist, Kirchhoff by name, performed in his laboratory the classical experiment of reversing the sodium or D lines; reversing, that is, by passing the continuous spectrum formed by the carbon points through hot sodium vapors, he caused the D lines to be alone selected in the process of filtration for absorption, and to appear dark instead of bright on the screen. The arc being taken to represent the Sun, and its continuous spectrum the background of the solar spectrum, the sodium vapors would stand in place of a burning atmosphere around our luminary, and hence the lines of sodium, or indeed of any other metal, being found as dark in the solar spectrum, would indicate the presence of the vapors of that metal in the Sun's atmosphere. This one experiment may truly be said to have created a new branch of astronomical physics, a branch which has already been prolific of most marvelous results, and which is full of promise of greater marvels yet to come. For it is wonderful that stars or suns so immeasurably distant, that the light traveling from them at the rate of 186,000 miles a second, consuming in some cases half a century or more to reach our planet, are by means of the spectroscope analyzed, and the materials out of which they are built up, catalogued with almost as great an ease as the chemist tests the terrestrial matters in his laboratory.

Confining our attention, however, to the solar spectrum, it is evident that the first requisite, before we can hope to unravel any of its hidden teachings, is that we should possess as perfect a map as possible of all its multitude of lines. Kirchhoff was not slow to perceive this necessity, and in conjunction with Bunsen he commenced and nearly finished a beautiful map of the solar spectrum. It was published in 1861, having been completed by the labors of Hofmann. The spectroscope employed consisted of four prisms of flint glass, and the patient toil required for the drawing of such a map must have been enormous, especially when we remember that since the instrument was without the modern refinement of an automatic action, it was necessary to place each prism in the best position for viewing the spectrum for each portion of its length by hand alone. Kirchhoff affixed a scale to his map giving the distance of the lines one from another as measured by his micrometer, and he also subjoined the approximate positions of a great number of the bright lines observed in the spectra of the terrestrial elements. Many remarkable lines are still known by Kirchhoff's numbers, among them being the ray 1474 in the green, the chief bright line given by the solar corona during a total eclipse. But there is one great drawback common to every map of the spectrum constructed by means of a prismatic spectroscope, and that is, that it only perfectly represents the spectrum as produced by an identical set of prisms. The colors always succeed one another in the same order, but the spaces they occupy in the total length of the spectrum, as also the dispersion itself, alters with the refractive angle of the prism, with the substance of which it is made, and unless the prisms be placed in the standard position of minimum deviation of the rays, with the angle made by the incident ray with the first face of the prism. Again, since the resolving power of a spectroscope of prisms varies inversely as the third power of the wave-length of the light, and the wave-length of a violet ray is about one half of that of a red ray, it follows that with such instruments the extent given to the violet will be about eight times greater than that given to the red.

It would obviously be of great advantage if spectroscopes could be so constructed that this irrationality of dispersion, as it is termed, could be avoided, and that the same or a proportional scale could be always applied to measure the distances between the lines, whatever be the dispersion produced. This end is attained by the use of a diffraction grating to form the solar spectrum, and by employing a scale of wave-lengths. It may not be out of place, and will serve to the elucidation of what is to follow, if a few words be here devoted to the instrument and to the scale.

As is well known, light is propagated by waves set up by the molecular vibrations of the luminous source in the all-pervading ether. There are also two kinds of bending of the rays or lines of propagation of the wave-motion. The one termed refraction takes place when the wave-front passes from one medium to another, and this is made use of in the production of the spectrum by means of prisms. The other bending, termed diffraction, ensues when the main wave-front meets with an obstacle such as a screen. In this case some of the rays bend round the obstacle, forming what it has been proposed to call a *derived* wave-front, and without entering into the reasons why a spectrum should be formed, it will be sufficient to state, that if the source of light be white, a series of spectra will under ordinary circumstances be seen. Our readers may, if they be so minded, very easily verify this fact for themselves by a simple experiment. Taking a sheet of thick note-paper, cut in it a slit about two inches in length and one thirty-second part of an inch in breadth. In a second piece of paper one clean stroke of a penknife will cut a second slit requisite for our purpose. This latter we shall refer to as the eye-slit and to the former as the light-slit. Placing the light-slit in front of a gas flame, and looking at it through the eye-slit, after adjusting the distance between them so as to suit one's vision, a bright line of light will be seen, and on each side of it, to right and left, a series of thin colored spectra separated by dark spaces. It will also be noted that the violet ends of these spectra are turned towards the light-slit. If the eye-slit or diffraction slit be extremely fine, the spectra are too feeble to be seen. Two very fine slits, however, equal and parallel to one another, provided they be sufficiently close, will double the brightness of the spectral bands. If now a piece of glass be taken, and by means of a dividing engine that is furnished with a very accurate micrometer screw, a number of fine parallel lines be ruled upon it extremely close together, the result will be a diffraction grating giving the colored bands of a beautiful bright color, the brilliancy depending on the number of lines ruled to the inch and the dispersion on the product formed by multiplying the order of the spectrum observed and the total number of lines ruled, and divided by the width of the diffracted beam.

The earliest gratings of this sort were thus ruled by Nobert and Rutherfurd. Professor Rowland of Baltimore has by means of a magnificently even screw produced wonderfully fine gratings, some with 28,876 lines to the inch. They are ruled not on glass, but on polished speculum metal, and the spectra are produced by reflection from the minutely thin bright spaces between the lines, which correspond therefore to the eye-slit in our experiment with the two sheets of note-paper. The light is in this case diffracted as if the light-slit were at its virtual image behind the grating. Gratings of 14,438 lines to the inch are not uncommon, such a one of very perfect make forming part of the large spectrometer at Stonyhurst, the last instrument which the late Father Perry acquired for the Observatory. In passing it is worthy of notice that Professor Rowland has accomplished the feat of ruling as many as 43,000 lines to the inch. In all the spectra produced by the gratings, any two lines are distant from one another by an interval, which is always proportional to the difference of the wave-lengths of the light corresponding to the lines. On this account the same standard scale of wave-lengths can always be used with maps constructed by the aid of these instruments. Practically, then, all that is required is to determine the absolute wave-length of any one line, and the absolute wave-lengths of all the others can be obtained relatively to this line. Of the extreme red there are 36,920 wave-lengths in one inch, and 64,630 of the extreme violet, so that we cannot quite see an octave. But for the sake of uniformity the wave lengths of light are expressed in terms of a unit called a tenth metre, one tenth-metre being the one ten-thousand-millionth par of a metre, and one metre being a little over thirty-nine inches With good spectroscopes it is possible to recognize lines differin by as small an amount as the one-tenth of a tenth-metre. Taking the line D_2 as a standard, Mr. Louis Bell has by a mos thorough investigation determined its wave-length as 5890.18 of our units. Basing his observations on this value of D_2, Professor Rowland has published a list of four hundred and fift standard wave-lengths of lines.

The celebrated Angström was the first to draw a map of th solar spectrum as produced by a grating spectroscope, and witl a scale of wave-lengths, his standard being the mean of the pai of lines at Fraunhofer's E line. It appeared in 1868. A catalogue of wave-lengths was drawn up in the memoir whicl accompanied the plates, and this map and catalogue have beer used as the standards by spectroscopists up to the present day They are, however, surpassed in accuracy by the recent determination of wave-lengths at Baltimore and at Potsdam, so tha they will without doubt be supplanted in the near future.

With these preliminary remarks on mapping the solar spectrun in general, we may now turn to the review of some recent worl in this direction. The name of the late M. Thollon is one tha occupies a prominent place among those of modern sola observers. About ten years ago this eminent astronomer commenced a map of the solar spectrum, which as we are told in th Introduction to the accompanying catalogue which gives th places and intensities of the lines, was intended by its author t be nothing less than a standard work, furnishing to the spectroscopist similar data for his researches, as are provided for th celestial cartographer by such charts as those of Argelander Unfortunately for the cause of science the hand of death remove him before the completion of his self imposed task. Yet no before he had by the labors of seven years succeeded in mappin the lines, from A in the extreme red through the orange to *b* i the green. The reproduction of the charts by steel engravin by M. Legros, aided by M. Perrotin, the Director of the Nic Observatory, which it would be difficult to extol too highly, ha occupied another three years. They finally appeared last year i the third volume of the *Annals of the Nice Observatory*. M. Bischoffsheim most generously, as is his wont, furnished the necessary funds for their engraving and publication, and copies have been gratuitously distributed among observatories and private astronomers. M. Thollon's spectroscope consisted of prisms filled with bisulphide of carbon, giving a brilliant spectrum, the finest definition, and a great dispersion, equal in these latter respects, by the testimony of Mr. Rutherfurd himself, to any of the spectra given by his gratings. In order to secure an even temperature in the spectroscope, so as to avoid a change in the refractive index of the prisms, and hence want of uniformity in the scale readings, a circulation of water was maintained within the table on which the instrument rested, and also in the hollow sides of a metal case which was let down from the roof to cover it. A heliostat threw a beam of sunlight on to the slit of the collimator which passed through one side of the box, the telescope being similarly fitted into another side.

The atlas he drew is divided into 33 maps, each about a foot in length, and shows about 3,200 lines. Each map is divided into four strips, so as practically to quadruple the atlas. These show the solar spectrum under four different conditions; first, as obtained from the sun at an altitude of 10°, the air being fairly dry, secondly, with the sun 30° above the horizon, the aqueous vapor being in abundance, thirdly, with the sun at the same altitude, but the air being very dry, and lastly with our atmosphere hypothetically removed, and therefore only lines of purely solar origin remaining. The lines in each strip are drawn most accurately, with their proper shading and thickness. Any one who has ever even casually studied the solar spectrum, can form some estimation of the painstaking and continuous toil necessary for such a task. Those only who have tried to delineate a small portion of the spectrum can fully realize what a demand the drawing of such maps makes on the care and patience of the observer. It is only necessary to compare the picture with the original to see how perfectly M. Thollon has succeeded. The great utility of the map consists in its bringing together in parallel strips the solar spectrum as seen under various atmospheric conditions. It is thus possible by a comparison of the intensity of the same lines in the different strips to eliminate those caused by our atmosphere. For a true solar line will remain always of the same intensity, the atmospheric line meanwhile varying with the hygrometric state of the air. It would appear that of the 3,200 lines mapped by Thollon, 2,090 are purely solar, 866 are telluric or air lines, and 246 are traceable to the combined action of both the terrestrial and solar atmospheres. But as a standard the map has already been superseded by recent photographic studies, for it labors under the defect already noticed as inheren in all maps constructed by means of prismatic spectroscopes, not furnishing a normal scale. It is none the less an admirabl piece of work, and beyond all praise. Indeed, it seems difficult t imagine that more perfect or more delicate drawings could b produced, and it marks the highest level yet reached by means the pencil. It only remains to add that M. Trépied, the colleagu of M. Thollon, has undertaken to complete the remaining tw thirds of the work.

As early as 1843, J. W. Draper, applying the but recent inve tion of Daguerre, obtained a plate by this process of nearly th whole length of the spectrum. In 1874 again, Rutherfurd, work ing with a prismatic spectroscope, was able to publish a fin photograph of the blue and violet ends of the spectrum. No must we omit to mention the standard map of the ultra-viole unseen region of the spectrum, the fruit of the labors of Corn But the recent progress in photographic science, and mor especially the invention of the dry-plate process, which is bot cleanly and easy to manipulate, while capable of almost an extent of sensitiveness, has placed in the hands of the astronom cal physicist a most potent instrument of research when brough to the aid of either telescope or spectroscope. The photograp of the nebula in Orion obtained on a dry plate in 1880 by H Draper was the first of a series of triumphs in this kind of work and already celestial photography has advanced our knowledg of the heavens to an extent which could not have been dreame of by the astronomers of the middle of the century. Nor has th solar spectroscopist been backward in availing himself of thi powerful aid to unravelling the secrets of the solar spectrum The same year that Draper photographed the nebula in Orion Professor Rowland, of the Johns Hopkins University, invented plan, by which it became possible to vastly increase the accurac attainable in the cutting of micrometer screws. Possessing perfect screw, he commenced to rule correspondingly perfec gratings, without any periodic error in the ruling above th hundred-thousandth part of an inch. The spectra produced b Rowland's gratings are therefore particularly free from th obnoxious false images of the principal lines of the solar spectru termed "ghosts." These are caused by a periodic inequality i the spaces contained between the parallel scratches of th diamond point on the speculum metal. For instance, let us sup pose that one turn of the micrometer head be equivalent to th ruling of 1,000 lines, should any unequal spaces occur in th course of a revolution, they would occur relatively in the same places in every revolution. These periodic unequal spaces gave their own fainter spectra, which naturally were more evident in the principal lines, and so caused the "ghosts" already mentioned. Good gratings, as now ruled, such as the one possessed by the Stonyhurst Observatory, are quite free from this fault. This advance in the perfecting of the ruling of gratings Rowland followed up the next year by conceiving the brilliant idea of ruling the gratings on a spherical surface of speculum metal, instead of on flats as had hitherto been done. By this means it is possible to dispense with all the adjuncts of an ordinary spectroscope except the slit, the grating, and the eye-piece, in the place of which last a camera may be substituted. Such a spectroscope is simplicity itself, there being no need of a collimating lens to render the divergent pencil of light from the slit parallel before reaching the grating, nor yet of any telescope to focus the rays.

With a grating perfectly ruled on a spherical surface 6 inches in diameter and 21½ feet radius, the Professor undertook to photograph the solar spectrum. His map was published in 1886, followed in 1889 by a second more perfect edition. This second edition extends from wave-length 3,000 far down in the violet, to wave-length 6,950 beyond B in the red. Kirchhoff's coronal line 1,474, which was once supposed to be coincident with an iron line, was clearly separated into two lines, as was also b_1, which used to be attributed to both magnesium and iron. The E line was also first resolved.

But the most successful photographer of the solar spectrum who has yet appeared is undoubtedly Mr. George Higgs, of Liverpool. It has been our privilege to examine this gentleman's apparatus, processes, and original plates under his own guidance, and we propose to briefly describe some few of his methods and results. And first of all we must call attention to the fact that, except for the concave grating and the screw of the engine for ruling scales, every piece of apparatus used by this astronomer has been made by himself, and is remarkable alike for simplicity and the ingenuity displayed. Even the Rhumkorff coil for use in producing the spectra of terrestrial substances for comparison with the solar lines, is of his own constructing. This instrument, which was exhibited before the British Association at its Manchester meeting, is of such perfect insulation, and such complete economy of insulation and just proportion of parts, that with one quart bichromate of potash cell it gives a spark of ten and a quarter inches. And yet only fifteen miles of wire hav been wound upon it.[*]

Mr. Higgs first began work on the solar spectrum with prismatic spectroscope, with which he produced a very beautif photographic map. He then acquired a grating, one of Rov land's spherical instruments ruled with 14,438 lines to the inc having a diameter of four inches and a radius of curvature of te feet two inches. Now the purity of a spectrum is inversely pr portional to the width of the slit. From this it is evident that the jaws of the slit, the light-slit of our simple experiment, a perfectly sharply cut and exactly parallel, it becomes possible t make it excessively narrow, provided always that the illumina tion be sufficient. It would appear that a great deal of M Higgs' success is attributable to the fine steel-jawed slit which h has made for his spectroscope. The grating is mounted at o end of the diameter of a circular tabe, equal to the radius curvature of the grating, and the eye-piece or camera is placed the other extremity of this diameter. The slit also slides alon the circumference of the table, and is placed in different positio with regard to the grating and camera, according to the ord of the spectrum which is to be photographed. The circumferen is divided into parts by means of a scale encircling it, which also supplied with moveable verniers. These scales again are M Higgs' handiwork, and the perfection of adjustment attainab by their aid in his instrument is another source of its fine perforn ance. The light is conducted to the slit by a heliostat, this, to made, with its silvered mirror, by the observer. In phot graphing the solar spectrum the actinic action at the two ends the plate varies immensely, being in some cases as much as fif times greater at one end than at the other. The plate must ther fore be exposed at different portions of its length for differe times, otherwise while one end of the plate would be over-expose the other would have failed to have registered any line at a This difficulty is overcome by Mr. Higgs by means of a set shutters placed inside the camera, and worked by clock-work, a so arranged that the proper relative exposure is secured for eve portion of the sensitive film.

It might perhaps be imagined by such as are unacquainted wi

---

[*] At the time of our visit the instrument had not been employed for a c siderable period, and the battery had so deteriorated that it would ordinarily h been rejected as unfit for use. Yet it gave a spark which leapt across the ter nals at a distance of seven inches, and when the zinc and carbon were lifted ou the solution and put into clean water, it gave a continuous spark of one i and a quarter. Electricians will appreciate the accuracy of workmanship quired to attain such a result!

the action of light upon photographic films, that after all this care in adjustment nothing further was required but the exposure of the plate for the proper time in order to obtain a picture. But not so; for first, the actinic action of light is chiefly confined to the blue and violet regions of the spectrum, and secondly, although in spectra produced by means of gratings the first spectra on each side of the white image of the slit, called the spectra of the first order, are separated from those of the second order, yet the second, third, and higher orders overlap. Hence, should it be required, for instance, to use the greater dispersion of the red of the second order, it becomes necessary to block out the violet of the third order. The suppression of the obnoxious rays is effected by the absorbing action on light of suitable solutions, which are contained in glass cells and placed before the slit. But the problem of rendering the plates themselves sensitive to the lower wave-lengths of light is by no means an easy one. It has engaged the attention of several eminent photographers. One method devised by Captain Abney was the preparation of the bromide of silver plates, with the salt in a different molecular condition from that in which it is ordinarily found, so that it looked blue by transmitted light. By this means he was enabled to directly photograph the dark heat rays of the solar spectrum. Others, again, as Vogel and McClean, have proceeded in a different manner, and have sensitized the plates for radiations above the blue by staining them with various dyes. Higgs, too, has been most successful in this field, and has but recently communicated to the Royal Society a paper in which he announces the discovery, that plates stained with the bisulphite compounds of alizarin-blue or of cœrulin, while sensitive to the red and ultra-red rays between the wave-lengths 6,200 and 8,000, do not, like cyanin plates, lose the power of retaining the impression of the rays at the opposite end of the spectrum. With such plates he has been enabled to extend the range of his photographs to Z in the ultra-red, while his photograph of A exhibited at a British Association Meeting at Leeds, and to the Royal Astronomical Society, shows the lines of this beautiful group as they have never been seen before.

When the negative has been secured, it is enlarged four times, evenness of background and sharpness of detail being obtained by the use of a cylindrical lens, and by other ingenious arrangements which need not be described here. The prints which are the finished results, have the fineness of steel engravings. Moreover, by a very clever device Mr. Higgs photographs a scale of wave-lengths on his map, a boon which will be appreciated by every working spectroscopist. More than this, by photographing the unknown coincidently with the known regions on the same plate, and placing the scale between them, provided only the two slips are of different orders, a very simple relation enables the wave-lengths of the unknown lines to be determined. He has even an original method for securing a certain knowledge that the temperature of the scale has not altered during the time of its being ruled by the dividing-engine. Finally, it is his intention to publish in the near future a map of the whole spectrum from wave-length 2,990 in the ultra-violet to wave-length 8,500 in the ultra-red, with special studies on interesting regions.

When we look at some of the best maps of the solar spectrum, so crowded with lines that it would be impossible in parts to place a needle-point on the pictures without alighting on a line, the questions naturally arise as to what substances these innumerable lines belong to, and what progress has been made in identifying the relations between the solar spectrum and the laboratory spectra of the elements. We intend briefly to record some few of the more recent investigations. A most necessary preliminary step in solar spectroscopy is the discrimination of the lines of purely solar origin from those which are due to the absorbent action of the Earth's atmosphere. We have already called attention to the value of Thollon's map for this research, as by a comparison of the intensity and thickness of the lines in the four strips, it is possible to detect those which vary concomitantly with the altitude of the Sun above the horizon, and with the hygrometric condition of the atmosphere. One of the finest groups of lines in the solar spectrum occurs in the red at Fraunhofer's B. Some of Mr. Higgs' photographs bring out the rythmical arrangement of the lines in this group most beautifully. But it had by Egoroff and Janssen been identified as most probably not due to the Sun, but to the dry oxygen contained in our atmosphere. The latter astronomer, who bears a distinguished name in solar physics, has lately completed a series of observations remarkable alike for their intrinsic value, as also for the circumstances under which they were carried out. Arguing that if these lines are really due to our atmosphere, their intensity should diminish in direct proportion to the height from which they are viewed, and in the impossibility of getting rid of our atmosphere altogether, this intrepid observer, whom nothing daunts—for had he not already escaped the vigilance of the Prussians who were beseiging Paris, and passed out in a balloon to observe the eclipse of 1870

–would now have himself carried to the tops of the highest mountains to note the effect on the suspected oxygen lines. In accordance with his plan he ascended to the Grands Mulets in 1888, and last year was borne in a litter by a small army of guides to the very summit of Mount Blanc. The result was a complete verification of his earlier observations, so that we may conclude that most probably oxygen, at least in the state in which we know it here, does not exist in the solar envelopes. He has likewise experimented from his Observatory at Meudon on an oxygenless light set on the highest point of Eiffel Tower, the atmospheric strata traversed by the rays being nearly equivalent to the height of the atmosphere supposed homogeneous. The oxygen lines in this case appeared exactly as they are seen in the solar spectrum, thus adding another link to the chain of proof of their terrestrial origin.

With regard to other lines due to the Earth's atmosphere, Dr. L. Becker, of the Edinburgh Royal Observatory, has quite recently published the results of long and laborious observations of the solar spectrum at low and medium altitudes. The spectrum drawn extends from wave-length 6,024 to F in the blue-green. In this range of the spectrum, 3,637 lines are identified as due to the sun, and 928 as air lines. For the purposes of such an investigation, the photographs of Mr. Higgs will, when published, be extremely valuable. For they have been taken with the sun at various altitudes, and under different conditions of saturation of the atmosphere. One plate in particular showing D and the lines constituting the rain-bands, when the Sun was only just its own diameter above the horizon, is a superb production. Again, in several cases the enlarged photographs show metallic lines and air lines so close together that no spectroscope except those of the very greatest resolving power could separate them. Such results may not improbably have an effect upon theories which are founded upon the behavior of lines in the spectra of Sun-spots. In passing too we may remark that of some other lines, which it is considered a feat to have split, the photographs of this observer divide not only the coronal line, but also the E line and one twice as close at 5264.4. The head of the B group too is seen to be composed of three lines, while from twenty-five to thirty lines are registered between the D's and no less than one hundred and fifty between H and K.

Nor in the meantime have Professor Rowland and his assistants been idle, but they have brought the powerful apparatus of the Johns Hopkins University to bear upon the photographing of the lines in the metallic spectra coincidently with the solar spectrum. Kirchhoff's list of metals in the Sun, deduced from his observations taken about twenty-five years ago, consisted of sodium, iron, calcium, magnesium, nickel, barium, copper, and zinc. To these Angström and Thalen added chromium, cobalt, hydrogen, manganese, and titanium; while Lockyer, later still, by an ingenious method of laboratory work, brought the total up to twenty-three. He detected aluminum, strontium, lead, cadmium, cerium, uranium, potassium, vanadium, palladium and molybdenum. Of these coincidences with the dark solar lines, about six hundred were attributed to iron alone. And now the latest list, quite recently issued by Professor Rowland from photographs taken between the ultra-violet and the D lines, gives the total number of terrestrial elements certainly present in the Sun as thirty-six, while eight more are doubtful. In this latter category is uranium, formerly admitted as present by Lockyer. Rowland's most important addition is carbon, the others being silicon, scandium, yttrium, zirconium, lanthanum, niobium, neodymium, glucinum, germanium, rhodium, silver, tin, and erbium. But the solar photosphere contains no gold, nor antimony, arsenic, bismuth, boron, nitrogen, cæsium, indium, mercury, phosphorus, rubidium, selenium, sulphur, thallium, nor praseodymium; while iridium, osmium, platinum, ruthenium, tantalum, thorium, and tungsten, are, together with uranium referred to before, recorded as doubtful. These lists have been arranged both according to the intensity of the metallic lines in the Sun, and according to their number. In the latter series iron occupies the first place with two thousand and nine lines, nickel comes next, and two hundred coincidences are due to carbon.

In concluding this necessarily brief summary of some recent spectroscopic studies in but one branch of modern astronomical physics, we may be allowed to again direct attention to the fact of the importance of the aid to research which the observer has acquired in the spectroscope and the photographic camera. Already we know that the materials of which our Sun is constituted are the same as we find here upon Earth. But our Sun is but one out of millions which glitter as stars in the heavenly firmament. It is a truly wonderful thing that a piece of glass cut into the form of a prism, and a plate of glass covered with a gelatine film, should be so arranged in position behind another piece of glass fashioned into the shape of a lens that these immeasurably distant stars should be compelled to tell us of what they are made. But wonderful as it seems, the mind of man has been able to effect so much, and has thus obtained a deeper insight into the marvelous harmony and unity which reigns in the starry skies. With this insight ought to come deeper reverence, and our spirit should be that of the pious Kepler, who was wont to cry out as he contemplated the heavens: "O God, I think Thy thoughts after Thee."

ST. BEUNO'S COLLEGE, St. Asaph, N. Wales.

SOLAR PHOTOGRAPHY AT THE KENWOOD ASTRO-PHYSICAL OBSERVATORY.

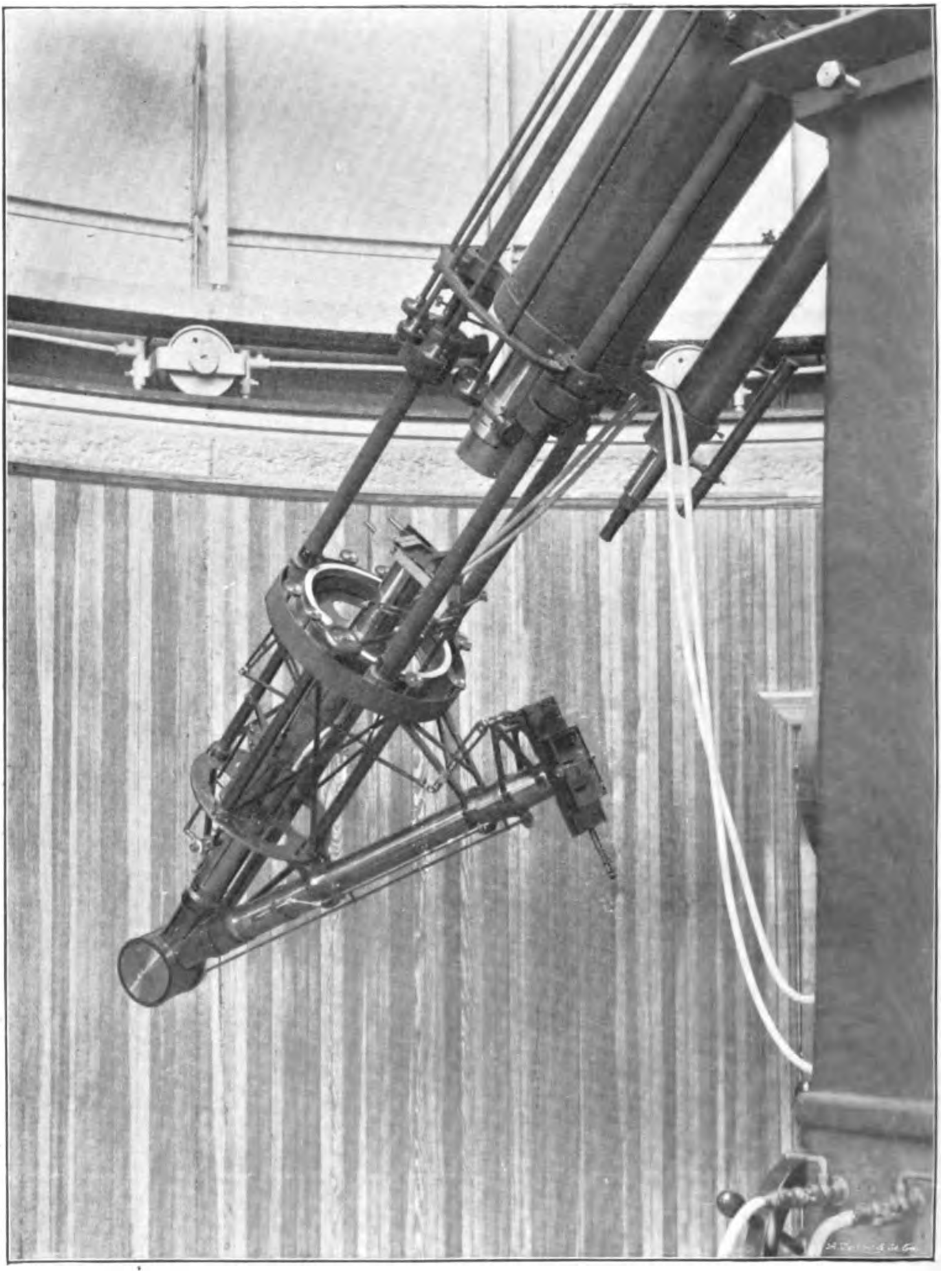
GEORGE E. HALE.

Immediately after the completion of our 12-inch equatorial refractor in March, 1891, an investigation was undertaken at the Kenwood Observatory which had for its object the application of photographic methods to the registration of all classes of solar phenomena. Up to that time, in spite of various attempts at photographing the prominences, the only phenomena at the Sun's surface which had been photographed with any degree of success were the spots, and the faculæ *when very near the limb.* As they are carried toward the center of the disc by the Sun's rotation, the faculæ no sooner leave a narrow area near the limb than they are lost to view on the brilliant background of the photosphere, and ordinary methods of photography serve no better than the eye itself in following the course of these objects. For lack of photographic means the numerous prominences rising from the Sun's limb must needs be drawn one by one—a laborious process at best, and one consuming far too much of valuable time. Moreover, the spectra of faculæ, spots and prominences in the invisible region of the ultra-violet were then uninvestigated, and there was the possibility that other phenomena, as yet unknown, might be brought to our knowledge by the peculiar powers of the sensitive plate. These considerations had first occupied my attention in 1889, and I had then devised methods to overcome some of the many difficulties in view, but though preliminary experiments had been carried on at the Harvard College Observatory in the winter of 1889-90, they had been quite without success, on account of the unsuitability of the apparatus employed. The field was, therefore, a practically untried one when we entered it at the Kenwood Observatory just a year ago.

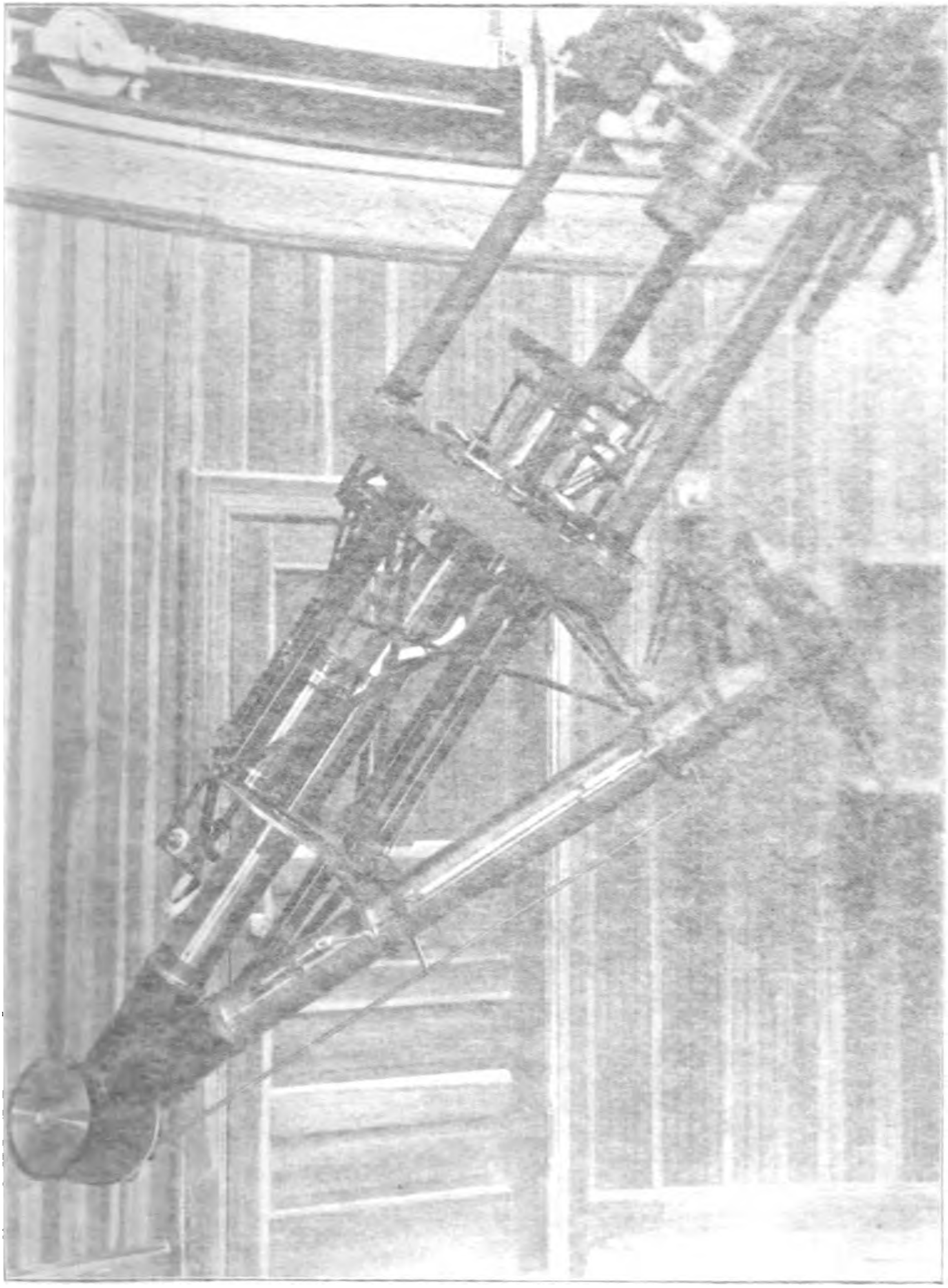
I have already described the new lines discovered in the spectra of prominences, spots and faculæ, and the photographs obtained of single prominences with the H and K lines and an open slit. In the present paper I wish to explain the method by which photographs are now made of all the prominences visible around the entire circumference of the Sun with a single exposure, and by which faculæ are clearly shown even in the brightest portions of the Sun's disc.

In the SIDEREAL MESSENGER, June, 1891, I described the difficulties experienced in photographing prominences by my first method. The apparatus as then used consisted of a cylinder in a closed box at the eye-end of the observing telescope of a large diffraction spectroscope. The axis of the cylinder was parallel to the lines in the spectrum, and the cylinder could be rotated at a uniform rate by a small clepsydra, attached to the instrument. Thus a strip of flexible celluloid photographic film on the circumference of the cylinder was slowly moved in the plane of dispersion behind a narrow slit at the focus of the observing telescope. The grating was rotated by a tangent screw until the K line in the fourth order spectrum passed through the narrow slit, and fell upon the sensitive film. By changing the rate of the driving clock of the telescope the Sun's image was made to drift slowly across the (first) slit of the spectroscope, while the film rotated at the proper speed. As K is always bright in prominences it follows that the successive images of this line as a prominence moved across the slit would build up the required form upon the photographic film. A number of fairly good photographs of prominences were obtained in this way, but so many defects were discovered in the apparatus, and the difficulty of securing the proper ratio between the motion of the film and the rate of the telescope clock was so great, that it was decided to construct an entirely new instrument, on the principle of my second method as devised in 1889.

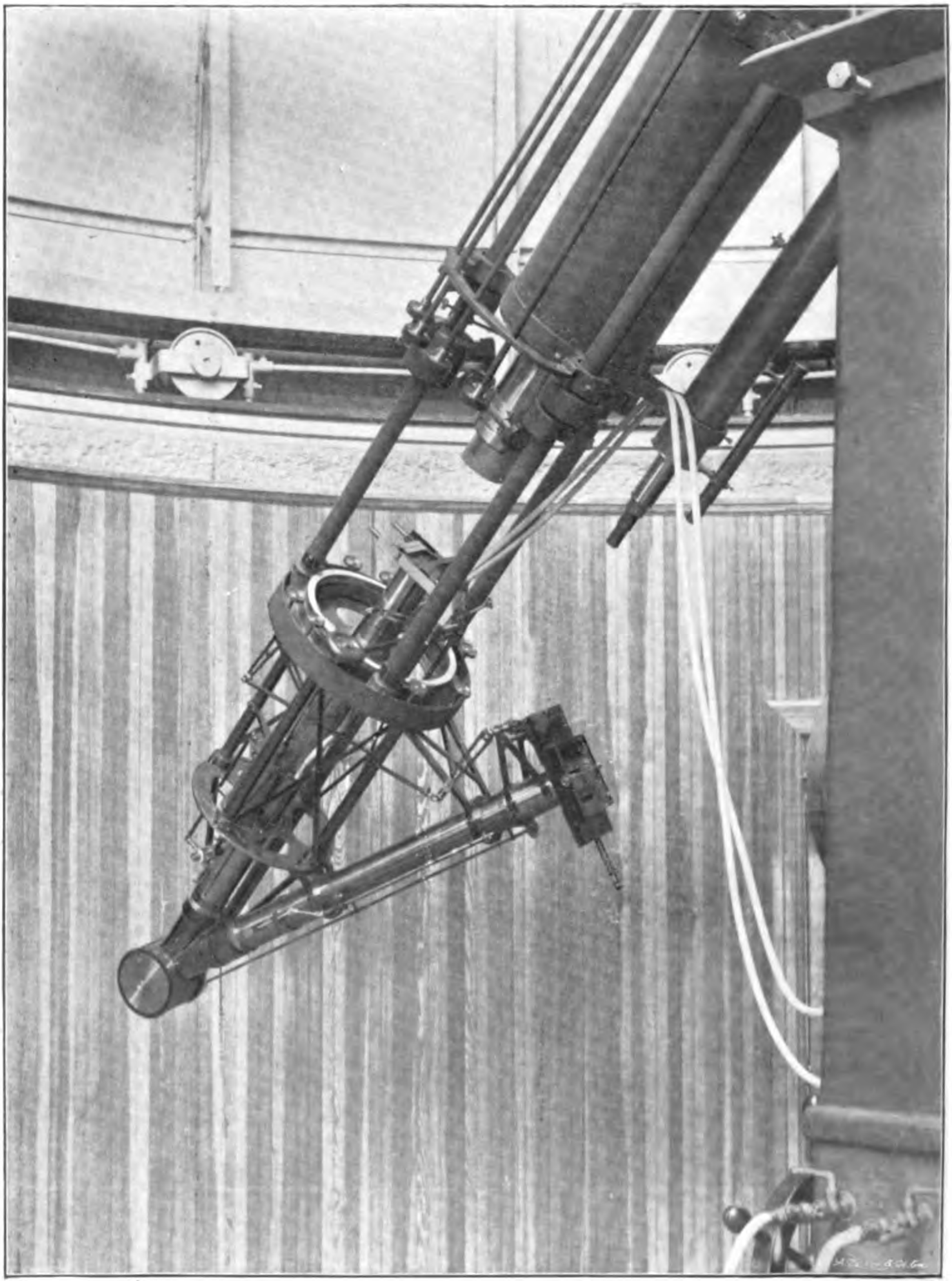
This apparatus, which I have called a "spectroheliograph," is shown in the accompanying Plates attached to the eye-end of the 12-inch equatorial. Its essential parts are two movable slits, one at the focus of the collimator of a large grating spectroscope, and the other just within the focus of the observing telescope. The slits are about 3¼ inches in length, and adjustable in width. They are attached to carriages mounted on steel balls, so that they may be moved with perfect freedom across the axes of the tubes, in the plane of dispersion. A photographic plate-holder is supported just beyond the second slit, and, after drawing the slide, the plate-holder can be pushed forward by means



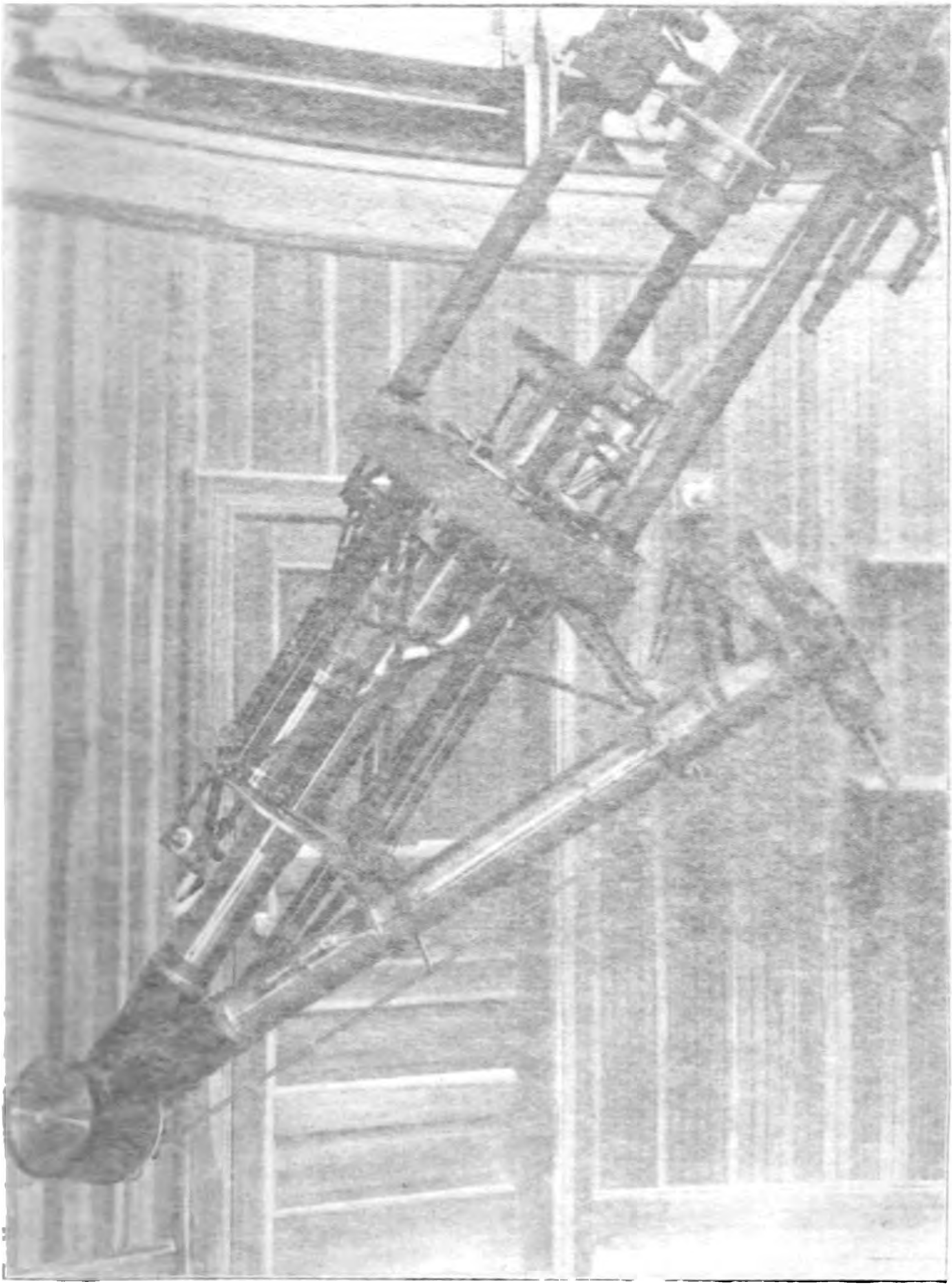
THE SPECTROHELIOGRAPH OF THE KENWOOD ASTRO-PHYSICAL OBSERVATORY, CHICAGO.



THE SPECTROHELIOGRAPH OF THE KENWOOD ASTRO-PHYSICAL OBSERVATORY, CHICAGO



THE SPECTROHELIOGRAPH OF THE KENWOOD ASTRO-PHYSICAL OBSERVATORY, CHICAGO.



SPECTROHELIOGRAPH OF THE KENWOOD ASTRO-PHYSICAL OBSERVATORY, CHICAGO

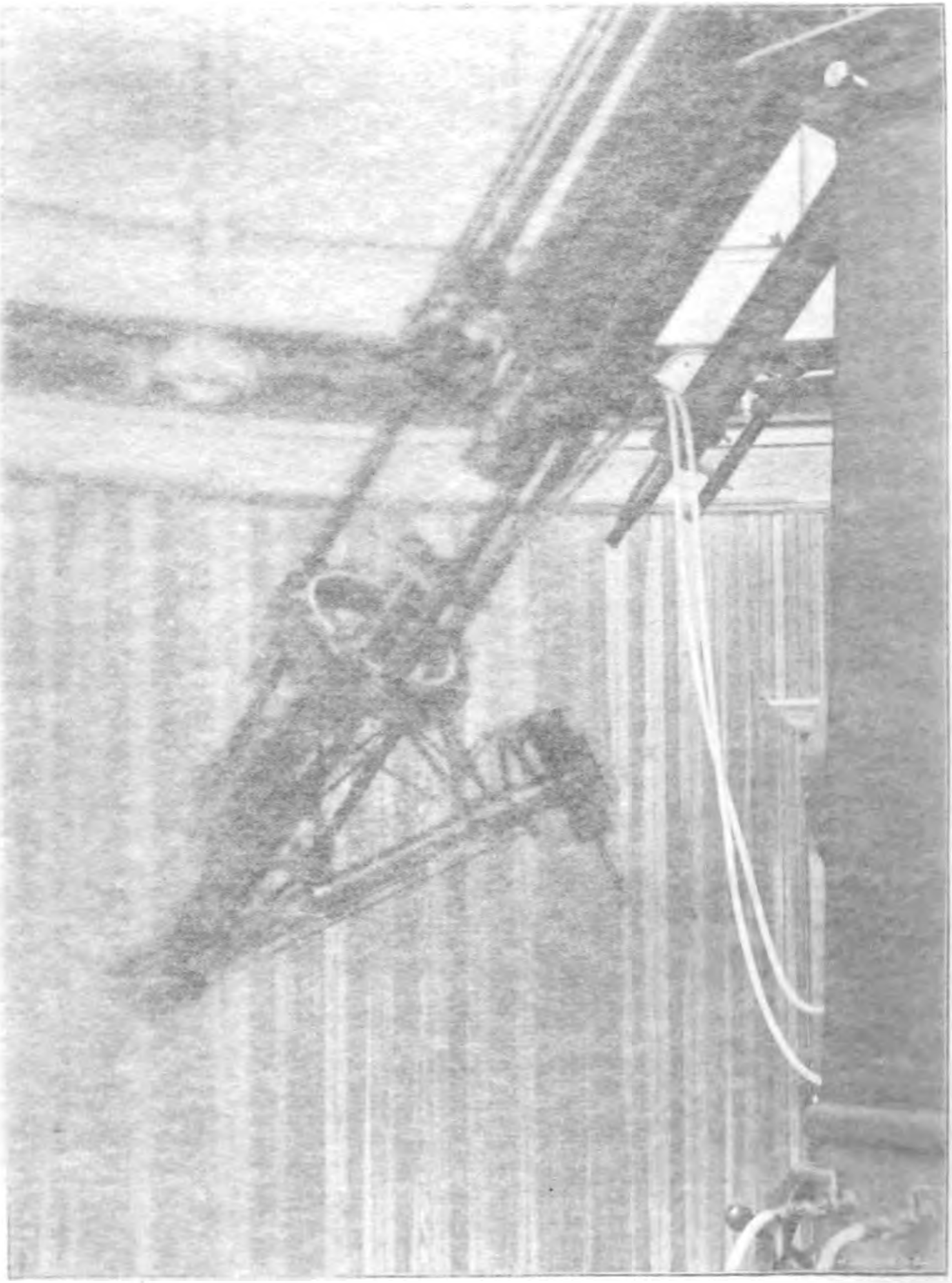
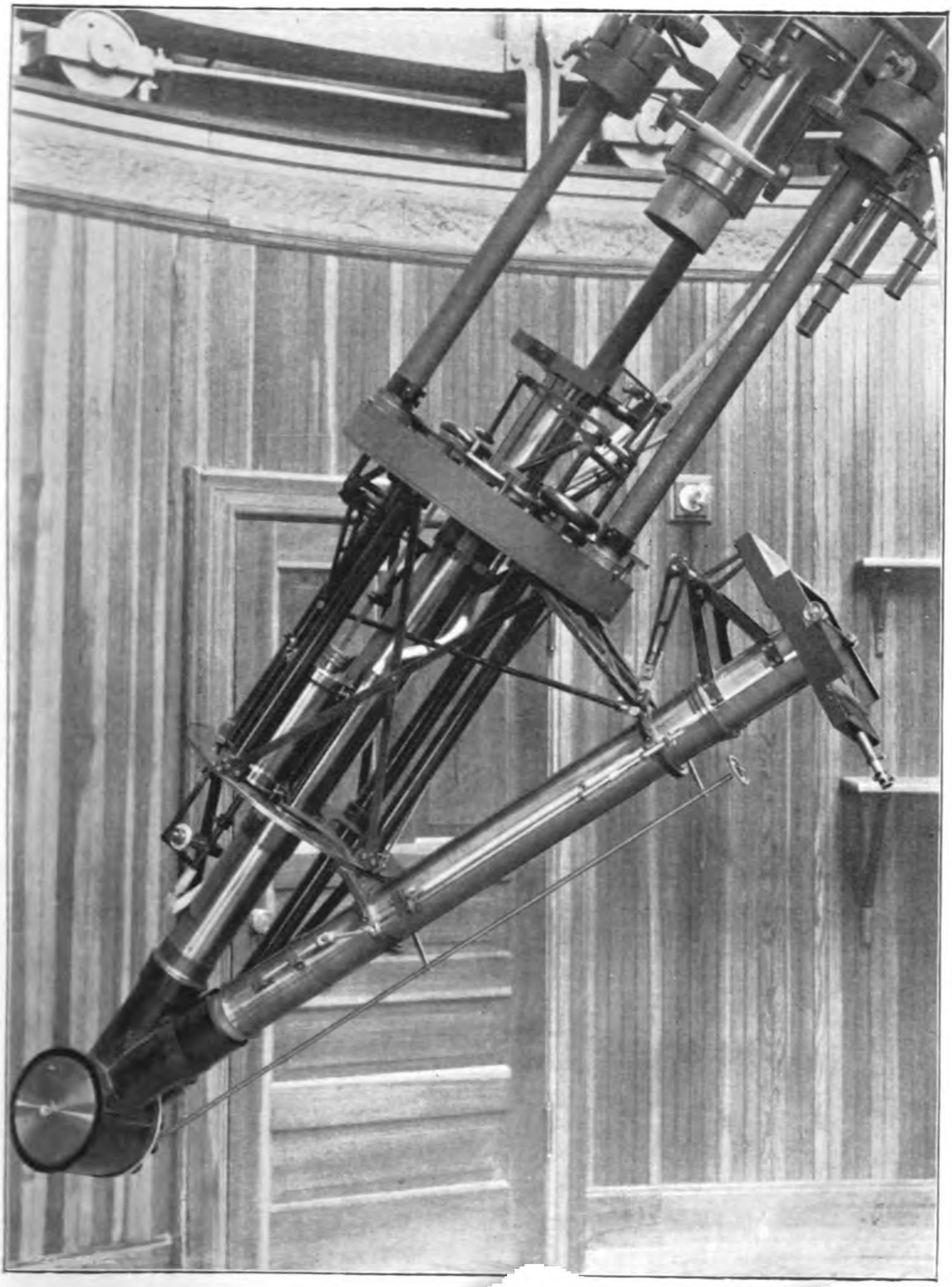
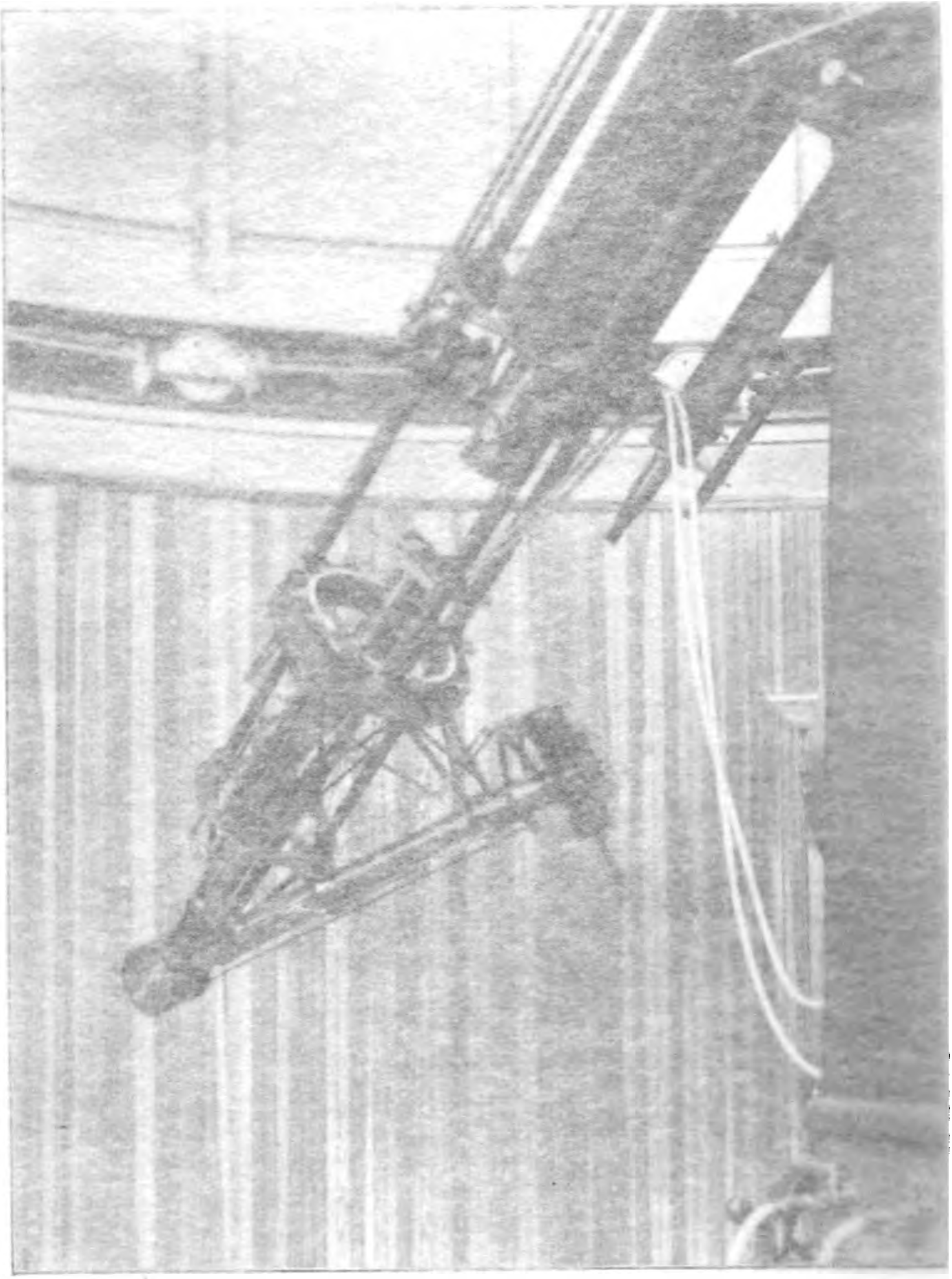


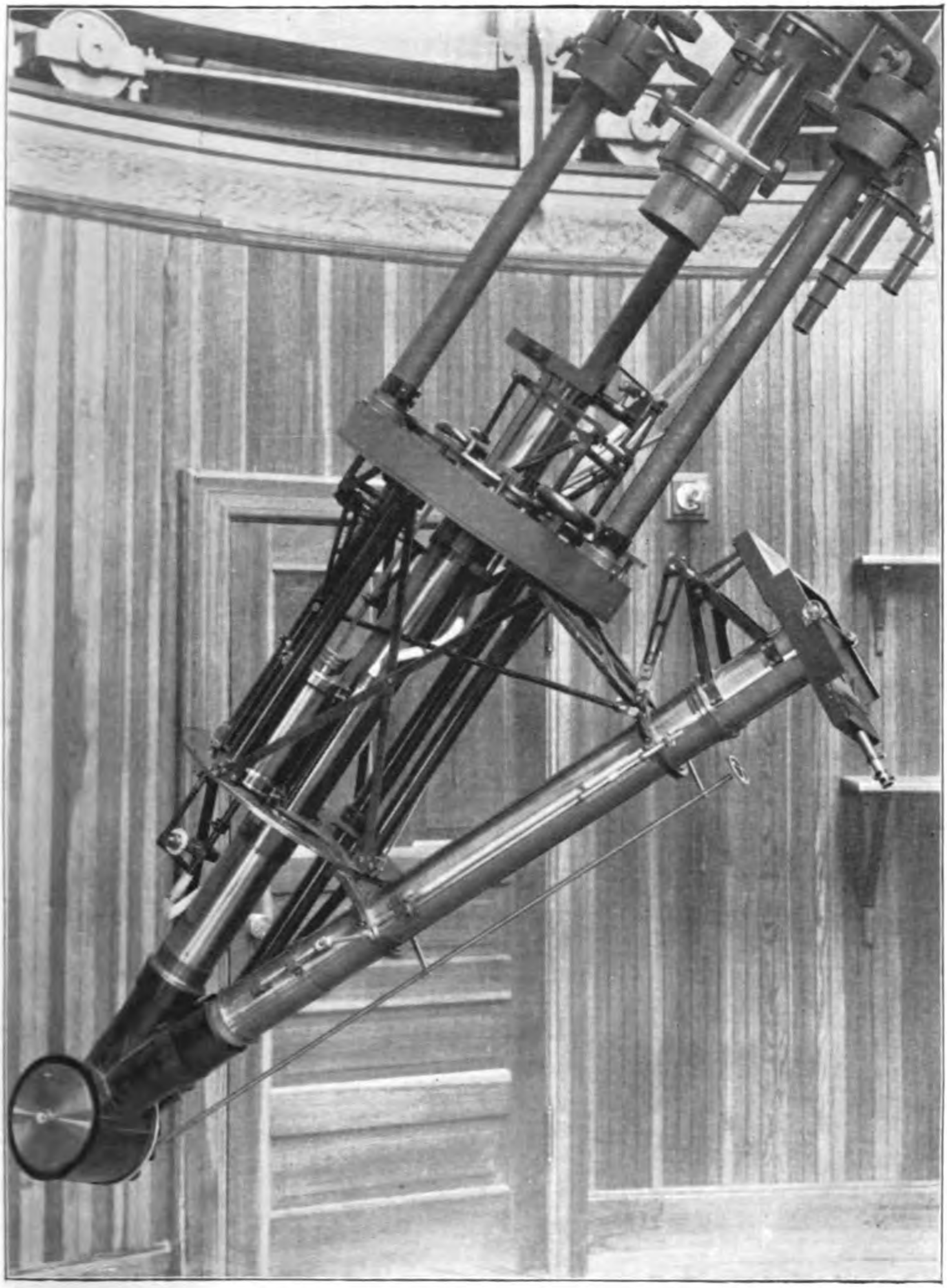
FIG. THE KENWOOD ASTROPHYSICAL OBSERVATORY, CHICAGO



THE SPECTROHELIOGRAPH OF THE KENWO OBSERVATORY



[illegible] PHOTOGRAPH OF THE [illegible] [illegible]



THE SPECTROHELIOGRAPH OF THE KENWOOD ASTRO-PHYSICAL OBSERVATORY, CHICAGO.

of a cam until the surface of the plate almost touches the jaws of the slit. A small 90° total reflection prism is attached to the slit carriage on the side toward the grating, and by a suitable combination of lenses a small portion of the spectrum can be viewed without disturbing the plate-holder.

The motive power is supplied by a specially designed clepsydra, which is mounted within the braced frame of the spectroscope. It consists of a brass cylinder of 3 inches bore and 6 inches stroke, supplied with two inlet and two outlet valves, and a very accurately made micrometer gate-valve. The piston has a cup-shaped leather packing, and the phosphor-bronze piston-rod passes through a stuffing-box in the upper head. At the end of the rod a system of bell-crank levers is attached, and these convey the motion to the slit at the focus of the observing telescope. An extension of the piston-rod passes through a guide in the upper frame of the spectroscope, and connects with the first slit by another lever system. It will be seen that when the piston is set in motion, the two slits will move simultaneously, and in opposite directions.

The city water supply could not be used to run the clepsydra for two reasons. In the first place the pressure must be constant or nearly so, while the city pressure undergoes marked variations. Again, the water would freeze in cold winter weather. I therefore had a hydraulic accumulator constructed, and placed in the cellar of the Observatory, with galvanized iron pipes leading up to the observing room, and terminating in stop-cocks on the iron pier of the equatorial. Union joints attached to flexible rubber tubing put the accumulator in connection with the clepsydra, and do not hinder in the least the free movement of the telescope. The liquid used is a mixture of water with about 30 per cent of alcohol, and this proved quite satisfactory even in cold weather. The accumulator consists simply of a large vertical cylinder, with a yoke suspending from the upper end of the piston-rod about half a ton of iron weights. The descending piston forces the liquid through a supply pipe at the bottom of the cylinder, and the returning liquid enters the top of the cylinder. When completely run down the piston is pulled up by means of a differential block, the liquid passing from above the piston to the bottom of the cylinder by an outside pipe, open into the upper part of the cylinder, but with a check-valve at the bottom. For summer work I intend to have the city water connected with the bottom of the cylinder, and the weighted piston will then make up for any variations in pressure. The city pressure will probably be sufficient to free us from the labor of using the differential block during the warmer months of the year.

It will be seen in the Plates that the supply pipe enters the clepsydra at the upper end, while the waste passes out through a pipe in the lower head. The brass pipe to which the supply tube is connected runs the whole length of the cylinder, and the liquid can thus be admitted on either the upper or lower side of the piston by opening the proper valve. In the photographs both valves are closed. Supposing the cylinder to be filled on both sides of the piston, we can run the piston down by opening the upper inlet valve and the outlet valve just above the micrometer gate-valve in the pipe leading from the lower head. The speed of the piston's descent, and hence the speed of the two slits, can be regulated with the utmost nicety by the gate-valve, the micrometer head of which is divided into 100 parts. The gate-valve has a pair of phosphor-bronze jaws in the form of an adjustable slit, and a wide range of motion is thus secured. Provided the pressure remains constant, a given speed can be obtained at any time by setting the micrometer head at the proper reading. When the piston has reached the end of its course the upper inlet and lower outlet valves are closed, and the lower inlet and an upper outlet valve, opening into an outlet pipe on the farther side of the cylinder, are opened. The piston then returns to the upper end, moving the slits to their opposite extreme positions. The full run of the slits is about 3¼ inches, corresponding with the aperture of the telescopes to which they are attached.

Although the spectroscope has been previously described, it may be as well to recall the general features of its construction, which has recently been modified. New objectives, corrected for the K line, have been supplied for the collimator and observing telescopes. In aperture (3¼ inches) and focal length (42½ inches) they are identical with the visual objectives formerly used, and they can be readily replaced by these for work in the visual region. A photographic objective of 85 inches focus is also available for photographing the spectrum, and for its accomodation the short section of tube carrying the second moving slit at the end of the observing telescope can be unscrewed, and a tube about 42 inches long, with a plate-holder at one extremity, screwed on in its place. The same plate-holder can also be used with the short focus objective, and the section of tube carrying the holder screws on for this purpose in place of the long tube. The observing telescope is focussed from the eye-end by a screw moving the objective along the axis of the tube. The Sun's image is brought to focus on the first slit by a motion of the entire collimator through collars in the supporting frame of the spectroscope. The Rowland grating has 14,438 lines to the inch, and is covered by a brass box. It can be rotated about an axis parallel to the lines of the ruling by means of a tangent screw in connection with a rod leading to the eye-end of the observing telescope. It is also supplied with the other usual adjustments. The whole spectroheliograph can be rotated about the axis of the collimator by means of a rack and either one of two pinions in the supporting ring, and the direction of the slit is shown by the moving index of a large fixed position circle. The moving slit on the collimator can be easily replaced by the excellent fixed slit formerly used. This has recently been much improved, and fitted with new pairs of straight and curved jaws, as well as a prism behind the slit, for use in accurately setting the instrument on a small object.

Although made as light as is consistent with thorough rigidity, the spectroheliograph weighs about 250 pounds. But as the mounting of the equatorial was constructed with this fact in view, the instrument is carried with great ease and smoothness.

I cannot speak too highly of the care and accuracy with which Mr. J. A. Brashear has constructed the entire apparatus. To his skillful foreman, Mr. George Klages, much credit is due for the excellent manner in which he has worked out many features of the design. I am also indebted to the experience in hydraulic engineering of Mr. T. E. Brown, for important suggestions as to the improved form of clepsydra.

Though the spectroheliograph is apparently somewhat complicated, its manipulation is extremely simple. The method requires that the first slit move gradually across the image of the Sun at the focus of the equatorial, while the second slit moves at such a rate that the K line constantly falls upon the fixed photographic plate. Images of any regions on the Sun in which the K line is reversed must then be obtained upon the sensitive surface, requiring only the ordinary method of development to permanently register them.

To make the use of the instrument clear I will describe the operation of photographing the prominences around the circumference of the solar disc. The center of the Sun's image formed by the equatorial (this image is about 2 inches in diameter) is made to coincide with the axis of the collimator, and maintained in this position by the driving-clock. The whole spectroheliograph is then rotated until the slit is parallel to the Sun's axis.

The dust lines, which are unavoidable in the spectrum when a narrow slit is used, are thus made to indicate the direction of the solar equator in the photograph. After having moved the collimator tube until the scale reading indicates that the first slit is at the focus of the equatorial for K, and the objective of the observing telescope until it is in focus for the same line, the slits are brought to the center of the field by opening the proper valves in the clepsydra. While observing the spectrum through the second slit with a positive eye-piece (the plate-holder being supposed removed) the grating is rotated until the region of the green in the third order spectrum which overlies the K line in the fourth order is seen in the middle of the slit. (This adjustment can be made once for all, for by next noting what line in the green falls on the cross-hair while observing the spectrum with the small diagonal prism described above, it is only necessary for subsequent exposures to set this line on the cross-hair, when K must pass through the second slit. For the prism moves with the slit, and the distance between them is constant in all positions of the latter. This allows all future settings on the K line to be made when the photographic plate is in place.) The direct light from the greater portion of the Sun's disc is then excluded by a circular diaphragm slightly smaller than the solar image, supported just in front of the first slit; the piston is run to the upper end of the clepsydra; the micrometer head of the gate-valve set at the proper reading; the plate-holder placed in position, the slide drawn, and the holder pushed forward into the focal plane by turning the cam; the proper valves of the clepsydra are opened, and as the slit sweeps across the middle of the field the moment of the exposure is recorded in the note-book. On developing the plate all the prominences around the entire circumference of the Sun are found in their proper forms and positions.*

Anyone familiar with the spectroheliograph can easily make all the adjustments and secure a photograph of the prominences in less than two minutes time. After the first photograph as many as are desired may be taken at intervals of about one minute. To say nothing of the gain in accuracy, the great saving of time

---

* Subject, of course, to the distortion which the grating produces in the plane of dispersion. Using the K line in the fourth order, the Sun's disc with the present instrument is an ellipse, with its minor axis in the plane of dispersion. The distortion does no harm in plates intended for measurement, as it may readily be allowed for. I have devised several methods, mechanical and optical, by which the circular form of the image may be restored. One of the simplest and most satisfactory of these is to use no driving-clock in photographing, but allow the Sun to move across the field during the exposure, in the same direction with the first slit. The speed of the slit then determines the form, and sharply defined circular images have thus been obtained.

is apparent when it is remembered that so skillful an observer as the late Father Secchi estimated that one hour is required to properly record all prominences around the circumference by the ordinary method. Our record may now be unbroken even on days when clouds prevent an hour's observation. Moreover, on clear days several photographs may be obtained in the morning and afternoon. As many prominences last but a few hours or even minutes, this is important. At present I do not know that more than one complete record of all prominences is made in a single day at any observatory, even under the clear skies of Italy.

But the great advantage of photography is most apparent during the sudden and short-lived eruptions, with which all solar observers are familiar. At such times I leave the visual observations of the phenomenon entirely to my assistant—who employs the 4-inch equatorial and small grating spectroscope—and spend my time making photograph after photograph, thus securing a most complete and accurate record of the development and dissolution of the prominence.

Let us now consider another class of solar phenomena, for the registration of which the spectroheliograph has proved to be of great value. I refer to the faculæ.

In his catalogue of the bright lines in the spectrum of the chromosphere, published in 1872,* Professor Young remarks as follows in regard to the H and K lines: "They were also found to be regularly reversed upon the body of the Sun itself, in the *penumbra and immediate neighborhood of every important spot.*" The observations referred to were made under the exceptional atmospheric advantages enjoyed at the summit of Mount Sherman, but even with the less favorable conditions common at the sea-level, the same observer has repeatedly made out similar reversals in many spots. I do not know that these observations were confirmed elsewhere until the photographs made at this Observatory in April, 1891, brought out the same thing with great clearness. A few months later Professor Young secured at Princeton some photographs of the reversals, but my own attention has, until recently, been so fully occupied with work on the prominences that I have had but little opportunity to go on with my proposed photographic study of spot spectra. Late in December, however, I secured some photographs of the spectrum of a spot in which the lines were so sharply defined that they were given a very careful examination. Not only were the

---

* *American Journal of Science*, Nov. 1872.

bright lines at H and K more prominent in the penumbra than in the umbra of the spot, but their extent in the surrounding region was so great as to arouse the suspicion that similar reversals might be found on the disc, at points remote from spot regions. To test this idea, a series of six photographs of the spectrum was taken, the slit in each case being placed parallel to the position it had occupied during the exposure just preceding, and about 3′ distant from it. My expectations were not only realized by these photographs, but greatly surpassed. In each of the six positions of a slit not more than 0.002 inch wide the K line was reversed in from three to ten places. H was, without doubt, similarly affected in all of these points, but in some cases it was too faint to be certainly seen. Most, if not all, of these reversals were double, *i. e.*, a dark line ran through the center of the bright line, as is frequently observed in the spectrum of the electric arc. I have since suspected in several cases a strengthening of the broad dark absorption bands of the solar spectrum for a short distance on both sides of the bright reversals.

Having thus found the surface of the Sun to be dotted over with regions in which the H and K lines are bright, I at once concluded that the *forms* of the reversed regions might be photographed with the spectroheliograph, in exactly the same way that prominences around the circumference are obtained. The first attempt to do this was made on January 12, when the adjustments of the instrument were incomplete, and connection had not been established between the accumulator and the clepsydra. In lack of more suitable motive power, the slits were moved by hand, and even in this way bright forms near a spot group were shown on the photographs, though they could not be seen with the helioscope. The completion of the apparatus a few days later enabled me to secure very good photographs of the bright regions, and on comparing them with drawings and photographs, taken in the ordinary way, of faculæ near the limb, it was found that the forms were identical.

The great advantage of the new method of photographing faculæ is at once evident. Taking little account of the difference in brilliancy between the limb and the center of the Sun's disc, it allows us to photograph faculæ wherever they may be in the visible hemisphere. The investigation of these objects has heretofore been so restricted, that it may be truly said that we are now enabled, for the first time, to study them with any degree of completeness.

One of the most interesting and important of all the solar questions with which we have to deal is the relation existing between spots, prominences and faculæ. In the long discussion in the *Comptes rendus*, in which M. Faye vigorously defended his theory of Sun-spots against all comers, he stoutly maintained that prominences and faculæ result from spots and pores, while his opponents, MM. Secchi and Tacchini, were as fully convinced that we must look to faculæ and prominences for the true explanation of spots. Both parties agreed, however, that faculæ are often the sources from which prominences spring, and this conclusion is sustained by the first results obtained photographically. In the large number of plates already secured, there are many instances in which faculæ at the limb are shown to project a short distance above the boundary of the photosphere. Indeed, though the prominences usually require a slower motion of the slit, and consequently a longer exposure, than that which is most suitable for faculæ, in several cases they have been bright enough to appear on plates where only faculæ were expected. As both have the same bright lines in their spectra, and both project above the level of the photosphere, a facula might almost be defined as a small prominence possessing a continuous spectrum in addition to its bright lines.

But while it is not difficult to separate the two classes of phenomena at the Sun's limb, the distinction becomes much less evident, or even disappears, when they are photographed in projection on the disc. Given a *sufficiently bright prominence* at any point on the visible hemisphere, and the spectroheliograph cannot fail to show its form as well as those of the faculæ. A possible instance of this kind was given in my paper on the great spot-group of February, 1892 (ASTRONOMY AND ASTRO-PHYSICS, April, 1892). The forms of the bright regions in the midst of the spot-group as observed through the C line, and photographed through K, were found to agree. It has usually been assumed that the reversed regions, which have occasionally been seen in this way near spots, were prominences. I see no reason why they may not be equally well regarded as faculæ, for, like H and K, C is bright in both. As faculæ do not, as a rule, undergo rapid variations in form, a criterion may perhaps be found in this fact, for bright prominences are usually active ones. I have already mentioned that the bright H and K lines on the disc have as yet given no indication of motion in the line of sight, and this may point to their origin in faculæ, rather than in prominences. It seems probable that ordinary prominences cannot be seen when projected on the disc, as their temperature may be lower than that of the brilliant background.

At the meeting of the Chicago Academy of Sciences on April 12, 1892, I presented a preliminary note on the forms of the faculæ, as they are shown in the daily series of photographs obtained with the spectroheliograph. My attention was first directed to this subject by a remarkable facula photographed in the central region of the great spot group, as it appeared at the Sun's eastern limb on February 4, 1892. In shape this facula was similar to the letter S, one extremity of which terminated abruptly in a small but brilliant circular expansion. On looking over other plates to see whether curved forms occur frequently in faculæ, I was surprised to find several well-marked cases in every negative. This led to an examination of all the photographs of faculæ in our collection. Of 137 negatives, taken between January 22 and April 12, 49 were selected. These, with one or two exceptions, were obtained on different days. The remaining 88 were either taken on the same days with some of the above, or injured by clouds, etc., and they were therefore left out of consideration. On the 49 plates, 245 cases of smooth curves in the forms of faculæ were noticed on casual inspection, and in 98 cases the curved faculæ terminated in bright circular heads. Spiral forms were found to be not uncommon, but the form which appears in the vast majority of cases is like that of a figure 3, the open side facing in an easterly much more frequently than in a westerly direction. Of the intimate relation of such faculæ with the spots which they often enclose I shall be able to write more intelligibly in a future paper, which I hope to accompany with reproductions of some of the photogaphs.

Most of the following daily series of photographs are now in progress at the Kenwood Observatory, and the others will very shortly be undertaken:

α. Photographs of the Sun with a 12-inch photographic objective and enlarging lens, for sbots and granulation. Diameter of image between 10 and 16 inches.

β. Photographs of the Sun with the spectroheliograph; for faculæ and bright prominences on the disc. Diameter of image = 2 inches. (The general forms of spots are also shown on these plates.)

γ. Photographs of the Sun with the spectroheliograph; for chromosphere prominences around the circumference of the disc. Diameter of image = 2 inches.

δ. Photographs of the spectra of spots and faculæ with the 14,438 grating; for distortion, reversal and widening of lines.

ε. Photographs of the spectra of the chromosphere and prominences with the 14,438 grating; for reversal and distortion of lines.

While it is true that photography fails as yet to record the smaller details in prominences (as it also fails in the case of spots), the merely experimental side of the investigation has been fairly passed, and we have now entered upon the practical application of photographic methods in recording all of these various classes of solar phenomena.

KENWOOD ASTRO-PHYSICAL OBSERVATORY,
Chicago, April 15, 1892.

NOVA AURIGÆ.[*]

EDWARD C. PICKERING.

The new star in Auriga has now become very faint. It has been photographed at the Harvard College Observatory on about forty nights since December 10, 1891, and observed visually on about thirty nights since February 3, 1892. After undergoing slight fluctuations, it began to diminish in light during the latter part of February. It attained the magnitude 6.0 on the scale of the meridian photometer about March 4; 7.0, March 10; 8.0, March 13; 9.0, March 16; 10.0, March 20; 11.0, March 22; 12.0, March 25; 13.0, March 29; 14.0, April 6, and is now, April 13, of about the magnitude 14.3. After March 7 the cause of the outburst and fluctuations in light appeared to cease to act, and the star began to fade with such regularity that it promised to furnish a test of the correctness of Dulong and Petit's law of cooling. After three weeks, during which the light had diminished about six magnitudes, the change became less rapid and the light is now diminishing slowly. The remarkable increase of light of more than half a magnitude between February 16 and 17 was shown by various series of observations. The reality of several smaller changes can also be checked by the variety of methods employed.

The spectrum was last photographed on March 29, when the star had the magnitude 13, but the bright lines were not well shown after March 24, when the magnitude was 11.6. The prin-

---

[*] Communicated by the author.

cipal bright lines faded in the order K, H, α, F, h and G, the latter line becoming much the brightest when the star was faint.

A complete discussion of these measures will be published shortly. Observers are invited to send to the undersigned any comparisons they may have made of the light of the Nova with other stars. Observations are particularly desired on those nights on which it was cloudy at Cambridge.

HARVARD COLLEGE OBSERVATORY, Cambridge, Mass.,
April 14, 1892.

STARS HAVING PECULIAR SPECTRA.*

M. FLEMING.

A recent examination of photographs of stellar spectra taken with the 8-inch Draper telescope, at Cambridge, and with the Bache telescope under the direction of Professor Wm. H. Pickering, at the station near Arequipa, Peru, adds to our list of objects of interest the stars given in the following table. The successive columns contain the designation of the star, the approximate right ascension and declination for 1900, the magnitude, and a brief description of its spectrum. The date and station at which the photograph was taken are given in the last two columns.

Design.	R. A.	Decl.	Mag	Description.	Date.	Station.
	1900 h m	1900 ° ′				
DM. + 53° 379	1 38.7	+ 53 28	9.4	IV Type	Dec. 30, 1891	Cambridge.
DM. + 38° 2389	12 54.7	+ 38 20	8.6	IV Type	Mch. 28, 1892	Cambridge.
Z. C. XV*h* 4129	16 0.6	— 25 57	8½	V Type	Aug. 5, 1891	Arequipa.
A. G. C. 24550	17 57.7	— 24 22	6.1	F line bright	Aug. 2, 1891	Arequipa.
DM. — 11° 4593	18 13.5	— 11 40	8.7	V Type	July 14, 1891	Arequ
DM. + 61° 2233	21 57.6	+ 62 0	7.0	F line bright	Feb. 18, 1892	Cambridge.

The spectra of the third and fifth stars in the above list are of the same class as those given in the list published in the *Astronomische Nachrichten*, Bd. 127, p. 3, and they increase the number of these objects to 40. The galactic longitudes of these two stars are 290° 39′ and 347° 36′ respectively; their galactic latitudes are +17° 39′ and +0° 35′. The spectrum of the fourth star shows other bright lines besides F.

An interesting change has taken place in the spectrum of 11 Monocerotis (H.P. 1220), magn. 4.2, whose approximate posi-

---

*Communicated by Edward C. Pickering, Director Harvard College Observatory.

tion for 1900 is in R. A. 6^h 24.0^m, decl. —6° 58′. A bright line near F changes its position with regard to that line in a manner similar to the bright lines in β Lyræ. Photographs taken with the 11-inch Draper telescope on Dec. 14, 1888, Dec. 23, 1889, and Jan. 22, 1890, show this line as having a shorter wave-length than F, while those taken on Feb. 16, 1892, and Feb. 18, 1892, show it as having a greater wave-length. A detailed study of this object will be made.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., April 14, 1892.

THE TRUE FORM OF ALGOL'S LIGHT CURVE.[*]

J. PLASSMANN.

During the winter of 1890-91 I observed Algol not only at times of minima, but also, whenever this was possible, several times every clear evening. In all cases the star was compared with three comparison stars—α Persei, γ Andromedæ and ε Persei. On moonlight nights no observations were made. Ordinarily I did not know how far Algol was from a minimum. The observations[†] were carried on up to March, 1891, after which the constellation was too near the horizon.

The method of observation has the advantage that it is independent of the scale of the comparison stars. For if the three algebraic differences, $\beta - \alpha$, $\beta - \gamma'$, $\beta - \varepsilon$, have been determined by the observations, then:

$$\tfrac{1}{3}[(\beta-\alpha)+(\beta-\gamma')+(\beta-\varepsilon)]=\beta-\tfrac{1}{3}(\alpha+\gamma'+\varepsilon)=s.$$

The zero-point for s is thus the arithmetical mean of the brightness of the three comparison stars. I have used the same method advantageously for a number of variable stars with slight light-changes, *e.g.*, α Cassiopeiæ, η Geminorum, λ Tauri, β Pegasi, δ Orionis, μ Cephei.

To my eye the differences Algol—ε Persei, and Algol—γ Andromedæ are generally positive; β Persei—α Persei is generally negative. The *times* of observation were then reduced to Paris time and to the Sun; several observations and times of observations were united into means after the times had been arranged according to the *phase*, *i. e.*, the time elapsed since the last minimum. The values are given in the following table:

---

[*] Communicated by the author.

[†] See my paper, "Beobachtungen veränderlicher Sterne, III. Theil." Cologne, 1891.

Phase:	$3^h\,39^m$	$10^h\,44^m$	$21^h\,1^m$	$35^h\,57^m$	$45^h\,43^m$	$58^h\,30^m$	$65^h\,8^m$	$66^h\,2^m$
s	$+0.58$	$+2.59$	$+2.30$	$+2.56$	$+2.47$	$+2.62$	$+1.30$	-2.76
n	10	41	37	35	31	52	11	6

Sum: 223 observations or 669 estimates.

Here s has the signification mentioned above; n is the number of observations, each of which consists of three estimates.

The figures appear at first glance to run very irregularly. Some weeks ago I first saw Herr Scheiner's pamphlet: "Untersuchungen ueber den Lichtwechsel Algols nach den Mannheimer Beobb. von Professor Schoenfeld in den Jahren 1869-1875." From this pamphlet, which was published at Bonn in 1882, it appears that Schoenfeld made 357 observations of Algol at times other than minima with a view of discovering a possible variability of Algol during the 60 hours in which it was formerly considered to be constant. Each observation consists of two estimates, so that 714 estimates are given in all, while my 223 observations represent 669 estimates. Consequently I venture to believe that my observations are somewhat more reliable than those of my late teacher, because Schœnfeld's notes are scattered over a longer time, and because my observations were only made when there was no disturbing influence of moonlight, while Schoenfeld evidently observed even in the moonlight. Forming means by the same method that I have myself employed more recently, (see page 13 of his pamphlet) Scheiner finds "that the full light of Algol can be regarded as entirely constant during the mean course of a period." Scheiner united his observations by tens (20 estimates) to form a single mean. A further contraction of these figures, however, gives the following table, in which n is as before, while N is the step according to Scheiner's scale:

Phase:	10^h	20^h	30^h	40^h	50^h	59^h
N :	20.41	20.36	20.40	20.44	20.41	20.45
n :	60	60	60	60	60	57

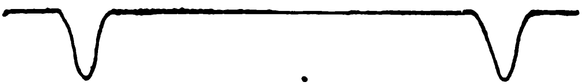
Here a minimum at 20^h is at once evident. The question then arose whether my own observations might not be united with Schoenfeld's. After several trials I found the equation:

$$N = 19.497 + 0.37s.$$

Reducing my values of s to the scale of N by the aid of this equation, the following table results, in which Schoenfeld's times and mean values are somewhat more accurately given than in the one above.

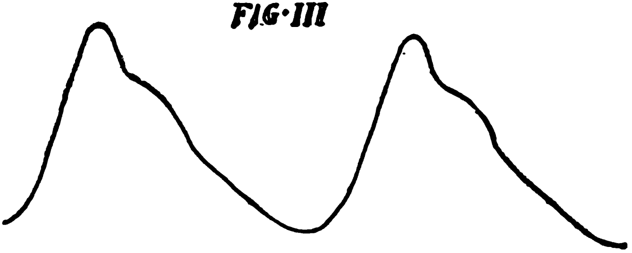
Phase.	Brightness Schoenfeld.	Number of Observations.	Brightness Plassmann.	Number of Observations.
7^h 25^m	20.360	30		
10 44			20.455	41
12 20	.463	30		
19 52	.355	60		
21 1			.348	37
29 48	.403	60		
35 57			.444	35
39 50	.438	60		
45 43			.411	31
49 20	.412	60		
57 11	.490	30		
58 30			.466	52
61 45	.397	27		

FIG·I

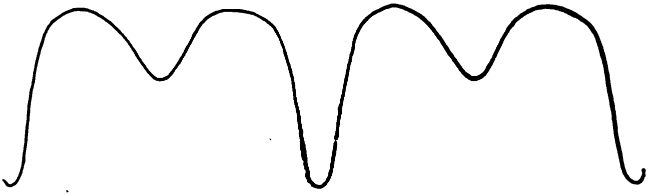


FIG·II

FIG·III



FIG·IV



It is at once evident that both sets of observations follow the same law. It may therefore be regarded as proved that Algol during the time of its full light undergoes certain variations, such as are shown in *Fig.* 2.

In this curve the light-changes are shown on a scale 250 times as great as that used in *Fig. 1*, which is the general curve of Algol according to Scheiner. The curve seems to have three maxima and three minima, as follows:

Minimum.	Maximum.
$0^h\ 0^m$	$12^h\ 30^m$
21 36	37 12
47 0	57 40

These points divide the curve into six nearly equal parts; exactly equal divisions would give:

$0^h\ 0^m$, $11^h\ 28^m$, $22^h\ 56^m$, $34^h\ 24^m$, $45^h\ 52^m$, $57^h\ 20^m$, $68^h\ 48^m$.

This result recalls the light-curve of β Lyræ, (*Fig. 4*, from Argelander's *Commentatio altera*) being divided by its maxima and minima into four nearly equal parts. But perhaps this agreement is only accidental. The slight undulations in Algol's brightness also recall the inflections in the descending branch of the curve of δ *Cephei* (*Fig.* 3, *after Heis*) and η Aquilæ.

Earlier observations by Schoenfeld are given in his article "Der Lichtwechsel der Sterner Algol in Perseus." (36. Jahresbericht der Mannheimer Vereins für Naturkunde.) They were made between 1859 and 1870; the mean values are given in the following table:

	h	h	h	h	h	h	h
Phase:	7.57	20.17	28.19	39 31	47.89	54.63	60.59
N'	20.77	20 58	20.88	21.10	21.04	21.04	20.73
N obs.:	20.393	20.365	20.410	20.443	20 434	20.434	20 432
n:	5.	5.	5.	5.	5.	5.	5.
N comp:	20.380	20.351	20.388	20.439	20.408	20.454	20.390
Comp.-obs.:	− 0.013	− 0.014	− 0.022	− 0.004	− 0.026	+ 0.020	− 0.042

Here N' is the brightness on Schoenfeld's earlier scale; its mean = 20.88, while Scheiner's mean = 20.41. The equation of reduction is

$$N = 20.41 + 0.15(N' - 20.88),$$

by means of which the third line (N, obs.) has been calculated. Every value is the result of 5 observations ($n = 5$); their accuracy cannot therefore be regarded as very great. The curve (*Fig. 2*) gives the values in the last line but one (N, comp.); the difference (comp.-obs.) is evidently not very marked, though N' is the result of only 5 observations. In Zoellner's "Grundzuegen einer allgemeinen Photometrie der Himmels," 4 *photometric* observations of Algol are given, each the mean of 4 measures, and all made, curiously enough, during the time of full light. In the first two cases Algol was compared with ω Persei, in the third with $\varkappa$ Persei; this case could be reduced to the others by the equation

$$\log\frac{\beta}{\varkappa} + \log\frac{\varkappa}{\omega} = \log\frac{\beta}{\omega}.$$

But the fourth observation (1860, Sept. 27), in which Algol was compared with δ Persei, could not be used, on account of a lack of information in regard to the comparison star.

Time.	*Phase.*	$\log\frac{\beta}{\omega}$	*N.*	*N.''*	*N–N.''*
1859, Dec. 15, $6^h\ 7^m$	$39^h\ 16^m$	0.97196	20.438	20.433	+ 0.005
1860, Jan. 12, 9 15	26 15	0.91444	20.370	20.366	+ 0.004
1860, Aug. 18, 12 1	54 59	1.00285	20.459	20.469	− 0.010
Mean:		0.96308	20.4223		

The above table gives Zoellner's times of observation reduced to Paris time and to the Sun, which, though possessing no great degree of accuracy, will suffice for our purpose. From them the phases were deduced, based on the minimum of 1856, Dec. 13, $7^h\ 59^m\ 31^s$ (Argelander B. B. VII, p. 38). The next column gives $\log\frac{\beta}{\omega}$ as deduced by Zoellner. For the third observation Zoellner took $\log\frac{\beta}{x}=0.64954$; taking account of the weights I find from many other determinations by Zoellner that $\log\frac{\omega}{x}=0.35331$, so that $\log\frac{\beta}{\omega}=1.00285$. The fourth column gives N, taken from my curve. By the aid of the mean, as well as the three values of N, and also Zoellner's three logarithms, the equation of reduction is readily found to be

$$\frac{\log\frac{\beta}{\omega}-0.96308}{10^{9.93420-10}}=N''-20.4223,$$

by means of which the logarithms may be reduced to the scale fo N. The values of N'' thus found are given in the fifth column, and the small amount of the difference, $N-N''$, may be regarded as a photometric confirmation of the determinations obtained by an entirely different method. The probable errors of his logarithms, given by Zoellner, are much smaller than the amounts of the variations, and his attention ought to have been aroused by this fact. Log $\frac{x}{\omega}$ is indeed shown by the various determinations to vary considerably. But the probable errors are perhaps larger than this astronomer believed.

Besides my own observations during the winter of 1890-1891 Herr Pannekock of Leyden, Holland, made some observations of Algol during its times of full brilliancy, but they are not yet numerous enough. It is very desirable that as many as possible accurate photometric observations be made.

To explain the changes in Algol's full light, atmospheric tides in the principal star may be suggested, and also a faint light proper to the satellite. A comparison of Zoellner's figures with my own and Schoenfeld's early and more recent ones shows that the amplitude of the variations is different in different years. But the reality of these differences may be doubted, as they may be caused by the methods of observation.

WARENDORF (Westfalen, Germany), 1891, Dec. 2.

ON THE DISTRIBUTION IN LATITUDE OF SOLAR PHENOMENA OBSERVED AT THE ROYAL OBSERVATORY OF THE ROMAN COLLEGE, DURING THE SECOND HALF OF 1891.*

P. TACCHINI.

The following results were determined for each zone of 10°, in both hemispheres of the Sun:

PROMINENCES.

1891.	Third Quarter.	Fourth Quarter.
90° + 80°	0.001	0.000
80 + 70	0.000	0.007
70 + 60	0.003	0.024
60 + 50	0.122	0.173
50 + 40	0.133	0.088
40 + 30	0.076	0.072
30 + 20	0.120	0.068
20 + 10	0.055	0.059
10 . 0	0.042	0.042
	0.552	0.533
0 – 10	0.020	0.018
10 – 20	0.038	0.066
20 – 30	0.077	0.085
30 – 40	0.111	0.083
40 – 50	0.112	0.101
50 – 60	0.085	0.096
60 – 70	0.004	0.018
70 – 80	0.001	0.000
80 – 90	0.000	0.000
	0.448	0.477

FACULÆ.

1891.	Third Quarter.	Fourth Quarter.
50° + 40°	0.000	0.007
40 + 30	0.027	0.051
30 + 20	0.259	0.221
20 + 10	0.324	0.272
10 . 0	0.114	0.088
	0.724	0.639

---

* Communicated by the author.

1891.	Third Quarter.	Fourth Quarter.
0 — 10	0.016	0.015
10 — 20	0.108	0.118
20 — 30	0.108	0.206
30 — 40	0.038	0.022
40 — 50	0.006	0.000
	0.276	0.361

SPOTS.

1891.	Third Quarter.	Fourth Quarter.
40° + 30°	0.000	0.000
30 + 20	0.250	0.271
20 + 10	0.472	0.390
10 . 0	0.014	0.017
	0.736	0.678
0 — 10	0.000	0.017
10 — 20	0.125	0.169
20 — 30	0.111	0.136
30 — 40	0.028	0.000
	0.264	0.322

ERUPTIONS.

1891.	Third Quarter.	Fourth Quarter.
40° + 30°	0.053	0.000
30 + 20	0.368	0.000
20 + 10	0.263	0.000
10 . 0	0.105	0.000
	0.789	0.000
0° — 10°	0.000	0.000
10 — 20	0.105	0.000
20 — 30	0.053	0.000
30 — 40	0.053	0.000
	0.211	0.000

The solar prominences were thus more frequent in the northern hemisphere, while in the preceding quarter, as in 1890 and 1889, a greater frequency was always found in the southern hemisphere of the Sun. The *faculæ* were also more numerous north of the equator, and the maximum of frequency occurred in the zones (± 10° ± 30°), that is to say, in lower latitudes as compared with the prominences than was the case in the preceding quarter. The spots followed the same rule as the faculae, being most abundant north of the equator, with the maximum of frequency in the zones (± 10° ± 30°). All the phenomena, including the eruptions, were most frequent in the northern hemisphere, and very feeble in the neighborhood of the equator and near the poles.

ROME, Italy, March, 1892.

THE DISTRIBUTION OF THE SOLAR PROMINENCES OF 1891.*

J. EVERSHED, JR.

In working out the relative distribution in latitude of the prominences observed by me in 1890, it was found that there was a well marked maximum of activity between the parallels of 40 degrees and 50 degrees on both sides of the equator. Besides this, other secondary maxima and minima were indicated in lower latitudes, which gave a wavy contour to the curve representing graphically the relative activities at the different zones. These lesser irregularities in the curve were thought at the time to be simply the result of insufficient observation, and that if the Sun could have been observed every day, instead of an average of only once in four the decrease in activity from the maximum to the equatorial minimum would have appeared far more regular.

But as further observation has tended rather to intensify than smooth away these peculiarities, I have thought it might be of some interest to put on record the results so far obtained.

A much more extended series of observations has been obtained during 1891. Mr. E. E. Read, of Camden City, New Jersey, using a 5-inch refractor and grating spectroscope, has observed the prominences during four months of the year, and he has kindly sent me the results obtained, which I have included with my own observations.

At Kenley, using a 2½-inch equatorial, armed with a spectroscope of 6 prisms, and circular slit, I have observed the Sun completely, as regards the prominences, on 123 days, and imperfectly on 11.

From the positions obtained it is found that the main features of the curve of 1890 are still maintained. In both years there are shown two principal maxima in the northern hemisphere, separated by a very pronounced minimum, whilst south of the equator there are three points of maximum.

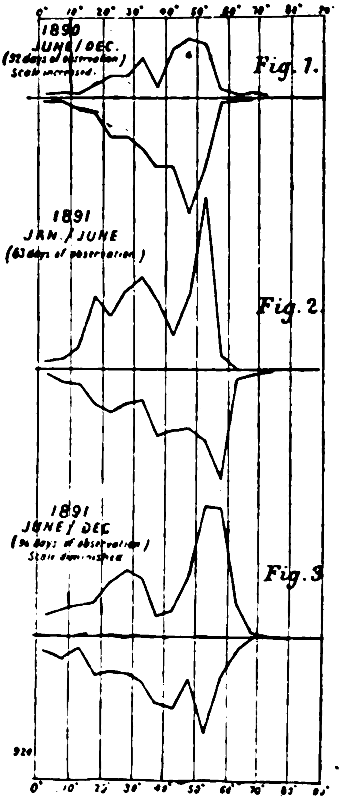
In order to bring out any slow changes which may be in progress in the latitudes of these zones of greater activity, I have worked out three separate curves each representing equal periods of six months, beginning in July 1890 and ending December, 1891.

In the diagrams, Figs. 1, 2 and 3, solar latitude is represented in a horizontal direction, the equator on the left hand and the poles on the right, the north hemisphere being above the

---

* In the Journal of the British Astronomical Association.

horizontal line and the south below it. The distance of any point on the curve from the horizontal line is measured by the total number of prominences observed between each five degrees of latitude, multiplied by their average estimated magnitude.



In order to make the three curves strictly comparable the vertical scale is made inversely proportional to the number of days of observation, so that the length of the ordinatés also represents the average activity per diem of the various latitudes during the specified period.

From these diagrams it will be seen that the principal feature of the 1891 prominences is the great increase in the activity of the northern zones as compared with 1890. This increase is, in fact, so marked as to produce a considerable total balance in favor of the north hemisphere, whilst in 1890 the south took the lead. In this respect the prominences seem to have been influenced by the same cause that produced a change in the distribution of the spots from south to north, to which the Director of the Solar Section calls attention in her interesting summary of the solar phenonena of 1891.

The following table exhibits the relative activity of the two hemispheres, 100 representing the total activity:

	Weighted.		Not Weighted.	
Period.	North	South	North	South
1890, July-December	37	63	41	59
1891, January-June	55	45	53	47
1891, July-December	56	44	55	45

In the second column the prominences are "weighted" according to their estimated size, and in the third the relation is shown by taking the total numbers observed, without allowing for size. In the latter the difference between N. and S. is a little less in each case which shows that the prominences were, on the average, larger in the hemisphere where the greater number was seen. This is found to be an almost invariable rule, and the points at maximum activity in the diagrams are therefore a little higher than they would have been had they simply represented the numbers observed unmodified by magnitude.

Another interesting feature shown is the advance towards the poles of the large high latitude prominences. In the northern hemisphere the principal maximum was between 40° and 45° during the first six months of 1890, and between 45° and 50° in the latter half of that year (*see* Fig. 1.). From January 1891 to June it advanced to between 50° and 55° (Fig. 2.), whilst in the last period (Fig. 3.) prominences were equally numerous and large between 50° and 60°. It is remarkable that the secondary north maximum between 30° and 35° has remained nearly stationary and has even receded a little towards the equator since June 1891, the result being a considerable widening of the intermediate minimum at about N. lat. 40°.

In the south the advance polewards has been less regular, starting in 1890 opposite the north maximum the most active zone advanced 10° in the second period (Fig. 2.), then receded 5° in the third whilst the two secondary zones in intermediate latitudes have remained nearly stationary.

In the equatorial regions prominences have been rare until the latter part of last year, when a considerable increase took place; but within 25° of the poles there has been a complete absence of them. Occasionally a little jet or cloud is seen, rising, perhaps, 20″ above the chromosphere, and lasting a few minutes only; but these can hardly be called prominences; about a dozen in all have been seen during the year, none, however, within 6° of either pole.

No distinction has been made in the diagrams as to the various classes of prominences. Those of the metallic and eruptive kind have always occurred in the spot zones, but have only rarely been seen. On May 31 an exceedingly brilliant metallic prominence was on the W. limb, in N. lat. 19°, the form of which could be made out in the sodium and magnesium lines; also a line not previously seen, between B and C,* was strongly reversed. The hydrogen lines in this prominence showed bright extensions of equal length on each side, reaching in the case of D_3 half way towards D_2. After an interval of 51 days (July 21) a very similar display was again seen on the W. limb, N. lat. 24; this was much better seen by Mr. Read, at Camden, N. J., who writes me that it was the brightest he had ever observed. It is rather

---

* The position of this line was not accurately ascertained, but it was probably the line at 6677 of Ångström's scale.

curious that another 51 days brings another bright metallic prominence on the N.W. limb, viz., that seen at Stonyhurst on September 10 (N. lat. 21°) accompanying the great spot group then on the limb.

Finally, on September 24, when the same spot region was on the E. limb, a bright dense prominence was seen there (in N. lat. 17°) which reversed Na and Mg very distinctly.

Large prominences of the eruptive order were observed on the following dates, all north of the equator, June 19 (described in Vol. I No. 9 of this Jounal), July 9, N. lat. 28° E. limb, and October 13 near the equator on the W. limb. The latter may have originated in a higher latitude, it appeared like the flying *debris* of a great eruption, and showed a great velocity of approach in the highest filaments, C being displaced towards the blue by about 5 tenth-metres, which would correspond to 140 miles per second. In connection with the disturbance of June 17, described by M. Trouvelot, it may be interesting to state that the Sun was observed here on that date from7 A. M. to 9. Nothing unusual was, however, seen on the disk (up to 8 A. M.), but a very brilliant and remarkable prominence was on the W. limb (P. A. 278° to 286°.) This had nearly died away at 8.55, when it was thought that the sun might safely be left to himself for the rest of the day, and observations were unfortunately discontinued.

With regard to the long duration of the disturbances which produce the quiet high latitude prominences, observations last year have confirmed those obtained previously. Some time during February a prominence was developed between 49° and 52° N. lat., and in a longitude that was on the E limb on February 21, and this re-appeared with great punctuality every 14 days on alternate limbs. It was seen on March 5 and every subsequent semi-rotation till June 28. On April 18 it had apparently attained its greatest size and brightness, and occupied three or four days in passing the limb. It is, perhaps, worth remarking that between the limits of the northern maximum, namely 45° to 55°, the region of longitude 180°, from this prominence, was quite devoid of prominences throughout the period February—June, and for a distance of about 120° in longitude. Also in the same latitude south of the equator a well-marked minimum is shown on this side of the sun (corresponding roughly to heliocentric longitude 300° to 55°.) This minimum does not extend to the lower zones, however, and the north equatorial prominences up to lat. 45° seem to be much more

---

*Journal of the British Astronomical Association.

numerous between long. 180° to 360° during the first half of 1891, but, like the high latitude prominences, they become more equally distributed in longitude later in the year.

The results obtained during the past two years with regard to the distribution in latitude do not seem to be quite in accord with the law discovered by Prof. Ricco, according to which one would expect to find both in hemispheres a well-marked maximum of activity, corresponding to the new series of prominences, and approaching the equator, while the old series in high latitudes approached the poles. This is perhaps indicated in the two well-marked zones of the northern hemisphere which may represent the two series; but south of the equator this relation is less obvious.

Perhaps some future observations may bring it out more clearly.

Kenley, Surrey, England.

PHENOMENA OBSERVED ON THE GREAT SPOT-GROUP OF FEBRUARY. 1892.*

JULIUS FENYI.

The enormous spot-group, which entered on the eastern limb of the Sun's disc on Feb. 5, gave evidence of remarkable activity during its transit, not only by continual variation in form, but also by special phenomena.

On Feb. 7, at 10^h Kalocsa Mean Time, distinctly rose colored spots such as P. Secchi has described, were certainly seen over the two members of the group, by means of both the helioscope and the projection apparatus. At this time the C line was seen in the spectroscope to be reversed over both nuclei (and on Feb. 10 over three nuclei), and as bright as the background of the spectrum outside the spot; *i. e.*, as bright as the photosphere itself appears in this line. The F line was also seen bright, but much less distinctly, and only in the preceding spot, in which the C line was also more brilliant.

Other lines were not reversed, D_1, D_2 and b_1, b_2, b_3 being quite normal. Small distortions of the C line were noticed over other parts of the group.

Reversals in C were seen near the Sun's limb as early as Feb. 5, at 10^h 47^m, but on the bright surface following the spot.

The time of passage of the center of the group over the west

---

*Communicated by the author.

limb of the Sun was determined by our calculations to be Feb. 19. The phenomena seen at this place with the spectroscope deserve particular mention. The base of a remarkably brilliant large prominence extended from position angle 219° 20′ to 216° 26′, and a few streamers rising from it met the limb again at 222° 32′.

The lower half of the prominence shone with an enormous brilliancy; the highest streamers were also so bright that the entire form could be seen with a widely opened slit, and its height was found by measurement to be 124″. The lower and dazzlingly brilliant half was the seat of extraordinary phenomena. At the middle of the base a bright band crossed the entire field of view; *the prominence gave a continuous spectrum.*

The width of this band was not far from 1½°—2°; its edges were not sharp but diffuse. I estimated its brilliancy as about 1½ times as great as that of the spectrum near the C line. The band was equally bright across the entire field of view, and ran through all the colors of the spectrum. The phenomenon was nevertheless not entirely new to me; on July 1, 1891, I saw for the first time a similar continuous spectrum in a prominence, but the appearance at that time showed itself only over a small breadth and height (*C. R.*, CXIII, August 17). In the present case the band appeared over an extended region, and at a distinct elevation above the Sun's limb, where it offered a very striking appearance. As I was measuring the height of the prominence by means of transits across the slit, I noted at the same time at what height in the prominence,—*i. e.*, at what time—the band was first visible. I naturally obtained values differing considerably among themselves in the seven transits, because the region which produced the continuous spectrum was not sharply bounded at its upper surface, and therefore the band only gradually appeared and disappeared. From the seven transits I found 25″.5 ± 3″.6 as the height of that part of the prominence which radiated white light.

We are hence justified in drawing the very remarkable conclusion, that in the midst of this prominence there was a dust-like (staubartige) mass, composed of solid or liquid particles, with a breadth of between two and three thousand miles, and a height of 2,400 geographical miles, which gave this faint continuous spectrum.

It might also be assumed that the gases in the center were so condensed as to give a continuous spectrum. The C line was, in fact, remarkably widened, and had a dark line running through the center, *i. e.*, a reversal. This reversal was very distinctly seen in [illegible] It may be mentioned here that the con- [illegible] visible in all the colors throughout the [illegible], *i. e.*, until 11h. The phenomenon re- [illegible] considered by M. Tacchini to be dust-like, [illegible] time have only been observed at solar [illegible] 1888, p. 41). It was not omitted to [illegible] form which appeared 1½ times as bright as [illegible] spectra of the atmosphere and corona, might not [illegible] Sun's limb without the aid of the spectrum. But [illegible] for this purpose by the assistant on the projected [illegible], and also with the helioscope, gave a negative [illegible] of a luminous form could be seen at the Sun's [illegible].

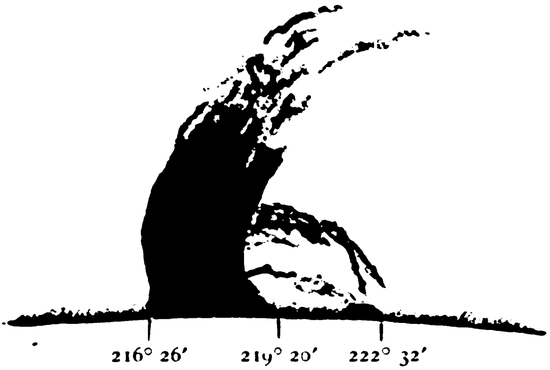
Another phenomenon, which, if not novel in character, was certainly so in brilliancy, was the appearance of large complete prominences in all of the metallic lines given in the following list, exactly in the position of the brilliant lower half of the prominence.

In most of these lines the prominence was so bright and sharp, that I could measure it through a widely opened slit with the filar micrometer. The form was the same in all the lines, and the details and structure were shown in the brighter ones. The height was also the same in all these metallic lines, which was easily determined by allowing the image of the prominence to move across the slit, and observing the simultaneous disappearance of the top of the prominence in all the lines in the same field of view.

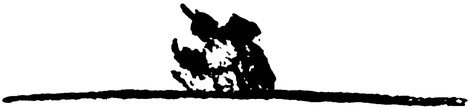
The prominence soon commenced to break up. When I completed the transits at 9h 39m the height in the C line had decreased to 95″, while the first transit, about 2m before, gave 106″. The same thing was true of the prominence in the line 6677; the first transit gave 62″ for the height, the last only 44″. The height of the region just described as giving the continuous spectrum, was, however, apparently increasing during the transits; but, on account of the ill-defined outlines of this object, this measure is too uncertain to be relied on. At 9h 44m I measured the height of the prominence in the red line 7055 with the micrometer, through a widely opened slit. The form and structure were particularly well seen in this line, even better than in 6677, and I found the height to be 39″, exactly the same in both lines. Immediately afterward I found in the sodium line D_2 that [illegible] 34″.5; the prominence was very brilliant in this line, and somewhat lower than in D_3. It should be noted that the prominence was at no time visible in the barium line 6140.5. This line [illegible] not even reversed at its base; there seemed to be only a [illegible] in the dark line.

About 9½h the height in the corona line was found with the

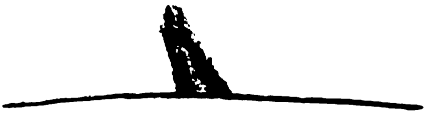
PLATE XVIII.



In C line. Feb. 17, 9^h 20^m. h = 124″.



In λ 6677. 9^h 44^m. h = 39″.4.



In Corona line (1474). 10^h 25^m. h = 33.″3

Plate accompanying Herr Fenyi's Paper on the Great Spot-Group of February, 1892.

Astronomy and Astro-Physics, May, 1892.

filar micrometer to be 33″; the very bright form showed two intense contiguous branches, inclined a little toward the pole, which corresponded exactly with two bright bands of the continuous spectrum running through them. This was also the case in all of the following lines.

At 10^h 38^m, the height of the prominence was once more measured in the 4923.1 line; I obtained 39″.7 as the result of three closely agreeing transits.

The following table gives the times in Kalocsa Mean Time. The wave-lengths will merely serve for identification in Angström's map, from which they, as well as the corresponding metals, have been taken. Under the remarks, the measured heights of the prominence are given in seconds; "M" signifies a micrometer measure, and "D" a measure by means of transits across the slit.

Time.	Line.	Remarks.
9^h 30^m	C	124″; M.
9^h 37–39^m	C	106″—95″; D.
9^h 37–39^m	6677	62″—44″; D.
9^h 45^m	70 . .	39″; M; very distinct.
	D_1 D_2	35″; very distinct.
10^h 22^m	D_3	46″; M.
	Corona	33″; M.
	5327 Fe	Line not seen with narrow slit. Prominence faintly visible with open slit.
	5323.4 Fe	
	5275	
	5269.5	Ca.
	5234.5	Co.
	5226.0	Fe.
	5207.7	Cr; all 3 very bright; 5201.8 not reversed.
	5205.2	
	5203.6	
	5197	Line itself not seen. Prominence only; exceedingly bright.
	5188.2	
	b_1, b_2, b_3, b_4	Ti; in this line the prominence is about 3 times as bright as in the next.
	5019.3	Ni.
	5016.6	Fe ?
	4945.5	Fe.?
10^h 38^m	4923.1	Te; 40″: D; about 3 times as bright in this line as in the next.
	4921	

No additional lines were seen in the region between 7055 and F.

In regard to the relation between this eruption and the great spot-group, the determinations of position show that, if we leave out of account the difference in longitude, the eruption took place at the edge of the southern spot nucleus, but entirely outside of it. Measures of the heliographic latitude showed the eruption to be between —31° 44′ and —34° 38′, while the heliographic latitude of the southern nucleus was calculated to be —29°.5 on Feb. 15.

According to the observations the center of the eruption seems to have been somewhat beyond the Sun's limb, that is, somewhat nearer to the preceding spot, the heliographic latitude of which was found to be —28°.4.

KALOCSA, Hungary, March 29, 1892.

[illegible]

[illegible] and other subjects [illegible] Ken- [illegible] are re- [illegible] illustrations, reprint

---

[illegible] article on [illegible] made it be- [illegible] the new star [illegible] be secured, and [illegible] important changes [illegible] have been learned

[illegible] made at the [illegible] of the spec- [illegible] indication. At He- [illegible] extending far [illegible] of bright [illegible] the white stars in Vo- [illegible] account of Professor [illegible] is given on [illegible]

[illegible] the spectrum [illegible] observatory. As the [illegible] the new 28-inch (not [illegible] than that of the 9- [illegible] Lassell [illegible] of the meridian, making a first [illegible] Mr. Lockyer succeeded in ob- [illegible] which were the following [illegible] dark lines—

[illegible] Academy contains a list of photo- [illegible] observatory, and notes a [illegible] Feb. 16. Professor [illegible] photographically and also with the [illegible] which indicate a slight [illegible] maximum values differ [illegible]

[illegible] photographs of the region about [illegible] diameters of the [illegible] 5 [illegible] and D.M. No. 899. "It [illegible] measured diameters of the [illegible] change in the brightness of the [illegible] between February 5 and 25, if we [illegible] on the 25th as the standard; [illegible] exposure, there would be [illegible] February 15 and 25."

[illegible]—In the accompanying table [illegible] in the Monthly Weather [illegible] days six hours and forty [illegible] by adding a day to [illegible] sixth day by adding a [illegible] each fourth period, and [illegible] beneath the table thus [illegible] to each thirty-sixth period, [illegible] as follows: The [illegible] a section showing [illegible] into as many [illegible] of the sun is considered to have [illegible] periods. The amount of [illegible] of sectors as there are days in each [illegible] in separate col- [illegible] upon each of these sectors [illegible] the year as given [illegible] of all sunspots at all observations [illegible]

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	¼	1-36	
1879 Jan. 3 to Jan. 29	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	1	.....	1	.....	1	.....	2	2	.....	.....	.....	1	.....	.....	.....	.....
Jan. 30 to Feb. 25	.....	.....	1	1	.....	.....	.....	1	.....	.....	.....	.....	1	1	2	1	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....
Feb. 26 to Mar. 25	.....	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	1	1	1	1	1	.....	.....	.....	3	1	1	1	2	.....	.....	.....	*
Mar, 26 to Apr. 21	1	.....	1	.....	.....	1	.....	1	.....	.....	.....	.....	1	2	1	.....	.....	.....	.....	2	.....	.....	1	.....	55	8	1	.....	.....	.....
Apr. 22 to May 18	1	1	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	1	.....	.....	.....	1	1	1	.....	.....	.....	1	.....	.....	.....	.....
May 19 to June 14	.....	2	1	.....	9	2	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3	4	4	1	.....	2	1	.....	.....	.....	.....
June 15 to July 12	1	2	34	5	3	.....	2	.....	1	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	2	2	.....	.....	*
July 13 to Aug. 8	.....	1	1	.....	2	2	2	.....	.....	.....	1	16	.....	.....	.....	1	.....	.....	2	1	.....	.....	.....	.....	2	3	1	.....	.....	.....
Aug. 9 to Sept. 4	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	5	.....	1	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....
Sept. 5 to Oct. 1	1	.....	.....	.....	7	24	10	3	3	.....	2	.....	2	1	3	4	3	2	2	3	3	1	1	.....	.....	.....	.....	.....	.....	.....
Oct. 2 to Oct. 29	.....	.....	.....	.....	3	17	.....	1	2	1	.....	.....	.....	.....	.....	1	1	2	.....	.....	1	.....	1	1	1	1	1	.....	.....	*
Oct. 30 to Nov. 25	.....	1	2	.....	2	.....	1	1	.....	.....	.....	1	2	3	2	2	1	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....
Nov. 26 to Dec. 22	1	.....	.....	.....	1	.....	.....	.....	.....	2	.....	8	6	1	3	3	3	.....	2	.....	.....	5	3	.....	.....	1	3	.....	.....	.....
Dec. 23 to Jan. 18	.....	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	.....	.....	2	2	.....	.....	2	.....	.....	.....	.....	1	.....	.....	.....	.....	.....
	26	20	.....	34	68	12	22	40	73	28	.....	.....	122	43	9	101	162	96	23	56	.....	9	.....	.....	28	21	88			
	33	31	.....	52	44	24	315	65	29	57	.....	.....	11	3	10	47	19	39	31	81	.....	.....	.....	.....	17	28	55			
	18	22	.....	23	.....	13	57	75	30	23	.....	.....	.....	46	12	34	137	56	26	58	.....	.....	.....	.....	.....	.....	16			
	10	33	.....	35	.....	25	282	70	.....	25	.....	.....	.....	3	9	12	6	52	31	172	.....	.....	.....	.....	.....	.....	7			
	.....	.....	.....	6	.....	.....	14	94	.....	5	.....	.....	.....	20	10	149	12	41	43	29										
	.....	.....	.....	6	.....	.....	172	46	.....	13	.....	.....	.....	.....	.....	20	162	29	34	138										
	.....	.....	.....	5	.....	.....	21	112	.....	.....	.....	.....	.....	.....	.....	135	12	18	11	.....										
					.....	.....	149	75								120	155	27	8	.....										
					.....	.....	59	98								.....	8	.....	.....	.....										
					.....	.....	164	101								.....	153	.....	.....	.....										
					.....	.....	64	105								.....	156	.....	.....	.....										
					.....	.....	163	90								.....	169	.....	.....	.....										
					.....	.....	150	60								.....	189	.....	.....	.....										
					.....	.....	120	81								.....	163	.....	.....	.....										
					.....	.....	102	8																						
					.....	.....	27	11																						
					.....	.....	23	9																						
					.....	.....	.....	10																						
					.....	.....	.....	137																						
					.....	.....	.....	38																						
					.....	.....	.....	236																						
					.....	.....	.....	131																						
					.....	.....	.....	56																						
					.....	.....	.....	226																						
					.....	.....	.....	232																						
					.....	.....	.....	211																						
					.....	.....	.....	265																						
					.....	.....	.....	219																						
					.....	.....	.....	217																						
					.....	.....	.....	160																						
					.....	.....	.....	92																						
					.....	.....	.....	105																						
					.....	.....	.....	5																						
					.....	.....	.....	58																						

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in Astro-Pysics, should be addressed to George E. Hale, Kenwood Astro-Physical Observatory, Chicago, U. S. A. Authors of papers are requested to refer to page 448 for information in regard to illustrations, reprint copies, etc.

The New Star in Auriga.—As will be seen from Professor Pickering's article on another page, the Nova has decreased so greatly in brilliancy as to place it beyond the range of spectroscopic observation. But the discovery of the new star was sufficiently early to allow a large number of photographs to be secured, and these are now in process of reduction. Of the interesting and important changes in the spectrum which we noted in the April number, we have, as yet, learned nothing further.

In addition to the visual observations of the Nova's spectrum made at the Lick Observatory, Professor Campbell secured some photographs of the spectrum with the 36-inch, and these will shortly be ready for publication. At Herény, Hungary, Herr Eugen von Gothard obtained a photograph extending far into the ultra-violet, and containing "an astonishingly large number of bright and dark lines." Among these "all the hydrogen lines of the white stars in Vogel's type *I a* are visible as bright lines." (A. N. 3078). An account of Professor Vogel's determination of the Nova's motion in the line of sight is given on another page.

In the *Monthly Notices* for March, Mr. Maunder has a Note on the spectrum of Nova Aurigæ, as it was shown in a photograph made at Greenwich. As the 12¾-inch refractor had been dismounted to give place to the new 28-inch (not yet completed), it was found necessary to attach an object-glass prism to the 9-inch photographic telescope. This instrument is carried by the heavy Lassell telescope, which shows considerable flexure when off the meridian, causing a drift in declination. In spite of his many difficulties, Mr. Maunder succeeded in obtaining a negative with an exposure of 70 minutes, on which were the following lines: bright lines—4919, 4860 (F), 4629, 4580, 4547, 4510, 4472, 4340 (G), 4229, 4174, 4101 (h), 3968 (H), 3933 (K), 3887.5 (α), 3834 (β); dark lines—4316, 4212, 4155, 4085, 3953, 3913.

Mr. Christie gives in the same number of the *Monthly Notices* a list of photographic determinations of the Nova's magnitude made at Greenwich, and notes a maximum on Feb. 3, and a secondary maximum about Feb. 18. Professor Pritchard communicates observations made photographically and also with the wedge photometer at the Oxford University Observatory, which indicate a slight secondary maximum on Feb. 22. Professor Pritchard's absolute values differ very widely from those of the Astronomer Royal.

Mr. Isaac Roberts obtained a number of photographs of the region about the Nova, and presents in the *Monthly Notices* measures of the diameters of the images compared with similar measures of 26 Aurigæ and DM. No. 899. "It will be observed, on examination of the table of the measured diameters of the Nova and the comparison stars, that no decided change in the brightness of the Nova has taken place during the interval between February 5 and 25, if we adopt the photo-images with 20 minutes exposure on the 25th as the standard; but if we adopt the image formed with 5 minutes exposure, there would be shown a fading of the light of the Nova between February 18 and 25."

The Relation between Sun-Spots and Auroras.—In the accompanying table the numbers of stations reporting auroras each day in the Monthly Weather Review are first arranged in periods of twenty-seven days six hours and forty minutes, the six hours or one quarter day being provided for by adding a day to each fourth period, and the forty minutes or one thirty-sixth day by adding a day to each thirty-sixth period, and then there is placed beneath the table thus constructed a section showing the attendant solar conditions as follows: The surface of the sun is considered to have been divided meridionally into as many lunes or sectors as there are days in each of the above periods. The amount of disturbance upon each of these sectors is obtained by entering in separate columns the sizes of all sunspots at all observations throughout the year as given

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	¼	1-36	
1879 Jan. 3 to Jan. 29	......	......	......	......	......	......	......	......	......	......	1	......	......	......	1	....	1	......	1	......	2	2	......	......	......	1	......	......	......	......
Jan. 30 to Feb. 25	......	......	1	1	......	......	......	1	......	......	......	......	1	1	2	1	......	......	......	......	......	......	......	1	......	......	......	......	......	......
Feb. 26 to Mar. 25	......	......	2	......	......	......	......	......	......	......	......	......	1	1	1	1	1	1	......	......	......	3	1	1	1	2	......	......	......	*
Mar. 26 to Apr. 21	1	......	1	......	......	1	......	1	......	......	......	......	1	2	1	......	......	......	......	2	......	......	1	......	55	8	1	......	......	......
Apr. 22 to May 18	1	1	......	1	......	......	......	......	......	......	......	......	......	......	1	1	......	......	......	1	1	1	......	......	......	1	......	......	......	......
May 19 to June 14	......	2	1	......	9	2	2	......	......	......	......	......	......	......	......	......	......	......	......	3	4	4	1	......	2	1	......	......	......	*
June 15 to July 12	1	2	34	5	3	......	2	......	1	2	......	......	......	......	......	......	......	......	......	......	......	1	......	......	......	2	2	......	......	......
July 13 to Aug. 8	......	1	1	......	2	2	2	......	......	......	1	16	......	......	......	1	......	......	2	1	......	......	......	......	2	3	1	......	......	......
Aug. 9 to Sept. 4	6	......	......	......	......	......	......	......	......	......	......	......	......	......	5	......	1	......	......	......	......	......	......	1	......	......	......	......	......	......
Sept. 5 to Oct. 1	1	......	......	......	7	24	10	3	3	......	2	......	2	1	3	4	3	2	2	3	3	1	1	......	......	......	......	......	......	*
Oct. 2 to Oct. 29	......	......	......	......	3	17	......	1	2	1	......	......	......	......	......	1	1	2	......	......	1	......	1	1	1	1	1	......	......	......
Oct. 30 to Nov. 25	......	1	2	......	2	......	1	1	......	......	......	1	2	3	2	2	1	......	......	......	1	......	......	......	......	......	......	......	......	......
Nov. 26 to Dec. 22	1	......	......	......	1	......	......	......	......	2	......	8	6	1	3	3	3	......	2	......	......	5	3	......	......	1	3	......	......	......
Dec. 23 to Jan. 18	......	......	2	......	......	......	......	......	......	......	......	......	2	......	......	2	2	......	......	2	......	......	......	......	1	......	......	......	......	......
	26	20	......	34	68	12	22	40	73	28	......	......	122	43	9	101	162	96	23	56	......	9	......	......	28	21	88			
	33	31	......	52	44	24	315	65	29	57	......	......	11	3	10	47	19	39	31	81	......	......	......	......	17	28	55			
	18	22	......	23	......	13	57	75	30	23	......	......	......	46	12	34	137	56	26	58	......	......	......	......	......	......	16			
	10	33	......	35	......	25	282	70	......	25	......	......	......	3	9	12	6	52	31	172	......	......	......	......	......	......	7			
	......	......	......	6	......	......	14	94	......	5	......	......	......	20	10	149	12	41	43	29										
	......	......	......	6	......	......	172	46	......	13	......	......	......	......	......	20	162	29	34	138										
	......	......	......	5	......	......	21	112	......	......	......	......	......	......	......	135	12	18	11	......										
					......	......	149	75								120	155	27	8	......										
					......	......	59	98								......	8	......	......	......										
					......	......	164	101								......	153	......	......	......										
					......	......	64	105								......	156	......	......	......										
					......	......	163	90								......	169	......	......	......										
					......	......	150	60								......	189	......	......	......										
					......	......	120	81								......	163	......	......	......										
					......	......	102	8																						
					......	......	27	11																						
					......	......	23	9																						
					......	......	......	10																						
					......	......	......	137																						
					......	......	......	38																						
					......	......	......	236																						
					......	......	......	131																						
					......	......	......	56																						
					......	......	......	226																						
					......	......	......	232																						
					......	......	......	211																						
					......	......	......	265																						
					......	......	......	219																						
					......	......	......	217																						
					......	......	......	160																						
					......	......	......	92																						
					......	......	......	105																						
					......	......	......	5																						
					......	......	......	58																						

in the Greenwich records. From these records also is obtained the location of each sector of the sun upon corresponding days of successive periods, thus determining where the columns indicating the amount of disturbance are to be placed. Thus upon the first day of each of these periods the same sector of the sun reached a certain location upon the visible surface, which location was in turn occupied upon the next day by the sector following and so on. The columns showing the amount of disturbance being entered accordingly it becomes apparent at a glance that the areas most persistently and actively disturbed were at the eastern limb appearing by rotation upon the series of dates characterized by recurrences of the aurora. M. A. VEEDER.

The Relation between Sun-Spots and Auroras.—The following letter was received from Dr. M. A. Veeder in reference to his preceding note:

Dear Sir:—As bearing upon the question as to the location of the disturbed portions of the sun concerned in the production of the aurora I enclose a specimen extract from one of the tables I have constructed. The year 1879 being at a time of minimum sun-spots and auroras does not bring the relation out so strongly as appears in some other years. I have selected it simply for convenience because the table is short on account of the paucity of disturbance. The year following (1880) gives a similar table several feet in length and is consequently somewhat cumbersome. The year 1879 answers very well however as a specimen of the method when the conditions were not very strongly defined perhaps but were nevertheless distinct. Yours truly, M. A. VEEDER.

April 8, 1892.

Magnetic Disturbances and the Great Sun-Spot.—We are indebted to the Rev. Walter Sidgreaves for enlarged copies of the Stonyhurst horizontal force records secured on Feb. 11-16 and March 11-14, 1892. The curves are most interesting, and we only regret that they cannot be reproduced in these pages. So great was the deflection in several cases, that the spot of light left the field, and the extreme maxima are thus unrecorded. Accompanying the curves was the following letter:

STONYHURST OBSERVATORY, Lancashire, 21 March 1892.

Dear Mr. Hale:—I am sending by same mail prints of the magnetic storms accompanying the central passages of the great spot of February. Both storms are found on the second day after the passages of the C. G. of the group. We have a similar record for the two great spots of April, 1882, when the magnetic disturbances occurred with the first, *one* day after, and with the second, two days after the meridional passage: but there was no repetition of magnetic disturbance at the returns of these spots.

They are to some extent confirmations of André's law from the observations at Lyons, for the forces of activity may not correspond with the C. G. of the group.

I think you have the best means of determining the centre of greatest activity in a group of spots, and my present remarks are mainly intended to suggest a line of operations for you.

We have a good record of spots and magnetic curves; and I hope to find the time to test André's law by our comparisons. If I find the time you shall have the results. Yours very truly,

WALTER SIDGREAVES.

A study of the Kenwood Observatory photographs of faculæ will shortly be made as Father Sidgreaves suggests.

At present we can only state that the area of the faculous region about the spot-group was greater at the March central passage than at the February central passage, although the most marked magnetic disturbances were those of February. In March, however, there was less condensation of faculæ in the near vicinity of the spots.

On account of its interest in this connection, we may be permitted to add a portion of a recent letter from M. Tacchini·

Collegio Romano, Roma, 17 Mars, 1892.

Mon cher et Honoré Collégue: J'ai appris avec le plus vif intérêt que vous avez réussi a bien photographier le bord solaire d'un seul coup. J'ai recu aussi les deux belles photographies de l' âppareil, qui vous sert pour les études photographiques sur le disque solaire. Vos observations seront très-importantes surtout lorsqu'il s'agit des grandes taches ou des groupes des facules, qui, à la manière ordinaire, nous voyons seulement près du bord du Soleil. Comme j'ai noté dans le dernier numéro des *Memorie*, j'ai montré autrefois, qu'avec plus de probabilité, ce sont les phénoménes chromosphériques et ceux qui se produisent dans l'atmosphère du Soleil, qui correspondent aux phénomènes magnétiques terrestres; de maniére que, si une tache passe sur le disque dans un état de calme, nous n'aurons pas des aurores ni des perturbations magnétiques correspondantes; au contraire, si un jour sur la tache ou sur les facules auront lieu des phénomènes extraordinaires, que nous ne pouvons pas constater avec les moyens employés jusqu'à présent, on aura encore sur la terre et sur les autres planètes des perturbations. Or c'est avec vos observations qu'on pourra vérifier si un groupe de taches on de facules en traversant le disque, se maintient calme toujours, ou si dans un temps donné se sont manifestés des phénomenes extraordinaires.

Votre devoué, P. TACCHINI.

Stars of the First and Second Types of Spectrum.

To the Editor of Astronomy and Astro-Physics:

In your number for February Mr. Maunder discusses the binary stars with the first and second types of spectra. I believe Professor Pickering gives a somewhat wider extension to the second type than most spectroscopists, but I find on comparing Mr. Maunder's list with the *Draper Catalogue* that seven of the twenty-one binary stars which he treats as Sirian are referred to the second (or solar) type in that catalogue. These are ζ Cancri (spectrum F), ω Leonis (spectrum E), γ Virginis (spectrum F), η Coronæ Borealis (spectrum F), ξ Scorpii (spectrum F), μ Draconis (spectrum F) and β Delphini (spectrum F). This would leave only 14 Sirian binaries against 37 solars, or rather 36, for according to the *Draper Catalogue* the spectrum of 36 Andromedæ is of the third type. Some of those classed by Mr. Maunder as Sirian are not in the *Draper Catalogue*, and possibly with further examination would give the predominating spectrum F. The spectrum assigned to μ^2 Bootis is probably that of the brighter star μ. About one-half the binaries which are found in the *Draper Catalogue* give the spectrum F.

This correction would reduce the density of the Sirian binaries from 0.0211 to 0.0153 or, if we omit the two doubtful stars O.Σ 4 and μ^2 Bootis, to 0.0066; a figure which contrasts strongly with that of the solar stars whose density would be but slightly reduced by the transfer. The high proportion of 36 to 14 however, seems to indicate that the solar stars are really more numerous than the Sirian, and that it is owing to the greater brilliancy of the latter (which renders them visible at greater distances) that the proportion appears to be about equal to the ordinary observer. The entire subject is well worthy of further investigation.

Dublin, Feb. 22. Truly yours, W. H. S. MONCK.

Photographic and Photometric Stellar Magnitudes.—In his article in the *Monthly Notices*, to which we have referred in a previous note, Mr. Christie remarks that "the Nova appears to be much brighter photographically than it is to the eye, judging from the visual estimations of magnitude which have been published." This is true when the Greenwich photographic values are compared with various visual determinations, but the Greenwich results are markedly different from any others we have seen. For instance, the magnitude on Feb. 13 is given by the Astronomer Royal as 4.50. Professor Pritchard's value for the same date, also determined photographically, is 5.35, while his measure with the wedge photometer is 5.28—in very good agreement with his photographic value. Mr. George Knott's visual estimation on Feb. 13 gave 5.3. In general, Professor Pritchard found the star to be slightly *fainter* photographically than visually, but in two or three cases this order was reversed, and in no instance were widely different values obtained by this observer. In a recent letter Mr. W. H. S. Monck calls attention to the same subject. He remarks that the photographic magnitudes in the *Draper Catalogue* do not at all correspond with the photometric. For stars brighter than 3.4 the photographic magnitude is less than the photometric; indeed the difference is so marked that Mr. Monck doubts if one photographic magnitude is as much as 0.75 photometric magnitudes. With faint stars this is reversed.

The Grating in Stellar Spectrum Photography.—We learn from Professor Campbell that he has succeeded in obtaining good photographs of stellar spectra with a grating. The spectroscope [illegible] already been described [illegible] and Astro-Physics was attached to the [illegible] refractor [illegible] servatory, and several negatives were secured [illegible] with iron comparisons [illegible] exposures 20 and 5 [illegible] a larger grating the [illegible] spectrum [illegible] was over-exposed [illegible] tive.

From these successful experiments [illegible] evident that the great [illegible] 36-inch will allow the determination of the motion [illegible] too faint to be investigated elsewhere. Professor Vogel [illegible] earlier work [illegible] prisms. Professor Young secured a photograph of the spectrum [illegible] grating attached to the [illegible] refractor [illegible] measurement. We therefore believe that Professor [illegible] stellar spectra are the first really successful ones [illegible]

Prominence Observations with Small Telescopes.—We [illegible] a paper by Mr. [illegible] Evershed [illegible] solar spectroscope [illegible] Sun's outfit consists [illegible] prisms. As we have [illegible] Mr. Evershed has [illegible] ing some experiments [illegible] obtained a photograph of [illegible] with an [illegible] of an isochromatic plate.

Comparative Photographic Spectra of the High Sun and the Low Sun, by Mr. F. McClean.—In addition [illegible] mentioned in our last number Mr. McClean has [illegible] set of five plates in which the effect of atmospheric absorption [illegible] brought out in the most striking manner. The [illegible] and the map of [illegible] of the apparatus used by Mr. McClean in his investigations [illegible] now in the last number of Astronomy and Astro-Physics.

CURRENT CELESTIAL PHENOMENA.

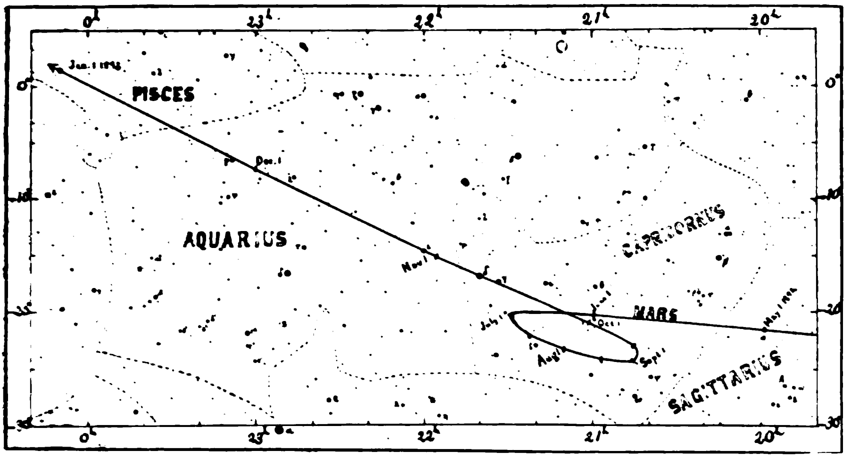
PLANET NOTES FOR JUNE.

Mercury will be in superior conjunction with the Sun [illegible] during this month he will be [illegible] Mercury and Neptune will be in conjunction June [illegible] Mercury and Venus [illegible]

Venus, the very bright planet which we see toward the west [illegible] will be at her greatest [illegible] June [illegible] and will after that [illegible] The illuminated portion of her disk decreases from [illegible] the apparent diameter increasing in the same time from [illegible] Venus will be in conjunction with the moon June 22 at [illegible]

Mr. Roger Sprague of Berkeley [illegible] the 2 inch [illegible] telescope [illegible] seen through [illegible] purpose [illegible] Mr. Sprague [illegible] when on the meridian [illegible] several times during the [illegible] of March. The planet is easily seen at any time during the [illegible] knows just where to look.

Mars [illegible] June will be in [illegible] the most brilliant object in that part of the heavens. He is approaching the earth so that the apparent diameter will increase from [illegible] June 1 to 22" [illegible] The summer [illegible] of this year will be [illegible] the study of Mars [illegible] ings [illegible] the southern hemisphere [illegible] the earth. We [illegible] sent [illegible] the [illegible] during the [illegible] of this year. From June to [illegible] he will describe an apparent [illegible] in Aquarius and after that will [illegible] through Aquarius and Pisces.



Path of Mars in the Sky during 1892.

Jupiter is coming out of the morning twilight so that he may be seen fairly well for a couple of hours in the early morning. His declination is increasing so that in the coming months he may be observed under much more favorable conditions than during last year. He is to be found in the constellation Pisces, which, in June at 3^h A. M., is a little south of east and about one third of the way from horizon to zenith. Jupiter will be in conjunction with the Moon, 1° 09′ north, June 19 at 5^h 40^m A. M., Central time.

Saturn will be at quadrature, 90° east from the Sun, June 13, crossing the meridian then at about six o'clock P. M. He will be in conjunction with the Moon, 2° 05′ south, June 2 a few minutes after midnight, and again on June 30 at 10^h 19^m A. M. During June Saturn may be well observed from 8^h to 10^h P. M., being then toward the southwest, about one-third of the way from horizon to zenith.

The rings now appear exceedingly narrow but will begin to open up somewhat after June. The belts on the disk of the planet are seen now at their best. With the 16-inch telescope we usually see four dark belts besides the black shadow of the rings which falls just a little to the south of where the ring crosses the planet's disk. The two belts in the southern hemisphere are much more distinct than those in the northern hemisphere. As they are seen projected upon the plane through the planet's center and perpendicular to the line of sight their distances from the equator are one-third and two-thirds of the planet's radius respectively. On the two hemispheres the belts are symmetrically situated. We have not yet been able to see any markings which would enable us to determine the planet's rotation period.

Uranus will be in good position for observation during June, as he crosses the meridian about nine o'clock. He is moving slowly westward in Virgo between *Spica* and the fifth magnitude star λ (See chart, Jan. No. p. 81). Uranus will be in conjunction with the Moon, 53′ south, June 6 at 4^h 22^m A. M.

Neptune is behind the Sun.

MERCURY.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
June 5......	3 47.4	+18 26	3 26 A. M.	10 49.1 A. M.	6 09 P. M.
15......	5 11.6	+23 19	3 50 "	11 33.8 "	7 18 "
25......	6 47.2	+24 40	4 39 "	12 29.8 P. M.	8 21 "

VENUS.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
June 5......	7 42.7	+23 29	6 58 A. M.	2 43.5 P. M.	10 29 P. M.
15......	7 52.6	+21 37	6 39 "	2 14.2 "	9 50 "
25......	7 46.8	+19 48	6 03 "	1 29.2 "	8 56 "

Date. 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MARS.		
June 5.	21 03.6	− 20 13	11 23 P. M.	4 02.4 A. M.	8 42 P. M.
15	21 15.2	− 20 04	10 55 "	3 34.8 "	8 15 "
25	21 22.8	− 20 15	10 24 "	3 03.0 "	7 42 "
			JUPITER.		
June 5	1 07.7	+ 5 55	1 44 A. M.	8 10.3 A. M.	2 37 P. M.
15	1 14.2	+ 6 32	1 08 "	7 37.4 "	2 07 "
25	1 20.0	+ 7 05	1 32 "	7 03.8 "	1 35 "
			SATURN.		
June 5	11 39.6	+ 4 45	12 18 P. M.	6 40.0 P. M.	1 02 A. M.
15	11 40.6	+ 4 37	11 40 A. M.	6 01.6 "	12 23 "
25	11 42.1	+ 4 24	10 04 "	5 24.4 "	11 45 P. M.
			URANUS.		
June 5	14 01.7	− 11 51	3 39 P. M.	9 01.7 P. M.	2 25 A. M.
15	14 00.8	− 11 47	2 59 "	8 21.5 "	1 44 "
25	14 00.2	− 11 44	1 19 "	7 41.6 "	1 04 "
			NEPTUNE.		
June 5	4 30.3	+ 20 19	3 59 A. M.	11 28.1 A. M.	6 57 P. M.
15	4 31.8	+ 20 22	3 21 "	10 50.3 "	6 20 "
25	4 33.3	+ 20 25	2 43 "	10 12.4 "	5 42 "
			THE SUN.		
June 5	4 56.9	+ 22 40	4 16 A. M.	11 58.4 A. M.	7 40 P. M.
15	5 38.3	+ 23 22	4 15 "	12 00.4 P. M.	7 46 "
25	6 19.9	+ 23 23	4 17 "	12 0.25 "	7 48 "

Occultations Visible at Washington.

Date 1892.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	IMMERSION Angle f'm N pt. °	EMERSION Washington M. T. h m	EMERSION Angle f'm N pt °	Duration. h m
June 4	$\varkappa$ Virginis	6	6 18	142	7 47	300	1 23
4	θ Virginis	5	14 20	126	15 16	282	0 56
5	*m* Virginis	6	5 10	92	6 13	344	1 03
5	B.A.C. 4591	6	10 18	56	11 11	12	0 53
12	ω Sagittarii	5	12 24	5	12 40	343	0 16
12	A Sagittarii	5	14 13	17	14 59	315	0 46

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A.……$0^{h}\ 52^{m}\ 32^{s}$
Decl……$+\ 81°\ 17'$
Period……$2d\ 11^{h}\ 50^{m}$

June	3	4 A. M.
	8	3 "
	13	3 "
	18	3 "
	23	2 "
	28	2 "

δ LIBRÆ.

R. A.……$14^{h}\ 55^{m}\ 06^{s}$
Decl……$-\ 8°\ 05'$
Period……$2d\ 07^{h}\ 51^{m}$

June	3	9 P. M.
	10	8 "
	17	8 "
	24	7 "

U CORONÆ.

R. A.……$15^{h}\ 13^{m}\ 43^{s}$
Decl……$+\ 32°\ 03'$
Period……$3d\ 10^{h}\ 51^{m}$

June	6	9 P. M.
	13	6 "
	17	5 A. M.
	24	3 "
July	1	1 "

U OPHIUCHI

R. A.……$17^{h}\ 10^{m}\ 56^{s}$
Decl……$+\ 1°\ 20'$
Period.……$0d\ 20^{h}\ 8^{m}$

June	1	8 P. M.
	5	4 A. M.
	5	midn.
	6	8 P. M.
	10	5 A. M.
	11	1 "
	11	9 P. M.
	16	2 A. M.

U OPHIUCHI CONT.

16	10 P. M.
21	3 A. M.
21	11 P. M.
26	3 A. M.
26	11 P. M.
27	8 "

Y CYGNI.

R. A.……$20^{h}\ 47^{m}\ 40^{s}$
Decl……$+\ 34°\ 15'$
Period……$1d\ 11^{h}\ 56^{m}$

June	2	4 A. M.
	5	4 "
	8	4 "
	11	4 "
	14	3 "
	17	3 "
	20	3 "
	23	3 "
	26	3 "
	29	3 "

Mr. Marth's Ephemerides of the Satellites of Saturn.

[From *Monthly Notices*, Mar. 1892.]

In this table the times have been changed from Greenwich Mean Time to Central Standard Time. The abbreviations *Rh.*, *Te.*, *Di.*, *En.*, and *Mi.*, stand for the names of the satellites Rhea, Tethys, Dione, Enceladus, and Mimas. The letters *a*, *b*, *c*, *d*, and *e*, stand for conjunctions of the satellites in order as follows: With the preceding end of the outer ring; with preceding end of planet's equatorial diameter; with center of planet; with following end of planet's diameter; with following end of ring. The letters *n* and *s* signify that the satellite at the time of conjunction is north or south of the point designated by the preceding letter; *Sh.* means that the shadow of a satellite is near the central meridian of the planet; *Ecl. D.* and *Ecl. R.*, the disappearance and reappearance of a satellite at beginning and end of an eclipse.

May, 1892.		
5	1.7 pm	Di as
	2.0	Te as
	3.1	Di cs Rh cn —3.1″
	3.2	Te cs Rh cn — 3.0
	4.7	Rh an
	4.8	Di cs en cn —4.0
	5.1	Te cs en cn — 3.9
	6.2	Mi es
	7.2	Rh bn
	8.9	En an
6	12.1 am	Rh Ecl. R
	12.1	Mi as
	1.7	Rh en
	1.3 pm	Titan bn
	1.3	En es
	2.8	Di an
	4.9	Mi es
	5.0	Di bn
	7.2	Titan dn
	7.7	En as
	9.0	Di Ecl. R
	9.7	Di cn Titan cn + 1.9
	10.3	Di en
	10.8	Mi as
	11.1	Titan en
7	2.9	Rh cs Di cs + 6.0
	3.5	Mi es
	9.4	Mi as
	10.2	En es
	10.8	Rh es
	11.7	Di es
8	2.1	Mi es
	2.7	En an
	3.8	Rh cs Di cs — 5.9
	8.0	Mi as
	9.0	En en
9	2 7	Di Ecl. R
	4.2	Di en
	6.7	Mi as
	11.6	En an
10	12.1 am	Mi an
	12.4	Te an
	2.0 pm	Rh en
	3.1	En cs Rh cn + 2.8
	3.8	Di cs Rh en + 3.2
	4.0	En es
	5.3	Mi as
	5 3	Di es
	6.5	Rh cn Te cs + 4.5
	7.5	Di ds
	10.0	Di sh
	10.3	En as
	10.7	Mi an
	10.8	Di bs
	11.1	Te es
11	2.8	En en
	3.9	Mi as
	9.3	Mi an
	9.7	Te an
	10.7	Te bn
12	2.5	Mi as
	5.0	Rh sh
	5.3	En an
	5.7	Rh bs
	6.6	En cn Rh cs — 1.5
	7.9	Mi an
	8.2	Rh as
	8.4	Te es
	10.4	Te ds
	11.7	En en
13	12.3 am	Te sh
	3.6 pm	Di sh
	4.1	En as
	4.5	Di bs
	5.6	Te cn En cs — 3.1
	6.5	Mi an
	6.7	Di as
	6.9	Te cn Di cs — 2.4
	7.0	Te an
	9.0	Te bn
	9.9	Di cs En cn — 4.0
14	12.4 am	Te Ecl. R
	12.4	Mi en
	1.8	Titan es
	1.9	Te cn Titan cs + 2.3
	1.9	Te en
	3.3 pm	Titan as
	4.6	Rh cn Titan cs — 2.6
	5.1	Mi an
	5.4	Rh an
	5.7	Te es
	6.1	Di cn Titan cs — 3.3
	6.7	En es
	7.7	Te ds
	7.9	Di an
	8.0	Rh bn
	9 6	Te sh
	10.1	Di bn
	10.6	Te bs
	11.1	Mi en
15	12.6 am	Te as
	1.0	Rh Ecl. R
	1.0	En as
	3.8 pm	Mi an
	4.3	Te an
	5.4	En en
	6.3	Te bn
	9.7	Mi en
	9.8	Te Ecl. R
	11.2	Te en
16	3.0	Te es
	3.6	Di cs En cn — 40
	5.0	Te ds
	6.9	Te sh
	7.9	Te bs
	8.0	En an
	8.3	Mi en
	8.9	Te cs en cn — 1.7
	9.9	Te as
	11.6	Rh es
17	2.5	Te cn En cn — 1.7
	3.6	Te bn
	3.8	Di bn
	6.8	En as
	6.9	Mi en
	7.1	Te Ecl. R
	7.8	Di Ecl. R
	8.5	Te en
	9.2	Di en
18	2.3	Te ds
	4.2	Te sh
	5.2	Te bs
	5.5	Mi en
	7.2	Te as
	9.3	En es
	10.4	Di es
	10.9	Mi es
19	12.6 am	Di ds
	2.8 pm	Rh en
	4.1	Mi en
	4.4	Te Ecl. R
	5.8	Te en
	8.1	En en
	9.5	Mi es
20	1.5	Te sh
	2.5	Te bs
	2.8	Mi en
	2.9	Di en
	4.5	Te as
	7.3	Te cs — 3.8 cn en
	8.2	Mi es
	10.6	En an
21	2.6	Rh ds
	3.1	En es
	3.1	Te en
	4.0	Di es
	5.9	Rh sh
	6.3	Di ds
	6.5	Rh bs
	6.8	Mi es
	8.7	Di sh
	9.1	Rh as
	9.4	En as
	9.6	Di bs
	11.8	Di as
22	5.4	Mi es
	5.6	Titan dn
	7.8	Di cn Te cs — 4.8
	9.5	Titan en
	11.1	En cs Titan cn + 2.8
	11.3	Mi as
23	12.0 am	En es
	12.9	Di an
	4.0 pm	Mi es
	4.4	En an
	6.3	Rh an
	8.8	Rh bn
	9.9	Mi as
	10.8	En en
24	2.3	Di sh
	2 6	Mi es
	3.2	En es
	3.3	Di bs
	5.5	Di as
	8.8	Mi as
	8.7	Di cs En cn — 4.0
	10.0	Di cs Te cn — 4.6
25	5.7	En es
	6.6	Di an
	6.9	Rh cn Te cn + 4.9
	7.2	Mi bs
	8.2	Di bn
26	12.1 am	En as
	12.5	Rh es
	12.6	Mi an
	12.9	Di Ecl. R
	3.1 pm	Rh cs Te cs — 4.9
	4.5	En en
	5.8	Mi as
	11.2	Mi an
27	12.2 am	Te an
	2.4 pm	Di cs En cn — 4.0
	4.4	Mi as
	7.1	En an
	9.7	Rh cn Di cs — 6.3
	9.8	Mi an
	10 8	Te es
28	2.4	Rh Ecl. R
	2.5	Di bn
	3.0	Mi as
	3.7	Rh en
	5.9	En as
	6.6	Di Ecl. R
	7.7	Te cn En cs — 3.3
	8.0	Di en
	8.4	Mi an
	9.5	Te an
	11.5	Te bn
29	5.7	Te cs en cs + 3.6
	7.1	Mi an
	8.1	Te es
	8.4	En es
	9.1	Di es
	10.1	Te ds
	11.4	Di ds
30	12.1 am	Te sh
	12.4	Titan es
	1.9 pm	Titan as
	3.5	Rh ds
	5.0	Te cn Titan cs — 3.3
	5.7	Mi an
	6.8	Te an
	6.8	Rh sh
	7.2	En en
	7.4	Rh bs
	8.8	Te bn
	9.9	Rh as
31	1.7	Di en
	3.6	Di cn Te cs + 3.4
	4.3	Mi an
	5.5	Te es
	7.5	Te ds
	9.4	Te sh
	9 7	En an
	10.2	Mi en

May, 1892.		
	10.4	Te bs
June 1892.		
1	2.2	En es
	2.8	Di es
	2.9	Mi an
	4.1	Te an
	5.1	Di ds
	6.1	Te bn
	7.1	Rh an
	7.5	Di sh
	7.9	En cs Rh cn — 1.9
	8.3	Di bs
	8.5	En as
	8.8	Mi en
	9.6	Te Ecl. R
	9.7	Rh bn
	10.5	Di as
	11.0	Te en
2	2.8	Te es
	4.8	Te ds
	6.8	Te sh
	7.4	Mi en
	7.7	Te bs
	9.7	Te an
	11.1	En an
	11.7	Di an
3	1.4	Te an
	3.4	Te bn
	3.5	En an
	4.8	Rh cs Di cn + 6.1
	6.1	Mi en
	6.9	Te Ecl R
	8.3	Te en
	9.9	En en
4	2.0	Di bs
	2.1	Te ds
	2.3	En as
	4.1	Te sh
	4.2	Di an
	4.8	Mi en
	5.0	Te bs
	7.0	Te an
	7.0	Di cs En cs —4.0
June, 1892.		
	10.1	Mi es
5	3.3	Mi en
	4.2	Te Ecl R
	4.9	En es
	5.2	Te cn en cs + 2.2
	5.4	Di an
	5.6	Te en
	7.6	Di bn
	8.7	Mi es
	11.2	En as
	11.7	Di Ecl R
6	2.3	Te bs
	3.3	Rh Ecl. R
	3.6	En en
	4.3	Te as
	4.6	Rh en
	7.3	Mi es
	8.1	Rh cn En cn + 4 0
	9.6	Rh cn Di cs + 4.7
	10.8	Titan cn Te cs — 4.9
7	3.0	Te en
	4 5	Titan dn
	5.9	Mi es
	6.2	En an
	8.4	Titan en
8	1.3	Di bn
	1.6	Te as
	1.8	Rh es
	4.4	Rh ds
	4.6	Mi es
	5.0	En as
	5.4	Di Ecl R
	6 8	Di en
	7.8	Rh sh
	8.3	Rh bs
	10.5	Mi as
	10.8	Rh as
9	3.2	Mi es
	3.4	Te cn en cs + 4.0
	4.2	Di cs Te cn + 4 3
June, 1892.		
	7.5	En es
	7.9	Di es
	9.1	Mi as
	10.2	Di ds
10	3.5	Rh cn Te cs — 4.5
	6.3	En en
	7.7	Mi as
	8.0	Rh an
	10.6	Rh bn
11	6.0	Di cn Te cs + 50
	6.3	Mi as
	8.9	En an
12	3.3	Di ds
	5.0	Mi as
	6.3	Di sh
	7.1	Di bs
	7.7	En as
	9.3	Di as
13	3.6	Mi as
	5.0	Rh cs Di cn — 5.0
	9.0	Mi an
	10.2	En es
	10.5	Di an
	10.7	Te es
14	1.5	Titan cs Di cn + 5.6
	2.2	Mi as
	2.7	En an
	7.6	Mi an
	9.0	En en
	9.3	Te an
	9.9	En cn Titan cs + 2.8
	11.3	Te bn
	11.4	Titan es
15	2.1	En cs Titan cs — 2.7
	3.1	Di as
	4.2	Rh Ecl. R
	5.5	Rh en
	6.1	Titan cs En cs — 4.0
	6.2	Mi an
June, 1892.		
	6.3	Di cs en cs — 4.0
	6.9	Te cs Rh cn + 3.0
	7.0	Di cs Titan cs — 4.3
	8.0	Te es
	10.0	Te ds
17	2.8	Rh es } o + 2.3
	2.8	En en } o + 2.3
	3.5	Mi an
	4.1	Te cs En cn + 3.0
	5.3	Te es
	5.3	Rh ds
	7.3	Te ds
	8.7	Rh sh
	9.2	Rh bs
	9.3	Te sh
	9.4	Mi en
	10.2	Te bs
18	4.0	Te an
	5.3	En an
	6.0	Te bn
	8.0	Mi en
	9.5	Te Ecl. R
	10.9	Te en
19	2.6	Te es
	4.1	En as
	4.2	Di Ecl. R
	4.6	Te ds
	5.6	Di en
	6.5	En cs Rh cn — 3.5
	6.6	Te sh
	7 5	Te bs
	9.0	Rh an
	9.5	Te as
20	3.3	Te bn
	4.5 — 7	En closely followed but not overtaken by Di
	5.3	Mi en
	6.7	Eu es
	6.8	Di es

Occultations of Stars by the Planets.

[From *Astr. Nach.* No. 3073.]

STARS NEAR VENUS.

Date		Central Time of Conjunction. h m		Diff. of Decl. ″	Maximum Duration. m	Magnitude of Star.
June	6	1 53	P. M.	— 20	40	9.0
	23	12 26	P. M.	— 50	70	6.0
	29	7 23	A. M.	— 3	47	9.2

STARS NEAR MARS.

June	8	5 07	P. M.	+ 29	21	9.5
	19	7 06	A. M.	— 30	36	8.5

STARS NEAR JUPITER.

June	9	8.1	A. M.	+ 56	1.5^h	8.8
	15	9.6	"	+ 120	1.6	8.8
	19	12.1	P. M.	— 59	1.6	7.7

Phases and Aspects of the Moon.

	Central Time.				
		d	h	m	
First Quarter	June	2	3	51	A. M.
Apogee	"	5	12	36	P. M.
Full Moon	"	10	7	32	A. M.
Last Quarter	"	17	3	01	P. M.
Perigee	"	21	8	18	A. M.
New Moon	"	24	8	07	"

Two New Asteroids.—These were discovered photographically by Wolf at Heidelberg, March 26 and 28. Their positions were as follows:

		R. A.	Decl.	Daily Motion. R. A.	Daily Motion. Decl.
No. 328	March 26.4111	12h13m59.1s	+1°37′00″	−48s	+14′
No. 329	28.4460	11 22 44	+6 09	−52	+1

These will be numbered 328 and 329 if they receive subsequent observation so as to have their orbits determined. They were of the 12th and 13th magnitudes respectively.

COMET NOTES.

Designation of the Comets of this Year.—We were led into error last month, in designating the comets, by following the *Astronomical Journal*. A correction is made in the last number of the *Journal*. The first comet announced during the year was a re-observation of comet 1890 II (Brooks) which is not yet beyond the reach of the great telescopes. Swift's comet should be designated *a* 1892, Winnecke's periodic comet *b*, and Denning's new comet *c* 1892.

Search Ephemeris for Comet Brooks, 1886 IV.

[From Astr. Nach. 3064, continued from page 343.]

		Perihelion, March 31.					Perihelion, April 30.				
		R. A.		Decl.		Light.	R.A.		Decl.		Light.
		h	m	°	′		h	m	°	′	
June	9	21	32.1	−35	59	0.47	17	39.7	−44	00	1.77
	19	21	37.5	−38	12	0.42	17	40.8	−46	52	1.38
	29	21	35.8	−40	11	0.37	17	42.2	−48	28	1.01
		Perihelion, May 30.					Perihelion, June 29.				
June	9	12	53.4	−8	40	1.20	11	18.6	+10	53	0.37
	19	13	14.4	−15	06	1.01	11	41.6	+5	41	0.36
	29	13	38.6	−20	48	0.82	12	06.4	+0	19	0.34
		Perihelion, July 29.									
June	9	10	24.6	+19	16	0.15					
	19	10	47.6	+15	23	0.15					
	29	11	11.8	+11	10	0.16					

Orbit of Comet *a* 1892 (Swift.) From my own observations of March 9, 20 and 29, I have computed the following elements:

$$
\begin{aligned}
T &= 1892,\ \text{April } 6.80278 \text{ G. M. T.} \\
\omega &= 24^\circ\ 41'\ 10'' \\
\Omega &= 240\ \ 58\ \ 8 \\
i &= 38\ \ 47\ \ 25 \\
\log q &= 0.01158 \qquad q = 1.0270
\end{aligned}
$$

O. C. Wendell.

Harvard College Observatory, April 16, 1892.

Swift's Comet *a* 1892 is moving northeastward through the constellaton of Pegasus. On May 10 it will be near star *β*, the upper star in the square of Pegasus, as one sees the constellation when looking toward the east. The best time to see the comet is between 3h and 4h A. M. During April the comet has been quite conspicuous, easily visible to the naked eye.

Mr. Barnard has sent us from Lick Observatory copies on glass of two remarkable photographs of the comet taken with a six-inch portrait lens, on the mornings of April 5 and 7 when the comet was near perihelion. These show the tail of the comet with surprising distinctness, and exhibit a wonderful amount of detail in its structure. The most striking features are the creases, knots and bends in the streams of luminous matter apparently flowing out from the head and forming the tail. Another curious feature shown is the darkening of the sky about the head of the comet and in some parts of the tail, which darkening cannot be merely the effect of contrast, as suggested by Mr. Barnard (see page 386), as the dark areas are not symmetrical with reference to the bright ones. The apparent darkening of the sky about the head of the comet was noticed visually at Goodsell Observatory on the morning of April 23.

The ephemeris calculated by Mr. Sivaslian and Miss Harpham has represented the observations thus far so well that we continue it to the middle of June. The correction to the ephemeris on April 23 was — 12ˢ and — 12″.

Ephemeris of Comet *a* 1892 (Swift).

[continued from p. 344.]

Gr. M. Noon.		App. R. A.			App. Decl.			log Δ	log r	Br.
		h	m	s	°	′	″			
1892 May	16	23	15	12.6	+30	02	53			
	17		17	50.8	30	35	02			
	18		20	27.4	31	06	32			
	19		22	52.5	31	37	26	0.1456	0.0953	0.54
	20		25	25.9	32	07	43			
	21		27	57.8	32	37	42			
	22		30	28.0	33	06	28			
	23		32	56.6	33	34	59	0.1565	0.1082	0.49
	24		35	23.5	34	02	55			
	25		37	48.7	34	30	19			
	26		40	12.2	34	57	11			
	27		42	34.0	35	23	32	0.1668	0.1213	0.44
	28		44	54.0	35	49	22			
	29		47	12.4	36	14	42			
	30		49	29.1	36	39	32			
	31		51	44.1	37	03	55	0.1766	0.1345	0.39
June	1		53	57.2	37	27	50			
	2		56	08.6	37	51	17			
	3	23	58	18.3	38	14	17			
	4	0	00	26.2	38	36	50	0.1857	0.1477	0.35
	5		02	32.3	38	58	58			
	6		04	36.6	38	20	41			
	7		06	39.1	38	41	59			
	8		08	39.8	40	02	54	0.1943	0.1608	0.32
	9		10	38.7	40	23	26			
	10		12	35.7	40	43	36			
	11		14	30.9	41	03	24			
	12		16	24.2	41	22	51	0.2021	0.1738	0.29
	13		18	15.7	41	41	57			
	14		20	05.2	42	00	43			
	15		21	52.8	42	19	09			
	16	0	23	38.6	42	37	15	0.2093	0.1867	0.26

Winnecke's Comet is moving southwest between the Great Bear and Leo Minor. It is growing rapidly brighter according to the following ephemeris by Dr. von Hærdtl, and is now visible in our five-inch telescope.

Ephemeris of Winnecke's Periodic Comet 1892.

[From *Astr. Nachr.* No. 3083.]

Berlin Midnight		App. R. A.			App. Decl.			log r	log Δ	Br.
		h	m	s	°	′	″			
1892 May	5	11	26	19.6	+44	25	43.4	0.0867	9.6970	2.71
	6		24	48.7		28	42.1			
	7		23	19.5		31	08.6			
	8		21	52.3		33	03.6			
	9		20	26.8		34	28.1	0.0732	9.6809	3.10
	10		19	03.2		35	23.3			
	11		17	41.3		35	50.0			
	12		16	21.2		35	49.6			
	13		15	02.6		35	22.5	0.0596	9.6634	3.58
	14		13	45.6		34	29.4			
	15		12	30.0		33	11.2			
	16		11	15.7		31	28.7			
	17	11	10	02.6	+44	29	22.9	0.0460	9.6438	4.17

Berlin Midnight.		App. R. A.			App. Decl.			log *Δ*	log *r*	Br.
		h	m	s	°	′	″			
May	18	11	8	50.5	+ 44	26	55.0			
	19		7	39.3		24	05.2			
	20		6	28.9		20	53.7			
	21		5	19.1		17	21.4	0.0326	9.6220	4.91
	22		4	09.5		13	29.0			
	23		3	00.0		9	17.4			
	24		1	50.5		4	47.8			
	25	11	00	40.6	44	0	00.3	0.0195	9.5974	5.84
	26	10	59	29.9	43	54	55.3			
	27		58	18.2		49	33.4			
	28		57	05.1		43	55.1			
	29		55	50.1		38	00.7	0.0069	9.5694	7.04
	30		54	33.0		31	50.9			
	31		53	13.2		25	25.2			
June	1		51	50.2		18	43.7			
	2		50	23.4		11	46.0	9.9949	9.5376	8.61
	3		48	52.4	43	4	31.4			
	4		47	16.4	42	56	59.7			
	5		45	34.6		49	10.6			
	6		43	46.4		41	02.7	9.9837	9.5012	10.72
	7	10	41	50.7		32	34.0			
	8	10	39	47.0		23	42.0			
	9		37	34.4		14	23.5			
	10		35	11.8	42	04	35.6	9.9736	9.4596	13.60
	11		32	38.0	41	54	14.5			
	12		29	51.8		43	15.4			
	13		26	52.0		31	32.2			
	14		23	37.2		18	57.9	9.9649	9.4123	17.60
	15		20	06.0	41	05	23.9			
	16		16	16.8	40	50	40.3			
	17		12	08.0	40	34	35.5			
	18		7	37.9	40	16	55.3	9.9578	9.3588	23.27
	19	10	02	44.6	39	57	23.3			
	20	9	57	26.1	39	35	40.3			
	21		51	40.2	39	11	24.1			
	22		45	25.2	38	44	08.0	9.9524	9.2992	31.39
	23		38	38.9	38	13	21.4			
	24		31	19.3	37	38	30.2			
	25		23	24.7	36	58	55.7			
	26		14	53.5	36	13	53.2	9.9490	9.2350	42.86
	27	9	5	44.8	35	22	33.7			
	28	8	55	51.9	34	24	05.6			
	29		45	32.6	33	17	36.1			
	30	8	34	30.4	+ 32	02	12.7	9.9477	9.1710	57.89

Denning's Comet *c* 1892 is about five degrees north of *α* Persei and moving slowly southeast. It is extremely faint and will probably not be visible in very small telescopes. The following elements are by R. Schorr, of Berlin (*Astr. Nach.* No. 3082). The ephemeris has been extended from May 23 to June 15, by Miss Harpham. There seems to be a difference of about 18ˢ and 10′ between the two computers resulting probably from some error in the published elements:

$$T = 1892,\ \text{May } 6.13922 \text{ Berlin M. T.}$$

$$\left.\begin{aligned}\omega &= 126^\circ\ 39'\ 17.7''\\ \Omega &= 252\ \ 55\ \ 13.8\\ i &= \ \ 89\ \ 49\ \ 45.1\end{aligned}\right\}\ 1892.0$$

$$\log q = 0.298920 \qquad q = 1.9903.$$

Ephemeris of Comet *c* **1892 (Denning).**

Berlin Midnight.			App. R. A.			App. Decl.		log *r*	log *Δ*	Br.
			h	m	s	°	′			
1892	May	5	3	0	37	+ 55	54.2	0.4258	0.2989	0.85
		6		4	24	55	40.0			
		7		8	08	55	25.6			
		8		11	48	55	11.1			

Berlin Midnight.		App. R. A.			App. Decl.		log r	log Δ	Br.
		h	m	s	°	′			
May	9	3	15	23	+ 54	56.6	0.4311	0.2990	0.83
	10		18	54	54	42.0			
	11		22	22	54	27.2			
	12		25	46	54	12.3			
	13		29	07	53	57.3	0.4362	0.2994	0.81
	14		32	24	53	42.2			
	15		35	38	53	27.1			
	16		38	48	53	11.9			
	17		41	55	52	56.7	0.4411	0.3000	0.79
	18		44	58	52	41.4			
	19		47	59	52	26.1			
	20		50	57	52	10.8			
	21		53	52	51	55.4	0.4458	0.3008	0.77
	22		56	44	51	40.0			
	23	3	59	15	51	34.1	0.4476	0.3012	0.76
	24	4	02	02	51	18.6			
	25		04	46	51	03.2			
	26		07	28	50	47.8			
	27		10	07	50	32.3	0.4519	0.3024	0.75
	28		12	44	50	16.9			
	29		15	18	50	01.4			
	30		17	50	49	46.0			
	31		20	19	49	30.6	0.4558	0.3039	0.73
June	1		22	46	49	15.2			
	2		25	11	48	59.7			
	3		27	33	48	44.3			
	4		29	53	48	28.9	0.4594	0.3056	0.71
	5		32	11	48	13.6			
	6		34	27	47	58.2			
	7		36	41	47	42.8			
	8		38	53	47	27.5	0.4626	0.3075	0.69
	9		41	03	47	12.2			
	10		43	11	46	56.9			
	11		45	17	46	41.6			
	12		47	22	46	26.4	0.5654	0.3097	0.68
	13		49	25	46	11.2			
	14		51	26	45	56.0			
	15		53	25	45	40.8			
	16	4	55	23	45	25.6	0.4679	0.3120	0.66

NEWS AND NOTES.

It is expected that this journal will be mailed hereafter before the first day of each month of the year, except July and September, which are vacation months. Regular subscribers in America should receive their copies before the 5th and most of the foreign ones about the 12th of the month.

Portrait of Professor Adams which appeared in the April number of this journal was furnished with the compliments of the Astronomical Society of the Pacific. Credit for the same should have been so given previously.

Mr. T. J. J. See, author of the "History of the Color of Sirius," has been traveling recently in England. Writing from London, he gives an account of the views of prominent English astronomers, concerning the colors of the stars. He says: "It is chiefly the spectroscopists who consider the red stars the oldest, other astronomers regard them as equally likely to be younger than the blue ones and this is confirmed by colors of double stars."

Professor Pickering speaks of furnishing a number of articles for this publication during the present year containing results of important work well under way at the Arequipa station.

Report from Temple Observatory, Rugby, 1891. The Curator, Geo. M. Seabroke, reports for the year 1891, that Temple Observatory, at Rugby, has been open for instruction on 76 nights. As time has given opportunity, Mr. Highton has continued the measurements of the double stars, and Mr. Seabroke has given attention to the motion of stars in the line of sight. Instruction will also be given soon in photography as applied to Astronomy. For this purpose a 15-inch mirror, with focal length of 48 inches, has been mounted on the tube of the equatorial.

Harvard College Observatory, Arequipa, South America. Our frontispiece and articles in this issue by Professor W. H. Pickering concerning the Harvard College Observatory station at Arequipa, South America, make a theme of delightful interest. From a later private letter received during the last days of April, Professor Pickering says "I have recently received the February number of ASTRONOMY AND ASTRO-PHYSICS and find it very interesting reading. . . . . In my last paper, page 12, line 5, (in this number page 361 line 40) 'Its spectrum it probably gaseous,' referring to 30 Doradus. This conclusion was arrived at from its shape and general appearance in the telescope. Since then I have been able to examine it through the prism, and find that its spectrum shows a strong green line. This would therefore seem to settle the matter and the word 'probably' in the above quotation should be left out.

Partial Eclipse of the Moon, May 11.—This will be almost a total eclipse, .953 of the Moon's diameter being immersed in the Earth's shadow. It will not be visible in the United States, except in the extreme eastern portion, where only the end of the eclipse will be seen It will be visible generally in the western portions of Asia, in Europe, Africa, and the Atlantic Ocean.

The New Jena Glass. Professor Young in his article on the new spectroscope of Halsted Observatory makes a statement in regard to the Jena glass which is liable to misconstruction. He has reference, of course, to one kind of glass, a borate flint, and a potash crown. These two glasses in combination give, as Professor Young says, practically perfect color-correction, but must be protected in use to prevent tarnishing.

We have received three letters this week from parties interested in Jena glass, all fearful that Professor Young's remarks included Jena glass in general. In justice to Messrs. Schott and Gen, I should like to say that only a few of their glasses are perishable. Professor Young's objectives are of Jena glass but not the kind that rusts.

JNO. A. BRASHEAR.

Time of the Sun's Passing the Vernal Equinox.—A correspondent asks why the Sun passes the Vernal Equinox one day earlier this year than last. As the length of the solar year is approximately 365¼ days while the common year contains only 365 days, the Sun passes the Vernal equinox one quarter of a day later each year. But as we put into our year one extra day every fourth year, this throws back the spring equinox one day every fourth year, thus keeping it at nearly the same date for centuries. This year and next the passage of the vernal equinox will take place on March 19, astronomical time, or in the forenoon of March 20 civil time. The next year it will occur in the afternoon of March 20 civil time. In 1895 it will come on March 20 astronomical time, but on the morning of the 21st civil time. In 1896 another leap year will occur and the date will be set back one day.

Lick Observatory Lunar Photographs.—Referring to a note on the Lick Observatory negatives of the Moon in your April number, page 348, I wish to quote Professor Weinek's words in his letter to me dated April 9, 1891, as follows:

"Ich bemerke noch, dass Mädler und Neison den vom Krater A nordwestlich liegenden kleinen Krater unrichtig an den Aussenwall von *Thebit* verlagt haben. Es liegt gemäss der Photographic am Innenwalle, etc., etc."

This sentence was correctly translated and sent to the printer, who made the error of putting "N. W. on the crater *Thebit* A," instead of "N. W. of the crater *Thebit* A," in Publ. A. S. P. vol. III, page 253, line + 14.

This printer's mistake of a single letter was not discovered until I read the note in question. Whatever error there may be, it was not made by Professor Weinek, which is all that I am desirous of saying in this place. Be kind enough to print my letter in your journal and oblige, Yours very sincerely,

Mount Hamilton, April 11, 1892. EDWARD S. HOLDEN.

The Reduction of Rutherfurd Star-Plates. At the November meeting, 1891, of the National Academy of Sciences, held at New York City, Professor John K. Rees, read a paper entitled: Preliminary Notice of the Reduction of Rutherfurd Star-Plates, which was published in the last issue of *The School of Mines Quarterly*. From that paper we learn, that the best negatives by Mr. Rutherford previous to 1868 were taken by his 11¼-inch photographic telescope. He made his own machine for measuring the star plates, which consisted in getting position-angle and distance of every star on the plate from a central star, the latter measure depending on a micrometer-screw. Plates containing the clusters of the Pleiades, Præsepe and others, were measured under the direction of Mr. Rutherfurd, and reduced by Dr. Gould, showing value, in the method for determining parallax and relative proper motion. Later, Mr. Rutherfurd made a telescope of 13-inches aperture which could be used for either visual or photographic work.

The measuring machine was also improved by which work was carried forward after 1872. In 1883 these instruments became the property of Columbia College, and in 1890 Mr. Rutherfurd gave all his best negatives to the same institution, a complete list of which has been prepared and published in the *Annals* of the New York Academy of Sciences, Vol. VI, June 1891. At the suggestion of Mr. Rees, the Pleiades-plates taken with the 13-inch telescope and measured by the improved machine, are in process of reduction by Mr. Harold Jacoby of the Observatory, and the work is well nigh completed, and it is said that the accuracy of it compares well with the best heliometer work.
The results will soon be published in the *Annals*, and will fill about twenty folio volumes of two hundred pages each. This is only a part of the important labor undertaken with regard to the collections of the Rutherfurd star-plates.

Erratum.—In the last number of this publication, on page 348, in the note on Lick Observatory lunar photographs, the date Aug. 15, 1888, should read Aug. 16, 1888.

PUBLISHER'S NOTICES.

The subscription price to ASTRONOMY AND ASTRO-PHYSICS in the United States and Canada is $4.00 per year, in advance. For foreign countries it is $4.40 per year which is the uniform price. Messrs. Wesley & Son, 28 Essex Street, Strand, London, are authorized to receive subscriptions. Payment should be made in postal notes or orders or bank drafts. Personal checks for subscribers in the United States may be used.

Currency should *always* be sent by registered letter.

Foreign post-office orders should be drawn on the post-office in St. Paul as Northfield is not a foreign money order office.

All communications pertaining to Astro-Physics or kindred branches of Physics should be sent to George E. Hale, Kenwood Astro-Physical Observatory, Chicago, Ill.

All matter or correspondence relating to General Astronomy, remittances, subscriptions and advertising should be sent to Wm. W. Payne, Publisher of ASTRONOMY AND ASTRO-PHYSICS, Goodsell Observatory of Carleton College, Northfield, Minn.

Manuscript for publication should be written on one side of the paper only and *special care should be taken to write proper names and all foreign names plainly*. All drawings for publication should be *smoothly* and *carefully* made, in *India ink* with lettering well done, because such figures are copied exactly by the process of engraving now used. If drawings are made about double the size intended for the printed page, better effect will be secured in engraving than if the copy is less in size. As a rule the publishers have had to re-draw the figures sent during the last year at considerable expense. We hope to avoid this in the future. It is requested that manuscript in French or German be type-written. If requested by the authors when articles are sent for publication, *twenty-five* reprint copies, in covers, will be furnished free of charge. A greater number of reprints of articles can be had if desired, at reasonable rates.

Rates for advertising and rates to news agents can be had on application to to the publisher of this magazine.

Astronomy and Astro-Physics.

NEW SERIES No. 6. JUNE, 1892. WHOLE No. 106

GENERAL ASTRONOMY.

COLORS EXHIBITED BY THE PLANET MARS.*

WILLIAM H. PICKERING.

The following preliminary account of an investigation made in Cambridge at the last opposition of Mars, is published at this time, in the hope that others may take advantage of the present favorable circumstances, to verify the results here described. One of the most difficult branches in practical astronomy is that pertaining to the colors of the heavenly bodies, for no other optical illusions can be found to be so complete as those pertaining to color. The planet Mars is frequently spoken of as the red planet, yet its color is by no means as red as that of an ordinary candle flame. To illustrate this fact, let the observer so place himself that the planet Mars, an electric light, and a candle or gas flame, all appear to him to be of the same brilliancy. He will then find that while the planet is redder than the electric light, it is bluer than the candle flame, and is, in fact, very nearly half way between the two in color. If either source of light is made brighter than the other, its tendency is to appear whiter.

During the last opposition, sixty paintings were made of the planet, with the 12-inch Harvard refractor, and sixty-six uncolored drawings. They were all constructed upon a uniform scale of $\frac{1}{200000000}$, the planet being represented by a disc, 34 millimeters in diameter. Usually powers of 200 to 400 were employed. It was found that in the evening, the most prominent and striking color of the planet could be represented very well by carmine. It was also found that it could be equally well represented by golden yellow. When painted in the day-time it was orange, with more or less carmine, depending on various circumstances. If a high power was used it was much redder than with a low power. All of these changes may be readily explained by the elementary principles of Physics, but they illustrate very well some of the difficulties that were presented by the

---

* Communicated by the author.

research. As the planet is illuminated by sunlight, it is evident that in order to obtain a correct result, the pigment used to represent it should be illuminated by the same source. The paintings should, therefore, be made in the day-time.

Experiments were also made in a darkened room, the only light transmitted being through a small round hole bored in the shutter. Various pieces of colored stone were placed upon a mirror, which reflected the light of the sky into the room. Reflections of these stones were then viewed in two pieces of flat glass, supported inside the room. By varying the angles of the glasses, the intensity of the sunlight reflected from the stones could be varied, so as to render them either brighter or fainter than the planet, as seen in the telescope. Paintings of the planet, illuminated by the same light as that used in the evening, were then compared with the light from the stones.

The other shutters of the room were then opened, and the paintings illuminated by daylight. It was found that the same laws of color held good with the stones that had been previously found applicable to the planet. The various stones tried were a piece of brown lava from Vesuvius, a piece of red basalt, a piece of brown sandstone, a piece of very red granite, and two pieces of brick, one an orange red, and the other the color of dragon's blood. The former may be best represented by dragon's blood with a little Saturn red in it. The red granite, which is half way in color between the two pieces of brick, is well represented by dragon's blood and sienna, half and half. It was found that this piece of granite under suitable illumination could be made to match exactly any of the paintings of the planet. As its color was not far from that of an average brick, our next experiment was to select a distant building made of brick of the proper color, and make a painting of it as seen in the telescope. This painting was necessarily made by daylight, and another telescope had to be used, as the building was not visible from the dome of the 12-inch. The building selected was two ånd a half miles distant. The telescope employed was a 6-inch refractor by Clacey. The result was as anticipated, that when the painting of the building was compared with some of the daylight paintings of Mars, the colors were identical. In each case the colors were separately mixed at the time, although the components were the same, and in each case the result exactly satisfied the eye.

The reason that a red planet or distant brick building can be matched by daylight with an orange pigment is because of the bluish white light reflected from the atmosphere, lying between the distant object and the eye, which is mixed with the red light coming from the object, changing it from red to orange. If the brick is examined close at hand, a red pigment must be employed to represent it. When the planet is viewed at night, or when a piece of brick near at hand is illuminated by sunlight, but the pigment is illuminated by a yellow artificial light, this light by enforcing the red components of the pigment, and absorbing the blue, makes the pigment really appear red, and therefore match the Sun-illumined object. The object, therefore, although painted yellow by night, really appears to the eye redder than when painted orange by daylight. This fact was well brought out by an experiment made at night, employing the magnesium light instead of the oil lamp as a source of illumination for the pigment. In that case the color best matching the planet was found to be dragon's blood which, as we have seen before, is probably not far from its true color, which we considered to be the same as the red granite, and therefore to be represented by equal parts of dragon's blood and sienna.

But red is by no means the only color visible upon the planet. When near the limb, the reds always appear yellowish, indicating probably an atmospheric absorption of the red portion of the spectrum, an effect quite at variance with the action of our own atmosphere, which tends to absorb the blue rays.

Next to the reds and yellows, the most important colors are the grays and greens. The latter colors one would actually at first attribute to an optical illusion, due to contrast with the prevailing tint. If this were the case, however, these portions of the planet should be painted blue, blue being the complementary color of the orange seen by daylight. Blue pigment seen by lamp light becomes green, which is the complementary of the red seen at night. Therefore in either case blue would be the complementary color and not green. Experiments under both of these conditions, however, made upon several occasions, conclusively showed that these greens could not be matched by blue pigment of any tint, but were a true and genuine green. Although rare, yet upon four occasions it was noted that green was the most conspicuous color visible. This was due sometimes to its covering a large area, and sometimes to its being a more intense color than the red. This also indicated that the green could not be due to contrast. It was found by experiment that the effect upon green pigment produced by using an artificial illumination was very much less marked than upon red, the only effect being, that when so illuminated, it appeared rather more yellow than when seen by daylight. This would imply that the greens upon Mars were in reality slightly more yellowish than the evening paintings would indicate.

When the seeing became bad the greens and reds united to give a whitish tint, and the colors disappeared. This further indicated that the greens were not due to contrast. A piece of black paper was introduced into the field of view of the telescope, cutting off the red, but the green color remained unchanged. An examination was made of Jupiter, the disc being a bright yellow, but no green could be detected upon it. The greens, especially the light greens, usually appeared near the poles, which were necessarily near the edge of the disc, but on these occasions a region near the center was seen of a light green color. The green could not therefore be attributed to the secondary spectrum of the glass. Moreover, the telescope was thrown alternately slightly in and out of focus, changing the color of the outside fringe of light, but without altering the green hue upon the disc.

The green was not due to atmospheric refraction since it was seen near both poles, besides which the color due to this cause is easily overbalanced by that due to the lack of achromatism in the eyepiece when the planet is placed near the edge of the field. The green is not due to an optical illusion caused by the brightness of the snow. It is sometimes seen between the snow and the red regions of the planet, and is also seen when the snow is not visible. Indeed I think it has been often mistaken for the snow, as it is a much larger and more conspicuous object. The real snow is much more difficult to see than is generally supposed, and is frequently not visible at all. I have only seen it occasionally when it was readily distinguished by its extreme brightness and whiteness. An excellent idea of its appearance is given in Chambers' Astronomy, fourth edition, and I have seldom seen it of much greater extent. The drawing is by Green, and like all of his work upon Mars, is most accurate and life-like. The gray objects upon Mars, when the seeing was fine, acquired a slightly yellowish, and in the day-time a brownish tint, owing to their confusion with the surrounding regions, but when the seeing was good, they were either a pure gray, or of a slightly greenish color. This does not apply to all the darker regions, as we shall see later. There was no difficulty in obtaining distant green terrestrial objects to study through the telescope, and it was found that even upon very clear days, when over two or three miles distant, they appeared either gray or greenish gray. This was particularly true of the darker shades. In fact I never at any time saw any colors as brilliant as the bright greens upon Mars. Even when a piece of bright red paper was introduced into the field of the telescope, no appreciable contrast effect was produced upon the terrestrial greens. This fact, together with the other that the greens on Mars were seldom seen by daylight, make me think that those seen upon the planet must be due to some illusion, whose origin had not as yet been eliminated, for one cannot well conceive of more vivid greens than those due to some of our own vegetation. I had been observing a tree some two and a half miles distant with the telescope one very clear evening, when I noticed that there was an electric lamp just by the side of it. That evening I pointed the telescope again on the tree, and it instantly shone out a most brilliant bluish green, fully equalling in intensity anything I had seen upon the planet, and a trifle bluer. This explained why it was that in the day-time I had only detected the greens upon Mars with difficulty while at night they were conspicuously visible,—the white light reflected by our own atmosphere had corrected them into grays.

Numerous observations were made of the colors of particular regions, especially of those which appeared very dark in tint. Attempts were also made to determine the color of the canals. This latter is an extremely difficult undertaking, as the smaller the area, the harder it is to assign any particular color to it. The apparent area of any very small region always strongly affects one's judgement of its color, and in comparing two colors, it is most important that their apparent areas should be equal. Regarding the colors of these smaller regions, as it is very desirable that the opinions of others be formed independently of my own, I will defer describing them until another paper, merely stating that there is some evidence that certain regions do not seem to remain at all times of the same color.

In closing, I shall mention that these colors have been seen through three different telescopes, 12-inch and 15-inch at Cambridge, and more recently through the 13-inch telescope at Arequipa. The latter instrument brought them out very finely, the greens showing well even in the day-time. On April 5, I could see the great canal north of the Sinus Magnus with a power of 810 diameters. It will be noted that in what precedes I have carefully abstained from advocating any hypothesis regarding the true sources of any of the colors, merely confining myself strictly to a statement of the observed facts.

AREQUIPA, PERU, March 7, 1892.

THE TOTAL SOLAR ECLIPSE APRIL 15-16, 1893.*

H. S. PRITCHETT.

The total eclipse of the Sun which will occur in April, 1893, is the last in the present century which is likely to add to our knowledge of solar physics. Although the duration of totality is not so great as that which characterizes the two remarkable series to which the eclipses 1883 and 1886 belonged, it is quite large, amounting to $4^m\ 46^s$ at the maximum.

Not only is this eclipse valuable for its long duration, but observations of it are particularly desirable for two reasons.

In the first place the path of the shadow-cone on the Earth's surface is such that it permits observations widely separate in distance and time. Photographs of the corona taken in Chile will precede by some 3½ hours those taken on the west coast of Africa, Probably no observations could be made which are more likely to help in the solution of pending problems, or will afford more trustworthy data concerning the nature and behavior of the matter about the Sun than two photographs of the corona, the one taken in Chile or the Argentine Republic and the other in Africa. These should be strictly comparable.

An additional strong incentive for observation is found in the fact that the eclipse of 1893 takes place as a sun-spot maximum is approaching, and would therefore afford most interesting results for comparison with the mass of observations gathered in the two eclipses of 1889, occurring near a sunspot minimum.

Professor Holden has announced that the Lick Observatory will send a party to Chile under the direction of Mr. Schaeberle. The Harvard Observatory party already in Peru, under the direction of Professor W. H. Pickering, will, it is understood make complete photographic and spectroscopic studies of the corona from some point in Chile. It is therefore extremely important that the remaining points of observation should be manned.

I have endeavored to collect in the following memoranda such information as is accessible concerning the means of transit to available stations, and the meteorological conditions of the stations themselves.

After leaving Chile the track of the shadow lies across the northern part of the Argentine Republic and passes entirely across Brazil. In this entire region there seem to be but two available points, one in the Argentine Republic on the railroad

---

* Communicated by the author.

which runs up from Buenos Ayres, and the other in the province of Ceara in Brazil. The next available points for observation are on the African coast. The following table contains a list of such stations as are likely to be available.

Station.	Long.	Lat.	Beginning Totality. Local Time.	Duration Totality.
	° ′	° ′	h m	m s
Rosario de la Frontera Arg. Rep.	65 07	25 48 *S*	Apr. 15, 20 40	3 8
Para Curù, Brazil.........	38 30	3 42 *S*	Apr. 15, 23 40	4 44
Island of Goree............	17 16.7	14 39.9	northern limit of shadow.	
Portudal, Senegal........	16 49	14 23		
Joal, Senegal.	16 37	14 09	Apr. 16, 2 29	4 9

Rosario de la Frontera, in the Province of Salta, is a small town on the railroad which runs from Buenos Ayres to Jujuy. It is therefore easily acessible, and the expense of a party in reaching it would not be large. The distance from Buenos Ayres is some 600 miles.

The town lies almost exactly on the line of central eclipse. It has an altitude of 800 metres, and although the cloudy season will have commenced, the probabilities for clear weather in the forenoon seem good. The nearest point for which meteorological data are accessible is Salta, distant 80 miles. At this point the mean annual temperature is 63°.6 F. and the annual rainfall is 22.8 in., and the probability for clear weather at this season is estimated to be two-thirds. It seems extremely desirable that this station should be occupied. Observations at the eastern end of the shadow track are likely to be more numerous than at the west end, and for this reason it is desirable to increase the chances at the west end. There is a direct line to Buenos Ayres from New York, and this station is therefore easily reached.

Para Curù Brazil, is quite near Forteleza, a city of some 20,000 inhabitants and the capitol of the Province of Ceara, and lies almost exactly on the line of central eclipse.

It is also said that it would not be difficult to reach a point in the interior at a higher elevation. M. Cruls, Director of the Observatory of Rio Janeiro, proposes to collect full meteorological data at Forteleza during April, 1892, for guidance of observers in choosing points of observation for this eclipse. It must be said, however, that the chances for clear weather near Forteleza seem poor indeed. The annual rainfall here is something over 100 in., and from the best attainable data the average rainfall during April for five years past, including 1891, has been 10 in., and the average number of rainy days in April during the same period has been 15, and has been as high as 21 in one year.

The probability of cloudiness is stated by M. Cruls to be about two-thirds.

In spite of all this, however, taking into account the altitude of the Sun and the duration of totality, it may seem desirable to occupy a station in the region near Forteleza.

After leaving South America no points for observation present themselves till one reaches the African coast.

The Island of Goree, which lies some five miles off the coast and forms the protection to the harbor of Dakȃr seems to be the natural outfitting point for any parties destined to the Senegambiam coast. Goree is a point of great importance as a military and commercial post. The island, which is rocky and precipitous, is some forty acres in extent. A French garrison is kept here, and it is a coaling station for the French Navy, and is reached by steamers from Liverpool and Bordeaux. Sailing vessels from New York in the Senegambian trade make this a rendezvous.

The climate is described as most excellent and somewhat cooler than that of the neighboring mainland. Clear weather at this season is almost a certainty. A rainy day in April has never been recorded. The rainy season sets in about the middle of June.

Between Goree and the neighboring points on the coast there is almost daily communication by sailing vessels and small steamers, and unquestionably the French government would afford all needed assistance to observers.

With Goree as a base of operations there is apparently no difficulty in locating observing parties at either Portudal or Joal, the latter of which lies almost exactly in the line of central eclipse. There is a considerable discrepancy in the published values of the geographical position of Goree. The value given, taken from the *Annuaire de Senegal,* is presumably correct, as longitude and latitude are there given to the nearest second of arc. The other points in Senegal whose positions are mentioned have been referred to Goree.

The temperature seems quite tolerable, the average being about 70° Fahr.

From what has been stated, and considering Chile as already well occupied, there would seem to be but three points for remaining American expeditions to choose from. These are the regions near Rosario de la Frontera, Argentine Republic; Forteleza, Brazil; and either Joal or Portudal on the Senegambian coast.

In case any stations are to be occupied by American parties, it is exceedingly desirable that there should be an effective coöperation between such parties, both in choice of stations and in the arrangement of work. In the work of eclipse observations during the past there has been a serious absence of any attempt at a coördination of work, and very little effort to make the work of different observers comparable. It is with the hope that some such coöperation may be secured that attention is called to the matter at the present time.

It may be added that ambitious travelers who care to brave desert will find a favorable observing station on the caravan route just north of Timbuktu.

I am indebted to Professor Corti of San Juan, Arg. Rep., for maps and meteorological data concerning the province of Salta, and to Mr. John M. Sherwood, formerly of Goree, for similar data concerning Senegambian points.

EXPLANATION OF THE MYSTERY OF THE EGYPTIAN PHŒNIX.*

T. J. J. SEE, BERLIN.

The beautiful Egyptian fable of the Phœnix enjoyed great popularity among the ancients, and the mere fame of the legend renders the accounts left us by the Greeks and Romans necessarily somewhat inconsistent, on account of the distortions which it suffered from different writers; the gist of the mystery is, however, condensed in the following statements:—

The Phœnix was a miraculous bird of Arabian origin, the only one of its kind in the world, adorned with golden and red plumage, and in form resembling an eagle; it was sacred to the Sun and appeared at the Temple of Heliopolis at long intervals of time; when of a very great age it built a nest of twigs and branches, ignited it with fire, forthwith lighted upon the funeral pyre and was consumed to ashes, from the glowing embers of which the new Phœnix at once triumphantly arose.

The true explanation of the mystery of this acknowledged symbolism is a matter on which not even Egyptologists have ever been agreed; but since the story of the Phœnix seems to hinge upon astronomical phenomena, we may perhaps venture to offer an hypothesis which has presented itself in connection with the investigation of the ancient color of Sirius, and seems exceedingly probable.

---

* Communicated by the author.

Of all the authorities who have left us accounts of the Phœnix none are perhaps more trustworthy than Tacitus, who speaks of the bird Phœnix coming in Egypt after a long course of ages during the consulship of Palus Fabius and Lucius Vitellius (34 A. D.). After noticing the miraculous reports of the bird, and briefly describing it, the historian adds that it was sacred to the Sun, and continues:—

"De numero annorum varia traduntur. Maxime vulgatum quingentorum spatium: sunt qui asseverent mille quadringentos sexaginta unum interjici, prioresque alites Sesostride primum, post Amaside dominantibus, dein Ptolemæo qui ex Macedonibus tertius regnavit, in civitatem cui Heliopolis nomen advolavisse, multo ceterarum volucrum comitatu novam faciem mirantium. Sed antiquitas quidem obscura: inter Ptolemæum ac Tiberium minus ducenti quinquaginta anni fuerunt. Unde nonnulli falsum hunc Phœnicem neque Arabum e terris credidere, nihilque usurpavisse ex his, quæ vetus memoria firmavit."

(Annalium, Lib. VI., Cap. 28.)

Tacitus therefore says the Phœnix is vulgarly reported to live 500 years, but there are some (and he appears to imply that these are the "select few," the "learned ones," perhaps the Egyptian priests) who positively affirm that the miraculous bird lives 1461 years. This is the length of the Sothic Period, and such a coincidence in length of time cannot be the result of chance. Therefore a strong presumption is at once raised in favor of the idea that the Phœnix is a symbolization of the Dog Star Period. The Egyptian year, as is well known, consisted of 365 days, and consequently the calendar annually fell short of the Julian or natural year one fourth of a day; this annual difference would accumulate, and in 1461 Egyptian years amount to a whole year, so that the cycle would begin anew. This great cycle is what is known as the Sothic Period, which began when the first of Thoth (the first month of the Egyptian calendar) coincided with the heliacal rising of Sirius. This phenomenon of the Sun and the Dog Star rising together took place on the 20th of July, and marked the beginning of the inundation of the Nile.

In the preceding investigation* we have shown that Sirius was anciently fiery red, and this color will now enable us to explain not only the gorgeous plumage of the Phœnix (mentioned by

---

* See April and May numbers of ASTRONOMY AND ASTRO-PHYSICS.

Herodotus and Pliny), but also how the old Phœnix was mystically spoken of as consuming itself with self-ignited fire and the new bird arising from the glowing ashes. For the colors of the Phœnix were merely the hues of the golden Sun and of the ruddy Sirius. And the old Phœnix cycle closed its long career when the first of Thoth came round to the day of the fixed year (July 20) on which Sirius and the Sun rose together, and the new Sothic or Phœnix cycle began on the same day. Therefore, since the beginning and end of the Sothic Period was determined by the heliacal rising of Sirius, and that star was fiery red, it is easy to see why the priests represented the old Phœnix as consuming itself with self-ignited fire (of the Dog Star) at self-appointed time, and the new Phœnix as arising immediately from the ashes of the old. The "burning up" of the Phœnix therefore represents merely the "burning" of the ruddy Sirius, to which may perhaps be added the flames of the morning glow through which the priests observed the star coming with the rising Sun.

Since the Sothic Period was determined by observations of the heliacal rising of Sirius made at the Heliopolitan Temple of the Sun, we can readily understand why the Phœnix was spoken of as coming from Arabia, which lay to the east, in the direction of the expected phenomenon. The Phœnix being a symbolization of the Sothic cycle, there could of course be only one such "bird" in the world; and since the period extended over ages, it is easy to conceive how a very little mystic or even poetic fancy would enable the priests to represent it as a bird endowed with swift wings symbolic of the flight of time. The Sothic Period being reckoned from the heliacal rising of Sirius, it is also plain why the bird was sacred to the Sun, and why it appeared to the priests at the Heliopolis by whom the observations were made. Lastly, since the cycle repeats itself in endless succession, its duration is everlasting, and hence the secret of the immortality of the Phœnix.

The only point that needs further elucidation is the period. Tacitus relates that the first Phœnix appeared in the reign of Rameses II. (who was called by the Greeks Sesostris); and we learn from Censorinus that a Sothic Period was completed A. D. 139; therefore that Period must have begun B. C. 1322.

This epoch falls within the limits of the various dates assigned to the reign of Rameses by different chronologists—dates which hinge mainly upon different interpretations of the somewhat uncertain dynastic successions recorded in the fragments of Manetho's History preserved by Josephus—and agrees perfectly with the time assigned to Rameses II. by Sir Gardner Wilkinson. Tacitus also relates that a Phœnix appeared in the reign of Amasis (B. C. 564-526), and another in the time of Ptolemy III. Euergetes I. (B. C. 247-222), and finally in the year 34 A. D. Now it is evident that the periods here mentioned are very unequal and can not be reconciled to any fixed interval. Tacitus does not hesitate to question the genuineness of the last Phœnix, and we know from other authorities that a Phœnix exhibited at Rome during the celebration of the secular games in the year of the City 800 (A. D. 46) was in like manner an imposture. Therefore, since the period seems to be 1461 years, we may venture to suggest that none of the Phœnixes reported by Tacitus are really genuine except the first, which appeared under the reign of the Great Rameses. The interval of 1461 years, however, is so very long that only one in a great many generations could ever hope to witness the celebration of its completion; therefore it is likely that certain kings ambitious to glorify their reigns would occasionally celebrate the completion of some numerical part of the Sothic or Phœnix period, and proclaim as a special sign from Heaven the coming of the sacred Phœnix. All the Phœnixes reported by Tacitus (except that of 34 A. D., when Egypt was under Roman sway) appeared in the reigns of very powerful kings, and this circumstance adds decided plausibility to the suggestion just advanced, which seems indeed the only reasonable explanation of the irregular intervals.

It is therefore probable that the story of the Phoenix was devised at the beginning of the new Sothic Period in the reign of Rameses the Great, and proclaimed by the learned hierarchy in mystic symbolisms to the common people. This king was a great patron of art and science, and the institution of the sacred Phœnix as a new religious symbolism to mark the beginning of a great epoch extending over centuries is in keeping with the ambitious designs of his victorious reign.

Therefore, since Sirius was in antiquity fiery red, the Sothic Period explains in a particularly happy manner all the essential characteristics of the mysterious Phœnix—its great age and solitariness in the world; its color and sacredness to the Sun; how it burns itself up and the new bird arises from the glowing ashes; its Arabian origin and appearance at Heliopolis; lastly, why the symbolization assumed the form of a bird; and hence it seems to me that the theory here advanced ought to have some claim to acceptance, particularly since all the theories which I have hitherto read fail signally to explain why the symbolism took the form of a bird with swift wings, how it consumes and regenerates itself, and the very great age to which it attains.

If the theory here advanced be true, the legend of the Phœnix in turn adds to the certainty of the ancient redness of Sirius, which was therefore red not only in the time of Homer, but also in the time of Rameses; and probably from the very dawn of the ancient Egyptian civilization.

There is perhaps no more typical example of the mysticism characteristic of Egyptian learning under the Pharoes than that furnished by the marvelous story of the Phœnix—certainly the most wonderful and mysteriously beautiful of all the charming myths that have descended to us from the poetic lore of the early ages.

ROYAL OBSERVATORY, Berlin, Jan. 28th, 1892.

OBSERVATIONS OF NOVA AURIGÆ AT VASSAR COLLEGE OBSERVATORY.*

M. W. WHITNEY.

A series of comparisons in magnitude between Nova Aurigæ and neighboring stars was carried on by myself and my students during the interval from Feb. 9th to April 6th. On this last date, in the prevailing moonlight, the star was no longer visible in our twelve inch telescope. Our method of comparison was Argelander's, with the modification of that method suggested by Professor Pickering. In most cases, the magnitudes of the table given below are the means of two or more independent determinations.

The magnitudes of the comparison stars were taken from the Harvard Photometry, until the Nova fell below the limit of that Catalogue. After that time the magnitudes adopted were those of the Durchmusterung, except in the cases of DM 30°935 and 30°937, where there was an evident difference of magnitude between two stars, both of which were estimated at 9.3 in the Bonn Catalogue.

The following are the comparison stars:

χ Aurigæ	DM 29° 911
φ Aurigæ	29° 923
σ Aurigæ	30° 913
H. P. 983	30° 894
" 1033	30° 935
" 956	30° 937
" 969	30° 914
a of Professor Pickering's list Astronomy and Astro-Physics, March No.	

---

* Communicated by the author.

Eastern Stand.	Time. h	Est. Mag.	Instrument.	
Feb. 9	10.5	5.26	Opera Glass	Moonlight
13	8.6	5.29	"	"
15	9.6	5.42	"	
16	8.7	5.33	"	
18	9.2	5.40	"	
23	7.7	5.75	"	
	10.0	5.72	"	
26	8.6	5.68	"	
27	9.3	5.62	"	
Mar. 3	9.7	5.71	"	Moonlight
4	10.0	5.84	"	"
9	11.0	Barely seen	"	"
10	9.5	Not seen	"	"
	.	star, mag. 6.4 seen	"	"
11	10.2	7.7	3-inch glass	"
13	8.5	7.8	"	"
14	9.6	7.9	"	"
15	7.7	8.5	12-inch glass	
16	9.3	8.6	"	
20	8.3	9.3	"	
21	9.4	9.5	"	
24	9.6	$= u$	"	
26	8.3	$= u + 0^{m}.1$	"	
April 6		Not seen	"	Moonlight

VASSAR COLLEGE OBSERVATORY, April 26, 1892.

PRELIMINARY ADDRESS OF THE GENERAL COMMITTEE OF THE WORLD'S CONGRESS AUXILIARY ON MATHEMATICS AND ASTRONOMY.*

GEORGE W. HOUGH, LL. D., CHAIRMAN.

The World's Congress Auxiliary is an Organization maintained by the World's Columbian Exposition, and approved by the Government of the United States, for the purpose of organizing a series of Congresses or Conventions to be held during the progress of the Exposition in 1893, and which will bring together the leading scholars of the world for the mutual interchange of ideas on topics bearing on human progress.

A Scientific Congress, to present and consider investigations in its special lines of research from all parts of the world, cannot fail to exert an important influence in the progress of scientific development. The personal interchange of views in regard to methods of observation and investigation will undoubtedly be productive of mutual benefit to the members of the Congress, as well as of lasting value to science.

The General Committee on Mathematics and Astronomy presents this preliminary address, cordially inviting the coöpera-

---

* Communicated by the author.

tion of all persons and societies interested in the department of physical science.

As the matter assigned to this Committee covers a large field in physical science, it has been thought advisable to arrange the subjects to be considered under the following chapters and sections, in which in consideration of its recent development and growing importance, Astro-Physics has been assigned a separate chapter from other branches of general Astronomy.

The following are some of the topics suggested for consideration under the several chapters:

CHAPTER I.—PURE MATHEMATICS.
- *Section a.* History and Bibliography.
- *Section b.* Arithmetic and Theory of numbers.
- *Section c.* Analysis.
- *Section d.* Geometry.
- *Section e.* Analytical Mechanics.
- *Section f.* Mathematical Physics.

CHAPTER II.—ASTRONOMY.
- *Section a.* History of Astronomy.
- *Section b.* Astronomical Instruments.
- *Section c.* Methods of Observation.
- *Section d.* Physical Astronomy.
- *Section e.* Observatory Buildings.

CHAPTER III.—ASTRO-PHYSICS.
- *Section a.* Spectrum Analysis.
- *Section b.* Astronomical Photography.
- *Section c.* Stellar Photometry.

The object of this preliminary address is simply to bring the subject of the Congress to the notice of the scientific men of the world for advice and suggestions as to the general conduct of the convention, and in particular as to the scientific questions to be discussed. Recommendations of themes to be discussed and of persons to present them are especially solicited from the members of the Advisory Council of the Astronomical Congress. The Advisory Councils constitute the non-resident branches of the Auxiliary Committees. Additions to these councils will be made from time to time. Communications may be addressed to the chairman of the general committee, or to the chairman of the proper special committee.

It is expected that men eminent in special lines of research will be invited to furnish papers on the leading topics under consideration. The suggestions and recommendations invited will be used in the formation of the programme for the Congress.

The chairmen of the special committees of the several chapters under the charge of the general committee, are as follows:

On Pure Mathematics:

PROFESSOR E. H. MOORE, Chicago University, Chicago, Ill.

On Astronomy:

PROFESSOR G. W. HOUGH, Dearborn Observatory, Northwestern University, Evanston, Ill.

On Astro-Physics:

PROFESSOR GEO. E. HALE, Kenwood Astro-Physical Observatory, Chicago, Ill.

GEORGE W. HOUGH, *Chairman.*
ELIAS COLBERT, *Vice-Chairman.*
E. H. MOORE, R.W. PIKE,
GEORGE E. HALE, GEO. C. COMSTOCK,
G. A. DOUGLAS, W. W. PAYNE,
MALCOLM MCNEILL,
Committee of the World's Congress Auxiliary on a Congress of Mathematicians and Astronomers.

NEW BINARY STAR β 208.*

S. W. BURNHAM.

On March 12, 1874, when observing with the 6-inch refractor, I found that the sixth magnitude star in Argo, Lalande 17103, was a moderately close double star. The components were estimated as 6 and 9 magnitude, and the distance about 1″.4. It was a very fine object with that instrument, and not difficult for a new pair. Since that time it has been sufficiently often measured to show that the components have considerable relative motion, and that they must form a binary system. Indeed it hardly needed any observations with the micrometer to demonstrate this fact. Since the well-known proper motion of this star made it practically certain that the two components were moving together, or it would have been discovered before. As a single star it has an annual proper motion of 0″.466 in the direction of 331°.7, and with one star fixed in space, it would have formed a wide and easy pair at any time before 1870, and could not have escaped detection.

---

* Communicated by the author.

The following are all the measures down to this time:

	°	″			
1874.19	30.4	1.4 ±	6.0......9.0	β	1n
1877.13	31.7	1.71	6.0......9.0	Cin.	1n
1878.43	33.9	1.37	6.0......8.0	Cin.	5n
1882.21	40.9	1.21	6.0......9.0	Sp	3n
1886.18	43.2	1.27	6.0......8.0	Wilson	1n
1889.15	47.5	1.06	7.0......8.0	β	2n
1892.11	52.3	0.70	6.8......8.1	β	3n

It will be seen from these measures that the distance is now rapidly decreasing, and that it may soon become a very difficult pair. The angular motion will doubtless be rapid for some time to come, and the period cannot be very long. For the present at least it should be measured each year.

The place of this pair (1880) is:

$$\left.\begin{array}{l}\text{R. A. } 8^h\,33^m\,54^s\\ \text{Decl. } -22^\circ\,16'\end{array}\right\}$$

Mt. Hamilton, April 20, 1892.

52 HERCULIS (β 627).*

S. W. BURNHAM.

A recent set of measures of this pair seems to show that the companion has a slow direct motion about the primary. The distance is too large to look for any rapid movement, but there is hardly any doubt of their forming a physical system. Although this is an easy pair to measure, there are but few observations. It was discovered with the Chicago 18½-inch, but can be well seen with a much smaller aperture.

The following are all the measures:

	°	″			
1878.38	309.4	1.83	5 ......10.5	Burnham	5n
1881.42	306.6	1.76	5 10	Bigourdan	1n
1886.33	307.6	2.03	5.1...... 9.5	Engelmann	8n
1892.24	318.7	1.62	5 ...... 9.1	Burnham	3n

Bigourdan measures two 12m stars:

1881.42	228°.6	67″.01	1n
1881.42	267 .6	143 .15	1n

These distant stars have not been measured previously.

Mt. Hamilton, April 20, 1892.

---

[*] Communicated by the author.

ORBIT OF β 612.

(Letter from Prof. S. Glasenapp to S. W. Burnham.)

Observatoire de l'Université Imperiale,
St. Petersburg, April 12, 1892.

Dear Sir: You have had the kindness to communicate to me all the measures (published and unpublished) of the double star β 612 which you discovered in 1878. The following are the measures obtained by the four astronomers, Burnham (β), Hall (Hl), Schiaparelli (Sp) and Engelmann (En):

	°	"	
1878.33	56.1	0.23	β 3n
1878.96	60.5	0.24	Hl 4n
1884.02	52.4	0.28	En 5n
1889.46	166.8	0.3	Sp 3n
1890.39	179.7	0.3	Sp 2n
1891.28	191.1	0.28	β 3n
1891.44	191.1	0.32	Hl 3n
1891.48	186.1	0.2	Sp 1n
1892.12	198.7	0.35	β 1n

To obtain normal positions, we form simple arithmetical means for 1878 and 1891:

	°	"	
1878.65	58.3	0.23	2 observers.
1884.02	52.4	0.28	1 observer.
1889.46	166.8	0.3	1 "
1890.39	179.7	0.3	1 "
1891.40	189.4	0.27	3 observers.
1892.12	198.7	0.35	1 observer.

One of the first two positions is evidently erroneous. The first is derived from the measures of Burnham and Hall made on seven nights with large telescopes. The second position is the result of measures of one observer, the late Dr. Engelmann, made on five nights with a relatively small telescope. The measures of Burnham and Hall agree substantially, and therefore it seems probable that the position for 1878 is correct, and that there is considerable systematic or personal error in the position of Engelmann.

Rejecting the observations of Engelmann in 1884, we obtain by the graphical method, which I proposed several years ago, the following approximate elements:

$$
\begin{aligned}
T &= 1870.04 \\
U &= 38.64 \text{ years.} \\
\eta &= +9.32^\circ \\
☊ &= 314.1^\circ \\
i &= 17.0^\circ \\
\lambda &= 31.6^\circ \\
e &= 0.13 \\
a &= 0.28''
\end{aligned}
$$

We then find the corrections of η, T, ☊ and i, namely: $dT = +3.97$ years; $d\eta = +2°.68$; $d☊ = +3°.2$; $di = +6°.0$. Finally the elements have the following values:

$T = 1874.01$
$U = 30.00$ years.
$\eta = 12.00°$
$☊ = 317.3°$
$i = 23.0°$
$\lambda = 31.6°$
$e = 0.13$
$a = 0.28''$

The agreement of these elements with the observations is very satisfactory:

t	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$
	°	°	°	″	″	″
1878.65	58.3	58.9	− 0.6	0.23	0.24	− 0.01
1889.46	166.8	170.9	− 4.1	0.3	0.31	− 0.01
1890.39	179.7	170.4	+ 0.3	0.3	0.31	− 0.01
1891.40	189.4	189.1	+ 0.3	0.27	0.30	− 0.03
1892.12	198.7	196.2	+ 2.5	0.35	0.29	+ 0.06

The error of Engelmann's measure in 1884 is about 60° in the angle of position.

The element λ is probably uncertain because the eccentricity of the true orbit is small, but it will be possible to find its correction after the periastron passage which will occur in 1908.

From your catalogue I take the position of this star for 1880:

$$\beta\,612 = \text{B.A.C. } 4559 \qquad \left.\begin{aligned} \alpha &= 13^h\,33^m\,40^s \\ \delta &= +11°\,21' \end{aligned}\right\}$$

Very truly yours,
S. GLASENAPP.

NOTE. In the foregoing orbit by Professor Glasenapp the position for 1892.12 is from my first measure in the early part of the present year. Subsequently I completed a set of measures by observing it on two other nights. Professor Glasenapp, however, had not received the complete measures when he computed the orbit. The mean of the three measures is:

1892.14 198°.7 0″.31

It will be seen that this is identical in angle with the first observation, and differs so little in the distance that the substitution could not materially affect the elements of the orbit given above. S. W. B.

NOTES FROM THE TIME SERVICE OF THE WASHBURN OBSERVATORY.*

S. D. TOWNLEY.

In the time service of the Washburn Observatory, three sidereal chronometers are compared each morning with the standard

---

* Communicated by the author.

mean time clock, and as a check upon these comparisons it has been my habit to make a direct comparison of each of the chronometers with the standard sidereal clock.

The two standard clocks are compared also, so that if the direct and indirect comparisons of any chronometer were absolutely exact the resulting corrections to the chronometer would be identical.

Out of curiosity to see what accuracy could be attained in direct comparisons I have taken *all* the chronometer comparisons from 1892, Jan. 1, to 1892, March 11 (213 in all), and computed a probable error.

Taking the differences, without regard to signs, between the direct and indirect comparisons as residuals I find a probable error of ± $0^s.027$. Assuming the probable error of an indirect comparison to be ± $0^s.010$ then the probable error of a direct comparison of a sidereal chronometer beating half seconds with a sidereal clock beating seconds is ± $0^s.025$,

$$(r^2 = \overline{0.027}^2 - \overline{0.010}^2).$$

I have computed the probable error for each chronometer separately and find that the Tobias chronometer, which has a very clear beat, gives the smallest probable error, ± $0^s.021$, while the other two Bliss chronometers give ± $0^s.024$ and ± $0^s.031$. Taking into account the signs of the residuals, $I - D$, I find that the negative residuals predominate with each chronometer and for the mean of the 213 observations $I - D = - 0^s.006 \pm 0^s.002$. Applying this correction to the residuals would reduce the probable error of a direct comparison as computed above, but not appreciably. Of these 213 residuals two are $0^s.10$, six are $0^s.09$ and all the rest are smaller.

In making the comparisons I estimate the fraction of a second to the nearest 0.05 and if the difference between direct and indirect comparisons is ever more than one-tenth of a second, I know immediately that something is wrong in the reduction.

I have had nearly three years practice at this work and about twenty-five seconds is the time necessary for making a comparison.

Having noticed a reference, Chauvenet, Vol. II, page 193, to Professor Peirce's discussion of an observer's personal scale, I thought to investigate my time observations to see if any such scale existed. The observations are made with a three-inch Fauth transit, magnifying power of 115, eye-and-ear method, chronometer beating half seconds. I estimate the *time* of transit of the star, not the space passed over, to the nearest tenth of a second.

Theoretically, in a large number of observations, there should be as many transits on any one-tenth of a second as upon any other tenth. Upon investigation, however, I found this to be quite far from the truth. From 188 observations of stars of declinations from + 20° to + 65° there was a decided preference for the 0 and 5 tenths, and a decided neglect of the 4 and 8 tenths. It is easy enough to see why an observer should favor the 0 and 5 tenths, but I am at a total loss to know why the 4 and 8 tenths should be neglected rather than the other tenths. Feeling sure that such large discrepancies should not occur, I determined to watch myself in the future. A second series of 816 transits was obtained which are much more evenly distributed, but still there is a tendency to neglect the 4 and the 8 tenths.

The following table will show the results of these series.

	EYE AND EAR.				CHRONOGRAPH.	
	Series I.		Series II.		Series III.	
Tenth.	No. of Transits.	Per cent.	No. of Transits.	Per cent.	No. of Transits.	Per cent.
0	47	25.0	109	13.4	25	11.8
1	18	9.6	85	10.4	23	10.9
2	23	12.2	93	11.4	17	8.1
3	14	7.4	98	12.0	22	10.5
4	8	4.3	71	8.8	15	7.1
5	26	13.8	76	9.3	22	10.5
6	23	12.2	79	9.7	19	9.0
7	12	6.4	71	8.8	20	9.5
8	5	2.7	64	7.9	18	8.5
9	12	6.4	70	8.6	30	14.2
Totals	188	100.0	816	100.3	211	100.1

In Series II, there seems to be a tendency to put the transit in the first half of the second, and the 8 is still the most neglected digit. Why this particular figure should be neglected, I am unable to say, unless it is perhaps that this is the hardest figure to make. If that could have any effect, however, then I should think that 3 and 5 would be next on the list but the table shows these figures to be favored rather than neglected. Series III, transits recorded by the chronograph, lends additional evidence to the belief that I have some dislike for the figure 8, for the table seems to indicate that in reading the chronograph sheets, the figure 9 has been favored at the expense of the figure 8.

With all the peculiarities of these series, I find the observations are not bad, for the computed probable error of a single transit in Series I is $\pm 0^{s}.055$ and in Series III is $\pm 0^{s}.035$ while, according to the formula of Albrecht, the probable errors should be $\pm 0^{s}.071$ and $\pm 0^{s}.052$ respectively.

Madison, Wis., April 1, 1892.

THE EARTHQUAKE FOR FEBRUARY 23, 1892.*

WILLIAM H. PICKERING.

By a copy of the New York *Weekly Times* just received, I see that a severe earthquake shock was felt in San Diego, California, on Februrary 23, at 11^h 14^m P. M. This reduced to Greenwich mean time is 23*d* 19^h 14^m. By referring to our records I find that four earthquakes are mentioned as having occurred here during the month of February, none of them being very severe. Their dates are February 4, 9, 11 and 23. The latter occured at 23*d*, 21^h, 52^m, G. M. T., and is recorded as coming from the north. This is 2^h 38^m later than the one which occurred in San Diego. The approximate distance from San Diego to Arequipa, measured along a great circle, is 4,520 miles. Assuming our shock to have been identical in origin with the California disturbance, and the latter to have originated in the immediate vicinity of San Diego, this would give a mean rate of transmission of 2,510 feet per second. The distance traversed in this case is perhaps the greatest that has ever been accurately timed.

The great earthquake of 1868 shook the west coast of the whole continent, from California to Tierra del Fuego; but if accurate observations were made at that time I do not know of their ever having been collected. The great earthquakes of Lisbon and Charleston were each accurately observed through a distance of 1,200 miles. Observations made upon the Japanese and Indian earthquakes have been over still smaller distances. The velocities with which these earthquakes were transmitted when passing through the ground, have been found to vary greatly, ranging from a few hundred to over ten thousand feet per second. When the shock transmitted through the ocean on the other hand the results are much more accordant, and usually do not differ greatly from three thousand feet per second. Valuable sults in the present instance might be obtained by securing observations made at other points in the disturbed area. These would give not only the mean velocities at different distances from the centrum, but would enable us to determine with some precision its approximate location.

It is proposed if possible to collect at this Observatory general data pertaining to seismic disturbances from various points along the Pacific coast. Should this plan prove practicable, it is thought that in the course of a few years many disturbances might be found which had propagated themselves to considerable distances, and from which it would be possible to locate some of the more prominent earthquake centers near this coast.

AREQUIPA, Peru, April 5, 1892.

---

* Communicated by the author.

THE GERMAN VARIATION OF LATITUDE WORK.*

HAROLD JACOBY.†

In December, 1890, Professor Albrecht published the results of the variation of latitude observations made at Berlin, Potsdam and Prague. The volume is not printed, but is merely a lithographic reproduction, and is entitled *Provisorische Resultate der Beobachtungsreihen in Berlin, Potsdam und Prag, betreffend die Veranderlichkeit der Polhohe. Auf Wunsch der permanenten Comission zusammengestellt von Th. Albrecht.* In the present article it is intended to give an account of the methods of observation and reduction described in the above work, so that they may be accessible to the readers of this Journal. The high importance of keeping a close watch upon the movements of the terrestrial pole, and the comparatively inexpensive nature of the necessary instrument, make this class of observations well adapted to the smaller observatories; where, moreover, but little time can be given to observing, and still less to computation.

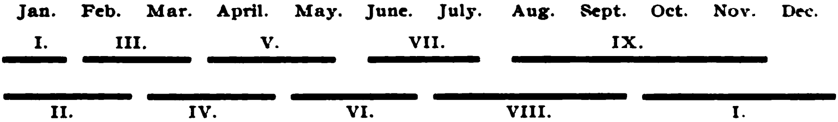
The observations at all three stations were made by Talcott's method. At Berlin Dr. Marcuse observed with a bent transit constructed by Bamberg, and having an aperture of 11.5 cm. It was mounted upon a pier of such height that the object-glass was almost in the open air when the telescope was pointed at the zenith. The Potsdam observations were made by Mr. Schnauder with a zenith telescope of 6.8 cm. aperture. This instrument has a straight telescope, and is modelled after the pattern of the earlier Coast Survey instruments. It has a diagonal eye-piece of considerable length, which is turned towards the east or west in observing. The micrometer is between the prism and the eye. The Prague observations were made by Professor Weinek and and Dr. Gruss with a bent transit of 6.8 cm. aperture. Each instrument was provided with *two* delicate latitude levels, both of which were read at each observation, whenever possible.

It is well known that the weak point of Talcott's method lies in the uncertainty of the declinations. But it is possible to determine the *variation* of latitude so as to be entirely independent of the declination errors. If we could observe a certain series of stars throughout an entire year, we should obtain the variation of latitude free from the uncertainty of the declinations. Of course this cannot be done, owing to the impossibility of

---

* Communicated by the author. † Columbia College Observatory, New York.

observing during daylight. We are therefore compelled to change one set of stars after it has been observed a certain length of time, and begin upon a new set. Now if we arrange matters so that the period of observation of the new set overlaps that of the old set by several weeks, we can derive from the overlapping observations the systematic differences between the sets. In this way we can get a value of the variation, which is independent of the declinations. Accordingly the following program was adopted at each station. Nine sets of stars were selected, each set containing eight or nine pairs, extended over about two hours of right ascension. On every clear night two sets were observed, and they were so arranged that *at least* three weeks' overlapping observations were secured for each pair of consecutive sets. The periods of observation were arranged in the following way:



The Roman numerals designate the numbers of the sets, and the lines show approximately how they overlap. In selecting pairs the following rules were adopted:

1. The mean of all the declinations of any set must not differ more than 1′ from the latitude of the station.
2. The difference in right ascension of the two stars of any pair must not be less than 3^m nor more than 15^m. The difference of zenith distances must not exceed 15′.
3. The absolute zenith distances must never exceed 25°.
4. Those stars are to be given the preference whose proper motions in declination are known, and as far as possible, the two stars of each pair must be taken of equal magnitude. No stars of the 1st or 2d magnitudes should be used.

Although the present method does not depend upon the accuracy of the declinations, yet for obvious reasons it is very dedesirable to use only well-determined stars. Moreover it is important that the declinations derived from the several catalogues be reduced to a uniform system by the application of the proper corrections. For this purpose the system of the *Berlin Jahrbuch* has been adopted. I have thought it desirable to set down in a table the systematic corrections which have been applied to the declinations of the other catalogues. These corrections for the older catalogues have been taken from the table given by Auwers in *Astr. Nach.* No. 1536, to which I have added the further corrections given by Auwers in *Publ. der Astr. Gesellsch.*, No. XIV, p. 12. The corrections for the Greenwich seven-year, new seven-year, and nine-year catalogues, as well as Pulcowa, 1845, have been taken from Auwers' *Publ. der Astr. Gesellsch.*, XIV, p. 10, 11. The Greenwich ten-year corrections are from a table given by Romberg in his new Pulcowa catalogue.* Declinations taken from the *Jahrbuch*, from Auwers' *Bradley*, or from Safford's catalogue have been used without correction. Whenever the proper motion was known, it was allowed for in the reduction to mean and apparent place. Several declinations were specially determined in the meridian by Küstner and Becker.

With regard to the adjustment of the instruments, the observers made it a rule never to let the azimuth error exceed 1^s, while the collimation and level errors were kept under $0^s.7$. Observations to determine these errors were made at least once a month. The barometer was read every night: and the temperature was noted both within the observing room, and in the open air. The bisection of the stars with the micrometer thread was effected four or five times at each transit, in order to eliminate errors of observation. These bisections were always made at certain fixed points, marked by vertical threads, and symmetrically situated with respect to the middle thread. *Both* latitude levels were read before and after each observation, whenever possible. To avoid error the two levels were numbered differently; one running from 0 to 50, the other from 50 to 100. The bubbles were kept as near as possible to the middle points of the tubes. At two of the stations it was found necessary to discontinue temporarily the use of one of the levels, as the observations showed that the tubes were not working well. After a thorough overhauling, they were found to be again in good condition. This circumstance shows the great importance of using two levels. When discordant observations occur, they can be traced to the level, if the fault is in that part of the instrument. The appearance of the star-images, and the steadiness of the air were recorded every night.

The reduction of the observations was carried out according to a plan which we will now outline briefly. This plan is not altogether rigorous, and the final results obtained are characterized by Dr. Albrecht as *provisional* only. Yet a complete definitive discussion of the observations would certainly not produce a change of more than a few hundredths of a second in any of the final results. The observations were first reduced in the

---

* Many of the above references were kindly sent to me by Professor Albrecht.

usual way, by applying the customary terms for micrometer, level, and refraction to the mean of the apparent declinations of the pair. The "reduction to the meridian" was also applied, and as far as posssible, the periodic and other errors of the micrometer screws were taken into account. The Prague screw had not been investigated, however, at the time the observations were reduced. The reductions from mean to apparent place were carried out in duplicate by means of the formula:

$$\Delta\frac{\delta+\delta_1}{2}=A\frac{a^1+a^1_1}{2}+B\frac{b^1+b^1_1}{2}+C\frac{c^1+c^1_1}{2}+D\frac{d^1+d^1_1}{2}+\tau\frac{\mu^1+\mu^1_1}{2}.$$

Having obtained in this way the separate values given by each observation of the several pairs, we can proceed to the combination of the observations, so as to derive the variation of latitude free from errors of declination.

For this purpose we begin by adjusting the declinations within each of the sets of eight or nine stars, so that they will conform to what may be called the mean declination system of that particular set. This is accomplished by comparing the mean value of the latitude as derived from all the observations of any particular pair with the corresponding mean value from all the eight or nine pairs of the set. The difference is the reduction which must be applied to all observations of the pair in question, so as to bring them into uniformity with the mean declination system of the set. Of course, in carrying out this adjustment, only the observations of those nights should be used during which all the pairs of the set were observed. Obviously the mean of all these reductions for any set must be zero. It is to be noted that the Potsdam observations showed slight discordances, probably resulting from astigmatism in the observer's eye. If the pair was observed in the order *circle-west—circle-east* the resulting latitude was too great by about 0″.18. The same pair observed in the reverse instrumental order gave a result which was too small by about the same amount. Accordingly a correction was applied to all the Potsdam observations, to remove the effect of this discordance. The correction was not quite constant, six different values being used during the period of observation. An error of this kind is almost completely eliminated from the results if the pairs of any evening are observed alternately *circle east—circle west* and *circle west—circle east*. Perhaps the use of a small reversing prism attached to the eye-piece would remove the trouble altogether. For the prism could be so turned that the micrometer thread would always appear to be horizontal, and to move in a vertical direction.

By adding the successive reductions of the consecutive declination systems, we can get the reduction of each system to one of their number, selected as standard; or if desired, to a system which would represent the mean of all. After the application of these last corrections, we may regard the means for each night as free from the uncertainty of the declinations, so far as variation of latitude is concerned. The final results so obtained showed that at Prague, where two observers took part in the work, an appreciable systematic difference existed between them. There is no very apparent explanation of this: but on the average Professor Weinek made the latitude 0″.16 larger than Dr. Gruss. A correction of ± 0″.08 was therefore applied to these observations, so as to refer them all to the mean system of the two observers. The final results, after all the corrections had been applied, exhibited at all three stations a variation of latitude of about 0″.5, as is now well known.

Before closing the present brief account of the German observations, attention should be called to a paper by Dr. Küstner* upon the determination of the constant of aberration by means of observations with the zenith telescope. Dr. Küstner points out that in order to secure the simplest conditions for obtaining both the variation of latitude and the constant of aberration, we should select only four sets, each of which may extend about two hours in right ascension, the mean right ascensions being at about 6^h, 14^h, 18^h, and 22^h. Such an arrangement would of course necessitate considerable observing after midnight. For we should have to observe each set during its entire period of visibility, beginning with observations just before sunrise and ending with observations just after sunset. But we would only have to observe during two hours each night, except during the overlapping periods, when four hours would be necessary. In the latter case, there would always be an opportunity for rest between the first two-hour watch, and the second one. If two observers are to take part in the work, as at Prague, it would perhaps be more convenient to have them observe alternate sets, instead of alternate nights. For there would then be considerable periods of complete rest for each observer. Of course any constant personal difference would still be eliminated from the cyclical sum:—in fact, the reductions of the consecutive declination systems would *include* any such personal differences. During the overlapping periods both observers would of course be on duty each night, one in the evening, the other in the early morning.

---

* *Astronomische Nachrichten*, No. 3105.

PHYSICAL OBSERVATIONS OF MARS.*

DR. TERBY, LOUVAIN, FRANCE.

I impatiently awaited the opposition of Mars in 1888 to try on this planet the power of my new 8-inch equatorial constructed by Sir Howard Grubb. Unhappily the small altitude of the star above the horizon and its distance did not permit me to hope for very complete results. When I shall have added that during the course of my observations, the most detestable atmospherical conditions continued to prevail, one will not be astonished to find the facts narrated here very insignificant in comparison with those which M. Schiaparelli has verified under the sky of Milan during much more favorable oppositions, with the aid of an instrument of almost the same size and an incomparably acute eye. While, under good conditions, the Grubb equatorial has already supported perfectly a power of about 650 diameters in observing Saturn and the Moon, for example, it has scarcely tolerated the power of 280 diameters during this unfavorable opposition of Mars.†

During the course of the observations, important news arrived from Nice, where M. Perrotin, aided by a telescope which is surpassed only by that at Mt. Hamilton, verified some most interesting facts; these facts can be placed in three categories: 1st, facts relative to Libya; 2d, presence in the north polar spot of a black streak as of ink; 3d, verification of the existence of the canals and of their doubling. On another side, M. Schiaparelli wished to keep me posted in the new discoveries which he made every day at Milan with his Merz 18-inch; I learned that he too saw the details noted by M. Perrotin. And at Louvain, on my side, by the aid of the 8-inch, I confirmed the existence of the black thread in the polar spot, that of a great number of canals, and the doubling at least of Phison. I also observed Libya distinctly. In proof of the actuality of these facts, I have mentioned some of my results in the *Comptes rendus, in Ciel et Terre*, and in Flammarion's *l'Astronomie*.

These partial and scattered notes could only give a very incomplete idea of the Louvain observations; six drawings (the total number published) printed in *l'Astronomie* have not even been ac-

---

* Extract from Vol. LI. of *Memoires couronnes et Memoires des savants estrangers*, published by the Royal Academy of Sciences, Letters, and Fine Arts of Belgium. Translated by Roger Sprague.

† And yet Dr. Terby speaks in his notes of having used 650 on Mars. Evidently, his meaning here is not clear.—*Translator.*

companied by a note as to the days and hours; further, these drawings do not represent the planet as it was really seen, but (to reduce their number) I have often collected the details furnished by many evenings' observation; whatever may be their importance in verifying the maps of M. Schiaparelli, they could not serve to give a perfect idea of the results obtained. A complete work alone, comprising all the details of observations made at Louvain, could fill these deplorable gaps, and that is the object of the present memoir.

Our principal end was the verification of the admirable maps of M. Schiaparelli, maps which are yet, even to-day, it is necessary to confess with regret, the object of an entirely unjustifiable suspicion. We took inspiration from the principle announced by some great observers: "Often," they say, "one can see well what one especially seeks;" M. Otto Struve would probably never have discovered the Maia nebula with the aid of the great Pulkowa equatorial if he had not been forewarned of its presence by the photographs of the MM. Henry, and if he had not sought it with attention. Likewise, we have sought the canals of Mars in the regions where we knew that M. Schiaparelli had proved them to exist; we have taken care to calculate in advance the approximate longitude of the central meridian for each observation, and, map in hand, we have patiently and obstinately pursued these very difficult details. It is to this method, we do not hesitate to say, we owe our partial success.* As M. Perrotin himself says, all this does not leap to the eyes even in the largest telescope; for succeeding here, the greatest attention and perseverance are necessary. With still more reason, the observer armed with a simple 8-inch in the unfavorable circumstances which we have experienced, would be discouraged very quickly if he was not sustained in advance with an unbreakable faith in the truth of the Milan results; this faith alone, in effect, could inspire him with the perseverance and, I may say, the obstinacy necessary. Furthermore, prodigious difficulties are a great help to incredulity, and it is permissible to believe that observers provided with adequate means, who have not succeeded in seeing the can-

---

* The translator can not entirely agree with this principle. The first time I ever looked at the Andromeda nebula, the definition was perfect, and I saw the "granular texture" of the principal condensation distinctly. Yet I knew nothing of it in advance, and my telescope was only a 6-inch. Such excellent observers as Swift and Barnard tell me that, with very much larger telescopes, they have specially sought for this granular appearance, and have never met with any success. On the other hand I may say that in observing the Moon with a 2-inch telescope I never saw the Hygines and Ariadæus rills until I identified their places by means of a map. Yet Neison calls them easy objects for such a telescope.

als and their doubling, have often abandoned the observation through lack of preliminary confidence or of anterior knowledge of the details sought for.

The north polar spot was constantly visible, white, brilliant, and reduced to very small dimensions; at times when the definition was best and especially with the powers 450 and 650, I saw its elliptical form perfectly and I observed that this ellipse was entirely on the interior of the visible disk, tangent to the limb.

Towards the south pole a marked whiteness always prevailed; further, one saw appear, from time to time, in these whitened regions, some shining, snowy, well-defined spots, but which in general I did not believe to belong to the south polar spot properly so-called; these are explained by the presence of special regions which shall be discussed further on, such as Hellas, Argyre, Thyle, Noachis (?), Thaumasia (?), notably.

Only the very small white and shining spot, entirely like a polar spot, observed on the 29th of April to the south of the Kaiser sea, left me in some doubt as to its nature and perhaps made parts of the south polar spot generally invisible in 1888; or might Novissima Thyle be seen there in spite of the fact that it seemed that its high southern latitude should remove it from sight?

Let us pass on to the most interesting feature offered (in 1888) by the north polar spot, a feature observed independently at Milan, at Nice, and at Louvain; I refer to a black streak dividing this snow-cap into two parts. Here are the observations which I have been able to make by the aid of the excellent Grubb instrument. Even before the 12th of May I had noticed something like a division in this polar spot; unfortunately I took the fact for an illusion due to the unsteadiness of the image and I did not take any notes concerning it. On the 12th of May, from $8^h 15^m$ to $9^h 8^m$, I saw that the north polar spot was composed of two parts separated by a black streak as of ink; the part situated on the side towards the east limb (considered geocentrically) was smaller than the other. I again followed the polar spot from $9^h 12^m$ to $10^h 28^m$ the same day, and the little satellite spot's motion of rotation around the pole was very sensible, as my drawings show. At moments the black thread took the aspect of a black point isolated in the midst of polar snows. At $9^h 43^m$ the center of the satellite polar spot reached the central meridian; we find in this manner an approximate longitude of 204°.3 for its center. At $10^h 28^m$ its eastern extremity (seen from the earth) was near the central meridian which gives it the longitude of 215°.3.

[TO BE CONTINUED.]

THE PHYSICAL NATURE OF SHOOTING STARS AND AEROLITES.*

W. F. DENNING, ENGLAND.

D. I. M. Tébar, in a paper on Shooting Stars, Bolides and Aerolites, presented to the Astronomical Society of the Pacific ("Publications," Vol. III, No. 19), advances the following theory in explanation of them:

"*Shooting Stars* are ball-lightnings which abound in the upper regions of the atmosphere and under certain conditions their number over one and the same region is so considerable as to present the appearance of a shower."

"When these lightnings are formed in the lower regions of the atmosphere or, in the case of their descending far down in the same, they originate the so-called *bolides*, and when the ball-lightning darts through a cloud or through air impregnated with substances lifted up from the surface of the soil and scattered in the atmosphere through cyclones and hurricanes or volcanic eruptions, their effect is to unite all those substances into a single mass, thus forming the *meteorolite* or *aerolite*. Ball-lightnings and rains of ball-lightnings are not of frequent occurrence in the atmospheric strata immediately above the surface of the earth; still there are instances of both kinds of phenomena."

These singular conclusions apparently carry us back to the times of our forefathers and recall the discarded theories of a past age, but Dr. Tébar's explanation can hardly be regarded as consistent with present knowledge; indeed there are several objections to it. Dr. Tébar's idea that the shooting stars are ball-lightnings high in the atmosphere, while aerolites are formed by substances united by the action of electricity in the lower part of the air, implies that a great distinction exists between these bodies, whereas no such distinction appears to have been observed. It is highly probable that shooting stars, bolides and aerolites are precisely similar in their general derivation and constitution, and the physical aspect they present is entirely consistent with the view that they are small planetary bodies undergoing combustion. There are considerable differences of size and differences also as to the materials in their composition. But the train of sparks often noticed, the expansion which occurs in the nucleus, its slackening speed due to atmospheric resistance and its final resolution into hot ashes, all prove that a meteor, whether shooting star, bolide or aerolite, is formed of a substance which is partially or wholly dissipated under the action of intense heat.

---

* Communicated by the author.

The telescope supplies us with similar evidence as to the character of the shooting stars which are too small to admit of naked eye observation. These have no features distinguishing them from the brighter class except such as are due to their remote distance from us.

The radiant points of meteor-showers are often visible in the same places amongst the stars for long periods, and this peculiarity is quite opposed to the theory that meteors have their origin in ball-lightning. The radiant of a shower generated within our atmosphere would not preserve the same astronomical position, but must participate in the rotation of the earth. Nor should we expect the "lightnings" to recur at the same dates in different years and always from identical points on the celestial sphere.

Many circumstances justify the commonly accepted view that meteors are planetary bodies entering our atmosphere from the outside and are not born within it by means of electricity. Luke Howard, the meteorologist, in describing a considerable shooting star seen by him on July 29, 1813, said, "the impression it left on my mind was altogether that of a solid ignited projectile," and I believe this impression contained a truth, and that it is one often received by careful observers.

BRISTOL, May 11, 1892.

PHOTOGRAPHIC AND VISUAL MAGNITUDES OF STARS. From *Nature* May 12, 1892, the following is taken:

"At the Amsterdam Academy of Sciences on April 2, Professor J. C. Kapteyn communicated the results of an investigation of the systematic differences between the photographic and visual magnitudes of stars in different regions of the sky. The comparison of the photographic diameters of stars of equal visual magnitude (according to Gould and Schönfeld's estimations) on 370 plates of the southern sky, shows that the actinic effect of stars in or near the Milky Way is much greater than that of stars in high galactic latitudes. Professor Kapteyn has examined the different causes which lead to this variation. There is, first of all, the influence of different meteorological conditions; next, systematic errors in the catalogue of visual magnitudes used for comparison; and thirdly, peculiarities in the light of the stars. The discussion leads to the conclusion that the difference of magnitude is not appreciably affected by the first of the causes. And since, taking everything into consideration, the errors of the estimated visual magnitudes could not possibly exceed 0.3 magnitudes there is no doubt that the difference of half a magnitude or more, indicated by the photographs, is due to the quality of light emitted. It is said that Professor Pickering's idea that the Milky Way ought to be considered as an aggregation of stars of the first type is only sufficient to account for a difference of about 0.1 magnitude. Thus it appears that the light of stars in or near the Milky Way, like those of group IV, is richer in violet rays than that of other stars.

Fig. 1

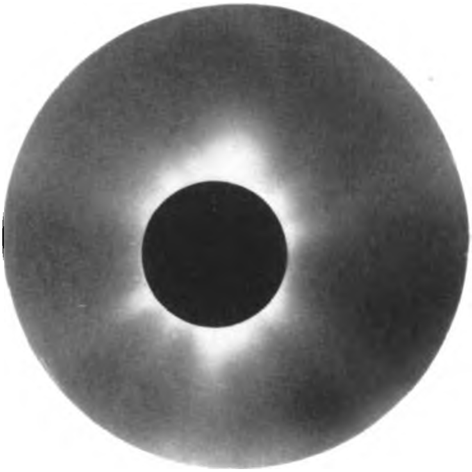


Fig. 2

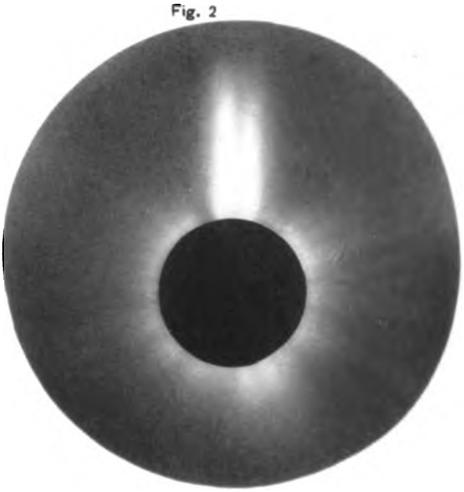


Fig. 3

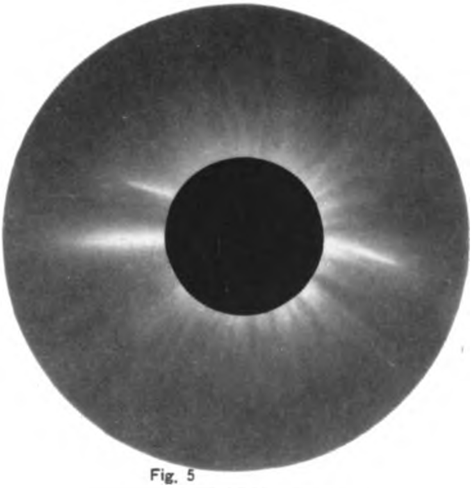


Fig. 4

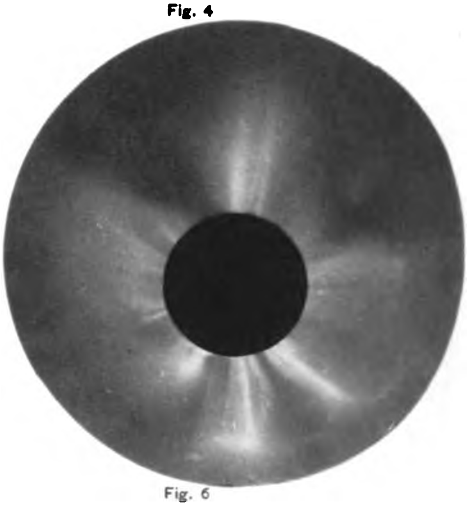


Fig. 5

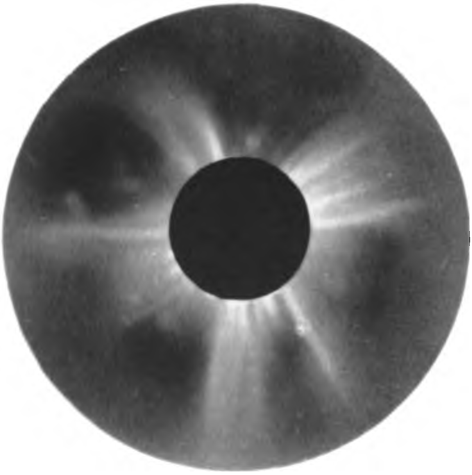


Fig. 6

CORONOIDAL ELECTRICAL DISCHARGES (PUPIN)

ASTRO-PHYSICS.

ON ELECTRICAL DISCHARGES THROUGH POOR VA[illegible] CORONOIDAL DI[illegible]GES.*

M. I. PUPIN

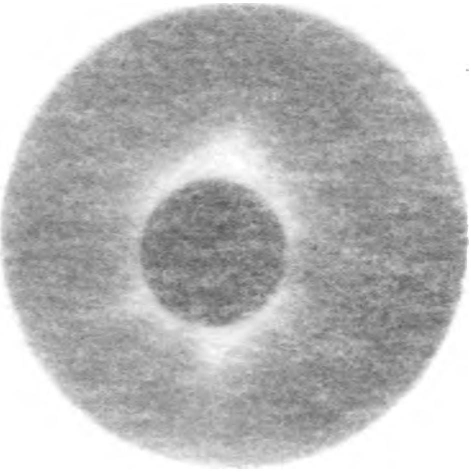
IN[illegible]UCTION.

The behavior of electrical [illegible]es throu[illegible]or vacua [illegible] not seem to have received the [illegible]ntion of e[illegible]mental inv[illegible]gators which it deserves. [illegible] seem strange in view of [illegible] uncertainty of our knowledge of [illegible] process by [illegible] the transfer of electricity thro[illegible]gh gases t[illegible]s place. Considering, however, that it was generally custo[illegible] to employ in [illegible]erimental investigations of this [illegible] a vacu[illegible]r with metal electrodes in connection w[illegible] an electric gen[illegible] of small capacity, it is easily explained w[illegible] the discharges [illegible]ugh poor vacua should have received so m[illegible]ess attention t[illegible]he discharges through high vacua and the s[illegible] discharges t[illegible]h gases at ordinary pressures. Neither the [illegible]cuum [illegible] nor [illegible]working of the electric generators ordina[illegible]ployed admi[illegible] of rapid, easily adjustable, but essential va[illegible]ons in the co[illegible]ns of the experiment; as, for instance, va[illegible]ions of [illegible] shape of the electrode, of the frequency [illegible]he disch[illegible] the strength of the electromotive force, etc. [illegible]t as I s[illegible] out in the course of this paper, it is thro[illegible]hese very [illegible]ns that certain fundamental features in [illegible]haracter [illegible]trical discharge through poor vacua are [illegible]ht out pr[illegible]

The fact that electrical discha[illegible] poor va[illegible]ble in many characteristic details the a[illegible]ce and [illegible] the solar corona, attaches additional [illegible] and [illegible] to that class of experimental investigat[illegible]h are [illegible]t, only, in this paper. Neither time nor [illegible]rm[illegible] aim at anything approaching complete[illegible]e prin[illegible] in my presenting this paper was to reco[illegible]st[illegible] my method of investigating it to those wh[illegible]mand [illegible] a larger experience and skill in experiment[illegible]tious [illegible] who also have more leisure and greater e[illegible]acili[illegible] than I could even pretend to possess.

---

[*] Read before the National Academy of Sc[illegible]2.



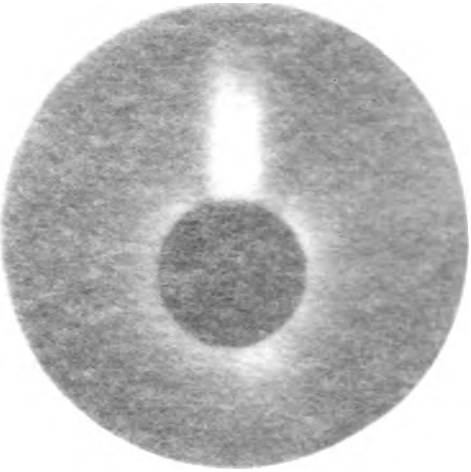


Fig. 4

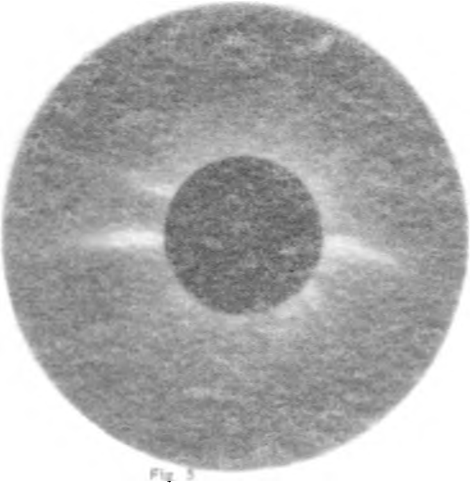


Fig. 5

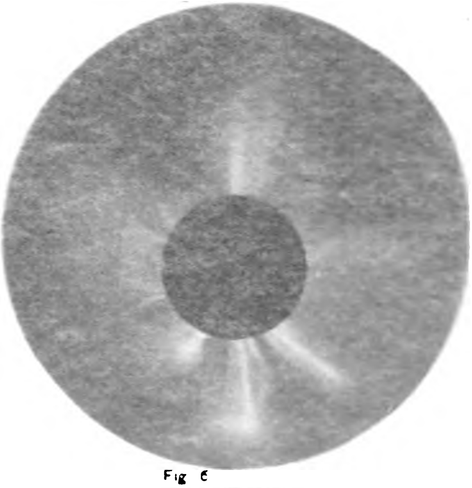
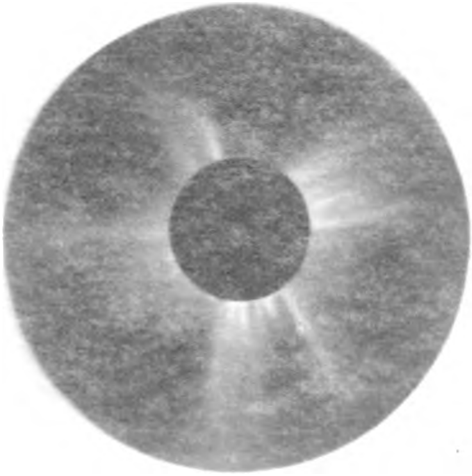
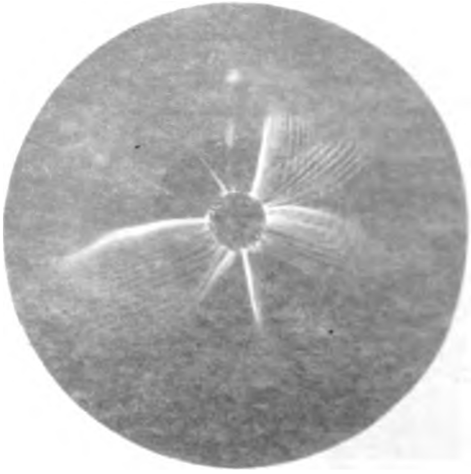


Fig. 6





CORONOIDAL ELECTRICAL DISCHARGES (PUPIN

ASTRO-PHYSICS.

ON ELECTRICAL DISCHARGES THROUGH POOR VACUA, AND ON CORONOIDAL DISCHARGES.*

M. I. PUPIN.

INTRODUCTION.

The behavior of electrical discharges through poor vacua does not seem to have received the attention of experimental investigators which it deserves. This may seem strange in view of the uncertainty of our knowledge of the process by which the transfer of electricity through gases takes place. Considering, however, that it was generally customary to employ in experimental investigations of this kind a vacuum jar with metal electrodes in connection with an electric generator of small capacity, it is easily explained why the discharges through poor vacua should have received so much less attention than the discharges through high vacua and the spark discharges through gases at ordinary pressures. Neither the vacuum jar nor the working of the electric generators ordinarily employed admitted of rapid, easily adjustable, but essential variations in the conditions of the experiment; as, for instance, variations of the size and shape of the electrode, of the frequency of the discharges, of the strength of the electromotive force, etc. But as I shall point out in the course of this paper, it is through these very variations that certain fundamental features in the character of an electrical discharge through poor vacua are brought out prominently.

The fact that electrical discharges in poor vacua resemble in many characteristic details the appearance and behavior of the solar corona, attaches additional interest and importance to that class of experimental investigations which are pointed out, only, in this paper. Neither time nor facilities permitted me to aim at anything approaching completeness. The principal aim in my presenting this paper was to recommend my subject and my method of investigating it to those who have command over a larger experience and skill in experimental investigations, and who also have more leisure and greater experimental facilities than I could even pretend to possess.

---

* Read before the National Academy of Sciences, Washington, April 22, 1892.

DESCRIPTION OF THE EXPERIMENTAL METHOD.

A brief description of the method by which I obtained my vacuum discharges seems in place now. It consists in producing an electrical current in a vacuum by means of the condenser effect of tinfoil coatings or other conductors placed on the outside of a vacuum jar.

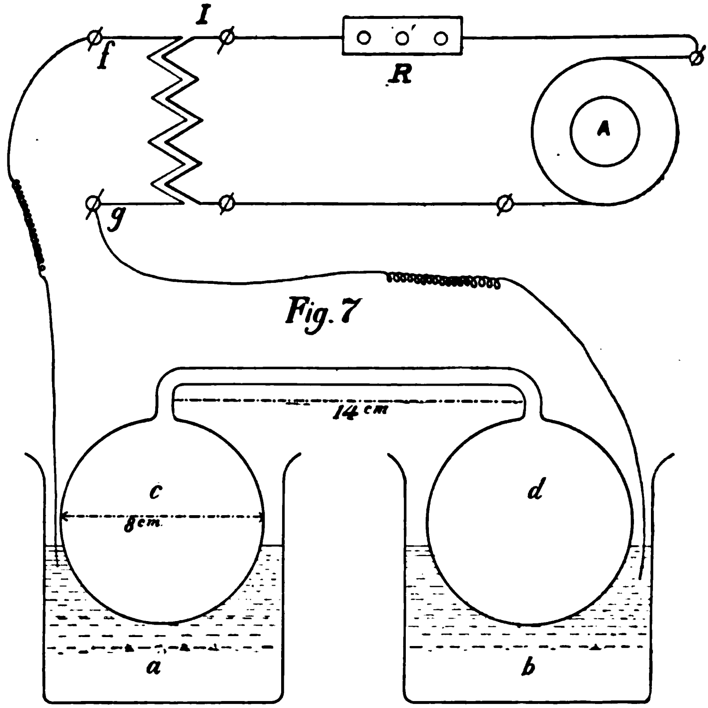


Fig. 7

The following experiment which I performed over a year ago will explain my meaning more fully. The poles, *f*, *g* ,(Fig. 7) of a small Ritchie induction coil are connected to two glass beakers, *a b*, containing water. The primary is fed by ¼ HP alternator *A*, giving an alternating current of about 80 periods. A resistance box *R*, regulates the strength of the primary current. The speed of the motor which drives the alternator regulates the periodicity of the current.

A vacuum jar *c d*, consisting of two glass bulbs (each about 8 c. m. in diameter) connected by a tube of narrow bore, was immersed into the beakers, one bulb in one beaker, the other into the other. The jar contained rarified air at about 5 mm. pressure.

As soon as the bulb reached a certain depth a discharge took place, producing a perfectly steady and continuously diffused crimson luminosity. The intensity of the luminosity increased with the increase of the surface of contact between the water and the bulbs. The same effect was produced by substituting a Holtz machine for the induction coil and the alternator. In this case the effect was due, of course, to the oscillations produced by the spark discharge between the poles of the machine. The two vacuum bulbs with the water surrounding them act like two condensers connected in series by the narrow tube. It seems superfluous to describe the obvious experiments which I had to perform to prove the following relation:

The intensity of the luminosity increases with the condenser surface of the bulbs, with the frequency of alternations, and with the effective electromotive force of the charging apparatus. Other things being equal, the total amount of light produced will increase with the increase of the conductivity of the vacuum. This relation may have been understood before, but to my knowledge it was never clearly stated.

The luminous effects which I succeeded in producing in the manner described were so powerful, that I thought it worth while to construct an electrical lamp on this principle. I mention this for the purpose of pointing out that this method of producing very powerful vacuum discharges was worked out by me several months before the publication of Nikola Tesla's and Professor J. J. Thomson's magnificent experiments. A considerable number of results which I obtained in my experiments are simply repetitions, on a small scale, of the results obtained by these scientists. There is, however, one line along which there seems to be but very few points of contact between their work and mine. This line runs in the direction of investigating the relation between the character of the discharge, the pressure in the vacuum, and the effective e. m. f. which produces the discharge. The following experiments will show some of the characteristic features of this relation.

ON THE CRITICAL POINTS OF THE DISCHARGE.

A vacuum jar, of the form and dimensions as given in Fig. 8, was substituted for the small double bulb *c d* in Fig. 7. The bulbs *A* and *B* were totally immersed in large glass beakers, containing clear, distilled, acidulated water. The air pressure in the bulbs was a little less than 2 mm. Instead of a small alternator a large alternating current machine fed the primary. On closing the primary circuit the discharge between the bulbs started long before the resistance box, *R*, indicated that the e.m.f. in the secondary coil had reached its maximum. The crimson luminosity was very soft, steady, and distributed in accordance with the distribution of the potential which one would expect in an electrical system of the above description. Touching the narrow tube at any point increased the luminosity below the point touched; evidently due to the increase of the static capacity at that point. Diminishing gradually the e.m.f. the luminosity of the discharge diminished with it, and then stopped suddenly as if a critical point had been suddenly reached. Reducing the e.m.f. gradually to zero and then gradually increasing it again, it was found that the discharge would cease at a point much lower than the point at which it would start again, the difference between the two points diminishing considerably with the rapidity with which these variations were made. The discharge will start at a much lower e.m.f. if solicited; that is to say, if the long tube is touched at one or more points. A wire bent in the shape of a Leyden jar discharger does very good service as a discharge "solicitor."

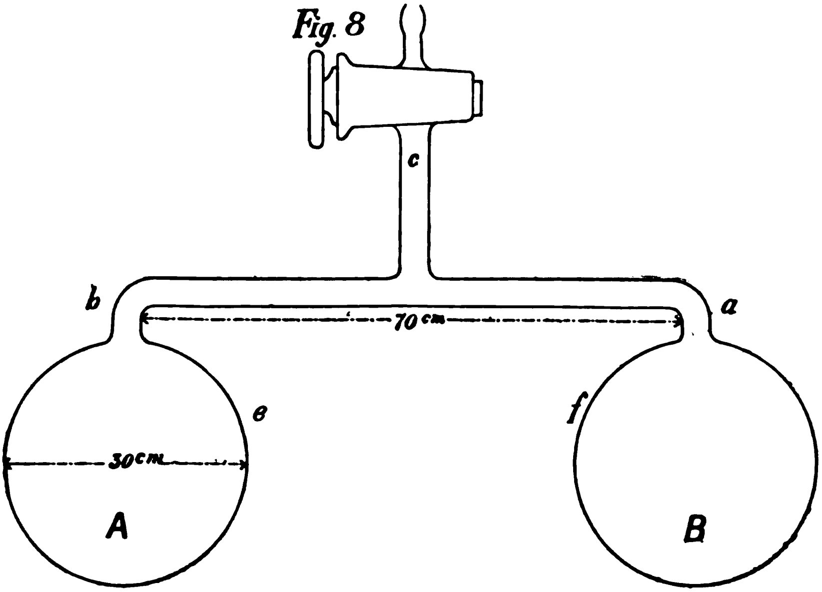
The discharge was similarly affected by varying the capacity. Performing the last experiment, but with the small vacuum jar *cd* given in Fig. 7, it was found that with a given low potential the discharge did not start until the bulbs *c d* had reached a certain depth, and then it started suddenly. Raising the bulbs gradually, and therefore diminishing the capacity, the discharge became fainter and fainter, but it did not cease until the bulbs were entirely lifted out of the water. On immersing again, the discharge did not start until a certain depth was reached. The depth at which the discharge would start this time was smaller than in the first case, and the smaller the shorter the interval between the time of taking the bulbs out and immersing them again. This difference is of course due to the improved conductivity of the gas, and this again may in a certain measure be due to the rise in temperature of the gas on account of the heating effect of the discharge; but only in a small measure, for the bulbs were under water, so that the rise in temperature must have been very small. Besides, heating the bulbs with a Bunsen burner before immersion did not diminish the depth at which the discharge would start nearly as much as a previous discharge would, no matter of how short a duration. As stated above, the discharge may be started far below the critical point by touching the connecting tube. But if the touch lasts only a very short time (a fraction of a second) the discharge ceases as soon as the touching conductor leaves the tube. In this manner the vacuum tube may be made to blaze up in quick succession.

This behavior of the discharge at all pressures, but very much more striking at pressures higher than the pressure under consideration, seems to support the dissociation theory of Professor J. J. Thomson (*Phil. Mag.*, 1891, Vol. 32, pp. 329, 454, 455).

II. PHENOMENA INDICATING A DISSOCIATION OF THE MOLECULES.

The following phenomenon appears to be an additional support to this theory:

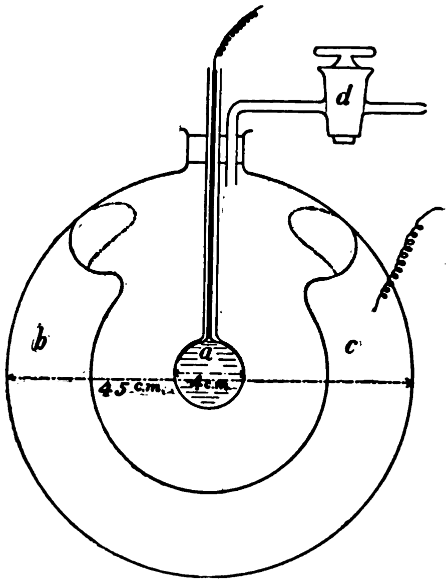
Fig. 8



A close inspection of the discharge going on in the bulbs *A* and *B*, Fig. 8, seemed to reveal the strange fact that the electrical flow was confined to a thin layer of the rarified gas which is in immediate contact with the inside surface of the bulbs, especially when the e.m.f. was not too far above the critical point, and therefore the supply of the current not too plentiful. To all appearances there was a gliding film of luminous gas in each bulb extending from the mouths of the connecting tube, spreading over the inside surfaces, and ending at the bottom of the bulbs in violently agitated luminous clouds which gave the discharge a hazy appearance. When the vacuum was very good both the film and the clouds were absent. There was no suggestion of a motion on the part of the gas, and the discharge had a clear luminosity. To study this phenomenon more closely the following experiment was performed:

A glass bulb, *a*, Fig. 9, blown out at one end of a thick glass tube of narrow bore, was filled with acidulated water and placed at the centre of a large glass bottle, as indicated in the figure.

Fig. 9



A wide strip (*c b*) of tinfoil was placed on the outside of the bottle, covering about one-third of the surface. The air was exhausted through the tube *d*, until the pressure was about 3 mm. The liquid in the bulb *a* and the tinfoil were connected to the secondary poles of the induction coil. When the e.m.f. was not too far above the critical point the discharge was in form of *numerous, quivering streamers*, which looked like the generators of a conical surface, with the centre of bulb *a* as vertex and the edge of the tinfoil as directing curve. There was *no visible discharge between the bulb and the central parts of the tinfoil.* But the discharge spread out and gradually approached these parts, and at the same time the streamers became less numerous and steadier, giving the discharge a more diffused appearance as the potential gradually increased. When the e.m.f. was gradually brought back to its original value the discharge diminished in intensity but did not return to its original form of distribution. It did that when the e.m.f. was considerably lowered below its initial value, which showed that the original distribution was not altogether due to the fact that at any moment the density of the electrostatic charge of the tinfoils was considerably larger near the edges. In this experiment, as well as in the preceding one, the number of streamers, their definition, their quivering motion, and their preference for the paths along which the discharge started increased with the increase of pressure in the vacuum. A discharge (especially in vacua of poor conductivity) will always start between parts of highest electrical density, and each successive discharge prefers the passage along the path of the first discharge on account of the increased conductivity along this path.

But if this increase in the conductivity is due to a rise in the temperature of the gas along the path of the first discharge and to nothing else, how can the fact be explained that a long, thin, discharge streamer, when forced through a poor vacuum, can be maintained steady, and permanent in form, even if the discharge continues for several minutes? It should broaden out continually, and become more and more diffused as the adjacent particles of the air get heated. In my experiments on solitary discharge streamers in poor vacua (see *Amer. Jour. of Science*, April, 1892), I did not observe any appreciable widening out, but I did observe a phosphorescent halo around the streamer which, as Professor J. J. Thompson assumes (*l. c.*) was *very probably* due to dissociated oxygen molecules that were ejected from the path of the discharge. (See farther below the effect of a blast on a discharge streamer).

Still another experiment which shows that something of the nature of a dissociation of the gas molecules is going on along the path of the discharge. A thick German silver wire, 60 cm. long, was bent zig-zag fashion into 12 zig-zag parts, and placed in horizontal position at the bottom of a bottle like the one in Fig. 9. A wire passing through a rubber stopper in the neck of the bottle connected this zig-zag electrode to one of the poles of the induction coil. The other electrode, a small brass sphere, was vertically above the zig-zag electrode, immediately under the rubber stopper. The shortest distance between the two was about 30 cm. The vacuum was about 3 mm. The discharge started between the nearest points of the electrodes, that is, between the lowest point of the sphere and one extremity of the zig-zag electrode. It had the form of a band about 3 cm. wide, intensely luminous at each end, but only very faintly luminous along the intervening three-fourths of its length. The length of the less luminous interval increased with the decrease of the e.m.f., but diminished with the increase of the gas pressure; it also seemed to have a different color, but I did not care to examine this point more closely. The phenomenon that interested me more was the gradual creeping of the discharge along the zig-zag electrode from one of its extremities towards the other. It did not increase in breadth but left its trail along the zig-zag electrode in form of a faintly luminous halo which surrounded this electrode just like a narrow luminous tube. Both the color and the gradual lateral motion of the discharge reminded me very much of the aurora borealis of Feb. 13, 1892. (In this connection it is well to remark that when the e.m.f. is below the critical point this auroral discharge can be started by powerful disruptive discharges of a Leyden jar in its vicinity. This, in connection with observations on coronoidal discharges given in the later part of this paper, may perhaps furnish a clue in tracing the connection between Sun-spots and auroral discharges.)

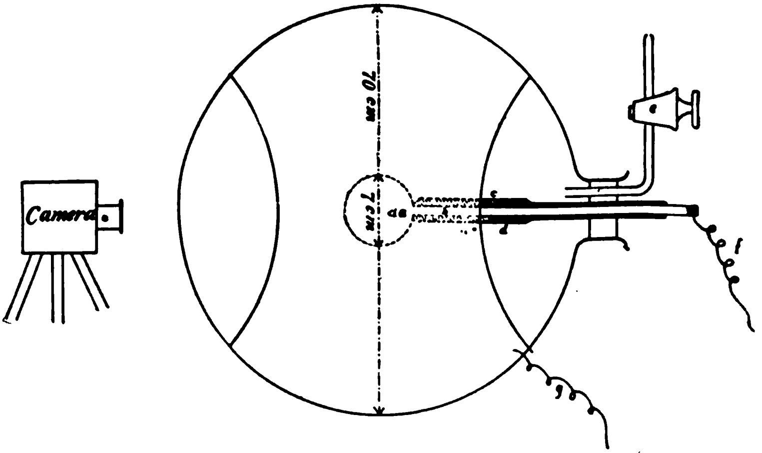
III. PHENOMENA INDICATING A TRANSLATIONAL MOTION OF THE GAS.

An interesting phenomenon was observed in the experiments with bulbs *A*, *B*, Fig. 8, when the vacuum was diminished by turning quickly the stop-cock *C* several times around. The vacuum pressure was about 20 mm. The induction coil had to be strained considerably to force a discharge through the long glass tube. The discharge looked like a luminous jet shooting from the tube into the bulbs, and in its path around the corners it seemed to strike against the necks of the bulbs at *a* and *b*, from which points it was reflected and glided along the surface towards the points *e* and *f*. Inside of the bulbs the jet oscillated rapidly; it was also split up in several parts, each part consisting of numerous more or less intense streamers. A slight modification in the curvature of the necks modified the general outline of the luminous jet without changing its general character. With the increase of the gas pressure the phosphorescence appeared and seemed to be strongest at *a* and *b*. It was very strong in the tube *C* leading to the stop-cock, although this tube was entirely free from the discharge proper. The height to which the phosphorescence rose in this tube increased with the current. Every slight variation in the current strength caused a simultaneous variation in the height of the phosphorescent column in *C*. (When the discharge ceased there was a strong phosphorescent after-glow all along the long tube). A similar behavior on the part of the phosphorescent gas which I observed in the experiment described in *Amer. Jour. of Science*, April, 1892, leads to the conclusion that the phosphorescent gas must have a translational motion, due to its being ejected from the path of the discharge proper. This strengthened my belief in a translational motion of the gas along the path of the discharge proper, which belief was due to the phenomena in the experiment just described. It was also strengthened by the phenomenon observed in the experiment described by me in the paper cited above, the phenomenon namely, that a discharge streamer made to curve way out (by the repulsive action of another parallel streamer), so as to strike against the walls of the vacuum jar will rebound from this wall just as a curved jet of water would if it struck against a rigid surface. In another experiment with an apparatus like the one described in the above paper, a thin rectangular sheet of mica was suspended between and parallel to two discharge streamers, and it was found that it prevented their action which I described in that paper, but it was made to swing back and forth as if acted upon by a wind coming from the path of the discharges. This action was hardly perceptible in high vacua, but increased quite considerably with the increase of gas pressure. It may, however, be due to a great variety of causes, like peculiar distribution of pressures due to a peculiar distribution temperature; so-called apparent (in my case continually varying) electrostatic charge over the surface of the mica, etc.

IV. ON CORONOIDAL DISCHARGES.

Wishing to perform additional experiments which could throw some more light on this particular feature of discharge I constructed the apparatus given in Fig. 10. A large glass bulb was coated with tinfoil along those parts of its external surface which would approximately correspond to its temperate zones, its neck being one of the poles. This tinfoil coating had a wire, *g*, attached to it by means of which it could be connected to the pole of the induction coil, and serve as an electrode of the bulb. The other electrode was a brass sphere *a* attached to a brass rod *b*. This brass rod was surrounded by a glass tube, *cd*, and the space between the two was filled with sealing wax. In this arrangement the pressure could be varied between very wide limits (up to about 100 mm.), without running the risk of refusal on the part of the induction coil to force a discharge through. A camera was placed in front of the bulb. as indicated in Fig. 10, and the discharges photographed. Figs. 1, 2, 3, 4, 5, 6,* are photographs of the discharges obtained in this manner, but in various degrees of rarification.

Fig. 10



I shall discuss the discharge given in Fig. 6 first. In this case the vacuum was very poor (about 60 mm. pressure). The discharge started in the form of four large streamers, together with a very large number of short luminous jets which were more or less uniformly distributed over the sphere. In consequence of these jets the appearance of the sphere reminded one very much of the granular structure of the Sun's disc as revealed by Rutherfurd's, Janssen's, and Vogel's photographs of the Sun. Very luminous spots appeared from time to time at several points of the surface, which reminded one very much of the Sun's faculæ. Both the jets and the large streamers rotated rapidly. This rotation is indicated very plainly in the photograph; for the number of streamers in each wing represents the number of maxima in the alternating discharge during the time of the exposure, which was a small fraction of a second. The thickest streamers indicate the place where the discharge started. It is evident that the streamers were distributed nearly systematically over the sphere at the start of the discharge; and that then one-half of them were gradually and almost uniformly displaced

---

* See plate at beginning of this article.

in the direction of the motion of the hands of a watch, the other half in the opposite direction. The peculiar curvature of some of these streamers indicates the presence of two kinds of motion,—one a translational along the prolongation of the radii of the small sphere, and the other a rotational. It was this rotational motion which led me to assume that there must be some sort of repulsive action between the streamers of a vacuum discharge. The existence of this action was demonstrated conclusively by the experiment described in the paper cited above. Additional researches in this direction lead me to the conclusion that two discharge streamers tend to blow each other out owing to the motion of the cooler gas between them, this motion being produced by the enormous heating effect of the discharge. The result is that the particles of the gas which at any moment form the path of a discharge are continually displaced (particularly in a discharge through a poor vacuum), and since every successive discharge prefers the particles through which the preceding discharge passed (for reasons given above), it follows that a sort of rotary motion is set up in the various parts of the discharge.

An additional evidence in favor of a translational motion along the paths of the streamers is furnished by the fact that all along the inside surface of the large glass bulb, which is below the tinfoil coating, there is a hazy luminosity which increases with the increase of the discharge, and which to all appearances is due to an accumulation of incandescent gas molecules which had impinged against and were reflected by the surface of the bulb.

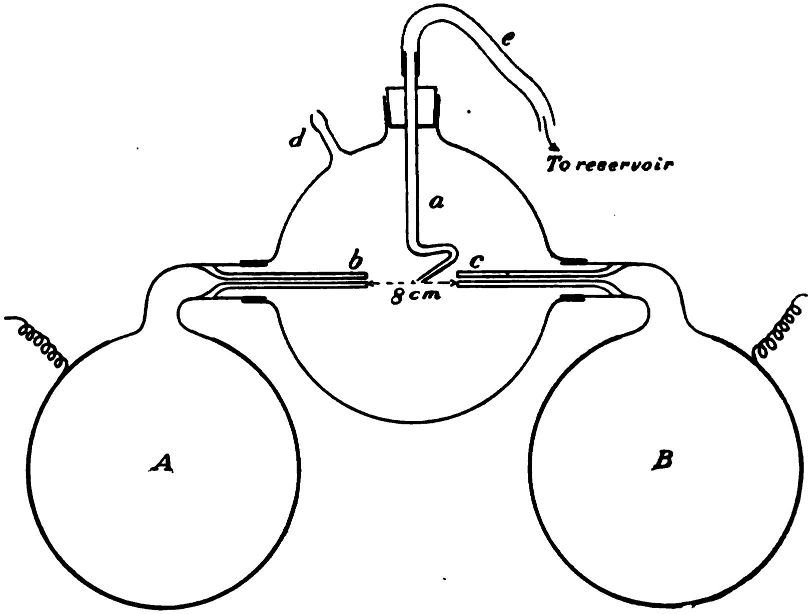
If the inside end of the exhaust tube *e*, Fig. 10, is lowered, so that it reaches the region of the discharge, it is observed that from time to time the incandescent gas shoots through this tube toward the stopcock way out of the bulb.

Effect of a Blast on a Discharge Streamer. Granting that there is a translational motion along the path of the streamer it follows that a rectilinear streamer may be transformed into a curved one by imparting to the gas in each part of its path a component velocity perpendicular to its original velocity. This inference was confirmed by the following experiment:

Two bulbs *A*, *B*, (Fig. 11) coated with tinfoil on the outside (the electrodes of the system) communicated with a reservoir (which I call the *principal reservoir*) by means of glass tubes *b*, *c*, of narrow bore. An L shaped tube *a* with a small orifice was fitted by means of a rubber stopper into the neck of the reservoir. By means of this tube and the tube *d* the *principal reservoir* communicated with two other reservoirs, which I call the *external reservoirs.*

The *external reservoir* connected with *d* communicated with a mercury pump. When the exhaustion had reached the point at which a steady rectilinear discharge could be forced from *b* to *c*, a stopcock connecting *d* to its external reservoir was shut off and the exhaustion continued until a good vacuum was obtained in the external reservoir *d*. The discharge was then started. It was a perfectly steady, narrow, rectilinear column of crimson luminosity, surrounded by a phosphorescent ellipsoidal column.

Fig. 11



But as soon as the above mentioned stopcock was turned on, the blast coming from the orifice *a* played up the column and the rectilinear path became curved at the point where the blast was acting. The discharge acted as if it bent around to get out of the way of the blast. The observation that the effect of the blast upon the phosphorescent column was imcomparably stronger than upon the crimson column needs no comment. The weaker the discharge the stronger is the effect of the blast, and *vice versa.* The effect of a blast upon the oscillatory spark discharge of a powerful Leyden jar battery is not perceptible.

In discharges through very poor vacua the heating effect is very unequally distributed throughout the vacuum jar. The temperature at certain points is enormously higher than at others. The result is that a very violent motion of the gas is set up, which motion may sometimes, on account of the effects pointed out in the last experiment, produce streamers of double curvature.

During an experiment with the apparatus given in Fig. 10, which I performed on Feb. 8, 1892, before the astronomical section of the New York Academy of Sciences, a leak occurred, so that the vacuum was exceedingly poor by the time I was ready to start the discharge. Finding that the discharge gave no sign of starting, I risked to turn the whole power of the 10 H. P. alternator on the induction coil. Long sparks shot immediately from almost every point of the edge of the tinfoil. The discharge between the brass sphere and the tinfoil looked like a black-faced Medusa with fiery serpents dancing all around her head. On repeating this experiment, I found that in very poor vacua the discharge streamers very often assume the form of spirals of very long pitch.

All these phenomena suggested to my mind a very strong similarity between the streamers of an electrical discharge through poor vacua and those of the solar corona, and for the purpose of pointing out this similarity to others otherwise than by verbal description only, I resolved to photograph these discharges under conditions similar to those under which the solar corona is observed. Photographs 1, 2, 3, 4, 5, 6 are the result.

The discharges were obtained with the apparatus given in Fig. 10. The only additions were that a circular tinfoil disc was pasted on the outside of the large bulb, in the line of sight between the camera and the brass sphere *A*. The diameter of this disc was about equal to that of the brass sphere. Also, the inside surface of the large bulb which formed the background of the brass sphere was blackened by means of camphor smoke, to avoid reflections. The discharge in Fig. 1 is that of a good vacuum (about 2 mm.); the succeeding ones represent discharges in poorer vacua, the pressures varying between 2 mm. and 60 mm.

The bearing which these experimental results may have upon the theory of the Solar Corona, I prefer to leave to others to decide. That they may prove a suggestive guide in the study of solar phenomena seems not unreasonable to expect.

I am greatly indebted to Professor John K. Rees for the interest which he took in my work, and to Mr. Mann, of the Columbia

College Observatory, for the very valuable service which he rendered to me in photographing the coronoidal discharges.

DEPARTMENT OF ELECTRICAL ENGINEERING,
Columbia College, March 31, 1892.

ON THE LINE SPECTRA OF THE ELEMENTS.*

C. RUNGE.

The distribution of the lines in the spectra of the elements is by no means so irregular as it might seem at first sight. Since Lecoq de Boisbaudran, in 1869, discovered the general plan in the spectra of the alkali metals, a number of interesting facts have been brought to light, which will probably one of these days find their mechanical explanation, and will then greatly advance our knowledge of the molecules.

Mechanical explanations of some of the facts have been attempted already. Lecoq de Boisbaudran explains the fact that the rays of the alkali metals are, on the whole, less refrangible the greater the atomic weight, by observing that the oscillations of a body suspended in a given elastic medium will become less frequent when the mass of the body is increased. This explanation, however, seems to me to remain rather vague and unsatisfactory as long as it does not lead to any numerical results that agree with the observations. Taken literally, it makes the oscillation-frequency inversely proportional to the square root of the atomic weight, which is far from being the case.

A second well-established fact has received different explanations by Julius† and by Johnstone Stoney.‡ It has long been observed by Hartley that in the spectrum of several elements a number of doublets or triplets of lines appear, the oscillation-frequencies in each doublet or triplet differing by the same amount. Recent measurements by Professor Kayser and myself have confirmed this observation. Julius believes that this phenomenon is due to a cause analogous to the combination tones in the theory of sound.

If two rays, with oscillation-frequencies α, β, combine with other rays, p, q, r, s, to oscillation-frequencies

$$\begin{matrix} p+\alpha & q+\alpha & r+\alpha & s+\alpha \\ p+\beta & q+\beta & r+\beta & s+\beta, \end{matrix}$$

---

* *Nature*, April 28, 1892.

† Julius, *Annales de l'Ecole Polytechnique de Delft*, tome v. (1889).

‡ Stoney, Trans. of the Roy. Dublin Soc., vol. iv. (1891).

the same difference $\alpha - \beta$ will occur several times. That the doublets under consideration are in many cases remarkably strong is accounted for by the fact that the intensity of the combination tone is proportional to the product of the intensities of the primary tones, so that it must become very strong when the amplitude of the primary tones is sufficiently increased.

Johnstone Stoney gives a different explanation of the doublets. He supposes that the path of the molecule from which light emanates is an ellipse, which by disturbing forces is gradually changed, and he shows that on this supposition, instead of one ray, two rays or more would originate, and the oscillation-frequencies of these rays would differ by an amount depending on the rate of change of the ellipse. If now, instead of the ellipse, the path of the molecule is any other curve, it can be considered as consisting of a number of superposed ellipses, all of which change in the same way on account of the disturbing forces. To each of the ellipses a doublet of lines corresponds, and the oscillation-frequencies of each doublet differ by the same amount. In this explanation I do not understand the decomposition of the arbitrary curve in a series of superposed ellipses. For the movement is supposed not to be periodical, and Fourier's theorem then would not apply, at least the periods of the superposed ellipses would not be definite, as long as there are no data except the arbitrary curve itself.

Besides, both Johnstone Stoney and Julius only try to explain one of a number of regularities that have been observed in the spectra of the elements. A plausible suggestion about the movement of the molecules ought to explain more than one of the observed phenomena. I think it may be useful to point out the other regularities that have been observed in the distribution of lines, and for which as yet no mechanical explanation has been attempted.

(1) The doublets and triplets existing in the spectrum of an element can be arranged in series which show an appearance of great regularity. These series seem to be analogous to the overtones of a vibrating body. But they possess a remarkable peculiarity, which, as far as I know, is without analogy in the theory of sound. The difference of two consecutive oscillation-frequencies decreases as these increase, and there seems to exist a finite limit to the oscillation-frequencies of a series. If n represents integer numbers, the oscillation-frequencies of a series may with great accuracy be represented by the formula—

$$A - Bn^{-2} - Cn^{-4},$$

where A, B, C are positive constants. B has nearly the same value for all the series of the different spectra. A is the limit towards which the oscillation-frequency tends, when *n* increases.

(2) For elements that are chemically related, the series are distinctly homologous, both in appearance of the lines and in the values of A, B, C, and with increasing atomic weight shift towards the less refrangible end of the spectrum. Homologous series have been observed in the following groups of elements:—

Lithium, sodium, potassium, rubidium, cæsium;
Copper, silver;
Magnesium, calcium, strontium;
Zinc, cadmium, mercury;
Aluminium, indium, thallium.

In the first two and in the last group the series consist of doublets,* while in the remaining two groups they consist of triplets. Thus we may say that the spectrum shows a relationship between the elements similar to that between their chemical properties. It is interesting to note that magnesium forms a group with calcium and strontium, and appears more nearly related to them than to zinc, cadium, and mercury.

(3) The doublets and triplets in each group broaden as the atomic weight increases. In the first group the difference of oscillation-frequencies is nearly proportional to the square of the atomic weight. The constant difference of the oscillation-frequencies in the doublets and triplets may also be noted in the values of A, B, C. For a series of doublets or triplets we have two or three different values of A, but only one value of B and one value of C.

(4) In each of the spectra of sodium, potassium, rubidium, and cæsium, a series of doublets has been observed, in which the oscillation-frequencies do not differ by a constant amount, the difference diminishing inversely proportional to n^4. For these series A and B have only one value each. The least refrangible doublet of the series has the same difference of oscillation-frequencies as the doublets in the other series of the same element. In the spectrum of lithium there is a homologous series of single lines. All the lines of these series have the same character; they are strong and easily reversed, and in all of them the first doublet is situated on the less refrangible side of the spectrum, and all the others in the violet and ultra-violet. The series shift towards the less refrangible side with increasing atomic weight.

For further details the reader is referred to the following

---

* Lithium has here to be excepted, whose lines are all single.

memoirs:—Kayser and Runge, "Ueber die Spectren der Elemente," *Abhandl. der Berl. Akademie*, 1890-92; Rydberg, "Recherches sur la constitution des spectres d'émission des éléments chimiques," *Kongl. Svenska Vetenskaps-Akademiens Handlingar*, Bandet 23, No. 11, 1890.

HANNOVER, Germany.

ON THE LARGE SUN-SPOT OF 1892, FEBRUARY 5-18, AND THE ASSOCIATED MAGNETIC DISTURBANCE.*

As the large spot seen on the Sun 1892, February 5–18, was the largest which has been photographed at Greenwich, and as its presence appears to have been associated with a great magnetic disturbance, some particulars may be of interest, though they must necessarily be imperfect pending the arrival of photographs from India and Mauritius to supplement the Greenwich series.

At Greenwich photographs of the Sun were obtained on five days during the first appearance of the group, viz. on February 5, 13, 16, 17 and 18; and up to the present time on three days during its second appearance, viz. on March 5, 7 and 8. The following table gives the heliographic coördinates of the center of the great spot, and the total area of the entire group, expressed in millionths of the Sun's visible hemisphere, for each day of observation during its first appearance:

Date G. Civil T.			Distance from Centre in terms of Sun's Radius.	Position-Angle from Sun's Axis.	Heliographic			Area.	
					Longitude from Central Meridian.	Longitude from Prime Meridian.	Latitude.	Umbra.	Whole Spot.
	h	m		°	°	°	°		
Feb. 5	10	24	0.985	118.4	− 81.9	259.0	− 29.0	96	1522
13	9	47	0.488	217.5	+ 19.8	255.6	− 29.2	451	2999
16	9	40	0.859	248.4	+ 58.5	254.9	− 28.1	256	2288
17	12	10	0.938	241.3	+ 70.4	252.3	− 29.3	139	1433
18	11	58	0.986	240.6	+ 82.5	251.3	− 30.1	84	1389

The great spot was on the central meridian February 11, 22^h G. C. T. On February 13, when the group was best seen, being then nearer the center of the disc than on any of the other days of observation, the group extended in heliographic longitude from 270° to 245°, a length of 25°; and in heliographic latitude from 23° S. to 33° S., a breadth of 10°. The principal spot of the group had a length of 14°, from 263° to 249°, and a breadth of 8°, from 25° S. to 33° S.

---

* *Monthly Notices*, March 1892. Communicated by the Astronomer Royal.

The group had greatly diminished in area when it reappeared on the east limb on March 5.

The following table gives the position of the principal spot and area of the entire group, as observed up to the present time, during its second appearance:—

Date. G. Civil T.			Distance from Centre in terms of Sun's Radius.	Position-Angle from Sun's Axis.	Heliographic			Area.	
					Longitude from Central Meridian.	Longitude from Prime Meridian.	Latitude.	Umbra.	Whole Spot.
		h m		°	°	°	°		
Mar.	5	9 51	0.927	118.3	− 68.4	250.9	− 28.8	28	208
	7	9 54	0.714	124.0	− 42.4	250.4	− 28.9	34	510
	8	10 39	0.571	132.8	− 28.5	250.8	− 29.2	35	521

It will be seen that the group has greatly diminished in area during the fortnight in which it was on the further side of the Sun. There seems, however, a slight tendency to increase again, especially with regard to the principal spot, the area of which rose from 101 on March 5 to 369 and 448 on March 7 and 8. The great spot has undergone but little change of place during the interval, for its latitude has remained practically unchanged, and though its longitude, as computed with a sidereal period of 25.38 days, appears to show a slight diminution, this is due to the rotation period of the Sun being longer for high latitudes, the rotation period adopted corresponding to a latitude of about 15°.

A great magnetic disturbance accompanied by an aurora, occurred on 1892, February 13–14, commencing about a day after the large spot was on the central meridian of the Sun's disc. The following particulars have been drawn up by Mr. Ellis:—

The magnetic disturbance commenced in all elements on February 13 at $5^h\ 32^m$, Greenwich Civil Time, by a sudden increase of declination, horizontal force, and vertical force, accompanied by strong manifestation of earth currents. Large motions were registered in all elements; between February 13, 19^h, and February 14, 3^h, they were unusually large, amounting to more than 1° in declination, the trace having passed off the sheet for one hour shortly after midnight. In horizontal force the disturbance exceeded 0.029 of the whole horizontal force, the trace having similarly passed off the sheet for nearly half an hour at about 22^h, and afterwards for more than 1½ hours from shortly before 1^h to $2\frac{1}{2}^h$. In vertical force the disturbance was also great, the trace having gone off the sheet in the direction of increasing force from $14\frac{1}{2}^h$ to 19^h, and in the direction of decreasing force from $0\frac{1}{2}^h$ to 2^h; the motion probably exceeded 0.020 of the whole vertical force. The disturbance ceased on the evening of February 14.

An aurora was seen at Greenwich between 0^h and 1^h, by Mr. McClellan.

The disturbance compares in magnitude with those of 1882 April and November, the registered motions being large in all elements on all three occasions. The disturbance of 1882, November, was, however, extreme, the motions then registered being apparently in excess even of those of 1882 April and 1892 February.

The following table shows how the recent disturbance compares with previous ones recorded since the commencement of the Greenwich series of solar photographs in 1873.

Particulars of Magnetic Disturbances from the Photographic Registers at the Royal Observatory, Greenwich.

	Period of Disturbance. Greenwich Civil Time.							Character of Disturbance.	Extreme amplitude of Motion during Disturbance.			
									Declination.		Horizontal Force.	Vertical Force.
			h				h		°	'		
1880	Aug.	12	12	to	Aug.	14	8	*c*	1	5	.016	0.08
1881	Jan.	31	12	"	Feb.	1	3	*c*	1	15	.018	.008
	Sept.	12	12	"	Sept.	14	2	*c*	1	0	.017	.008
1882	Apr.	16	23	"	Apr.	17	23	*g*	1	0 +	.030 +	.022 +
	Apr.	20	3	"	Apr.	21	8	*g*	1	10 +	.020 +	.008
	Oct.	2	10	"	Oct.	3	3	*c*	1	0	.014	no register
	Nov.	17	10	"	Nov.	21	4	*g*	1	50	.050 +	.025
	Nov.	21	15	"	Nov.	22	0	*m*	0	40	.010	.003
1883	Sept.	16	3	"	Sept.	17	17	*c*	0	50	.019	.005 +
1884	July	2	19	"	July	4	6	*c*	0	40	.018	.007
	Oct.	1	22	"	Oct.	3	6	*m*	0	30	.010	.004
	Nov.	2	13	"	Nov.	3	8	*m*	0	45	.012	.005
1885	Mar.	15	10	"	Mar.	16	6	*c*	0	55	.010	.009
1886	Mar.	30	8	"	Apr.	1	3	*c*	1	5	.020 +	.007
1892	Feb.	13	5	"	Feb.	14	18	*g*	1	10 +	.029 +	.015 +

In the column "Character of Disturbance" *m* indicates moderate; *c*, considerable; and *g* great.

The amplitudes in the case of Horizontal Force and Vertical Force are given in parts of these forces respectively.

The sign + attached to a measure indicates that the spot of light passed beyond the limit of registration.

Most of these magnetic disturbances occurred when an exceptionally large spot was visible on the Sun near the center of the disc, or about the time of some great change in a Sun-spot.

ROYAL OBSERVATORY, Greenwich, 1892, March 11.

ADDENDUM.

Since this note was drawn up, Mr. Maunder has found, from an examination of the photographs at Greenwich, that this Sun-spot appeared on the Sun on 1891 November 15, when it came into view close to the east limb as a spot of considerable size. It was also photographed at its appearances in December 1891 and January 1892, so that it has persisted through five rotations, with, however, a remarkable progressive drift in latitude from about 17° S. to 30° S. Several magnetic disturbances have occurred during its presence on the Sun, three being subsequent to that on February 13, described above, viz.: March 1^{d} 0^{h} to 16^{h} (moderate), 0° 45′ in declination; March 6^{d} 9^{h} to 7^{d} 9^{h} (considerable), 0° 50′ in declination; March 11^{d} 10^{h} to 13^{d} 5^{h} (great), 1° 15′ in declination.

ROYAL OBSERVATORY, Greenwich, 1892, March 25.

ON A REMARKABLE PROMINENCE.*

H. DESLANDRES.

On March 3 I observed a prominence remarkable for its brilliancy and radial velocity, which, moreover, belonged to the region of the Sun occupied by the great spot of last month (February). By the rotation of the Sun this region had arrived at the eastern limb on the day in question.

At 10^{h} 12^{m} A. M., I was struck while examining the chromosphere by the unusual brilliancy of the hydrogen and helium radiations at 96° from the north point of the Sun. The lines, with a narrow slit, had the form of a widely opened fan; the displacement was greatest on the side toward the red, and corresponded to a radial velocity of 20 km. per second.†

I immediately had recourse to a photographic spectroscope which gave me the radiation of the prominence in the invisible ultra-violet region, and furnished an exact image which could afterwards be examined at leisure. I have the honor to present to the Academy the series of photographs obtained. These are the first photographs which have been made of these curious solar phenomena, which are rare and of short duration.

In the region of the photograph between wave-length 400 and wave-length 360, the radiation of the prominence is remarkable. The H and K lines, attributed to calcium are extraordinarily brilliant; moreover the entire series of ultra-violet hydrogen

---

* *Comptes rendus*, March 14, 1892.

† Widening of lines may result in part from other causes, for example, a great elevation of temperature; but, as lines which are always narrow under ordinary circumstances, such as the line of helium, were included among those widened, this explanation is not the most probable one. In any case the magnitude of the phenomenon is simply and completely expressed in fractions of wave-lengths or in kilometres.

lines, which is obtained complete* for the first time in the Sun, is clearly shown; it is curious to find this characteristic series of the white stars in the atmosphere of a yellow star. Other lines not before recognized in the chromosphere may be added—the magnesium triplet at λ 383†, and the lines λ375.93, λ376.14, λ368.53, which have not been identified with any known element, and may furnish valuable suggestions to chemists in the investigation of new elementary bodies of low atomic weight.‡

Moreover, the widening observed on the bright lines was also found in the ultra-violet spectrum; in certain parts of the negative a continuous spectrum is shown, which corresponds with the brightest part of the prominence.

At $10^h\ 30^m$ the brilliancy of the prominence had greatly diminished; the lines no longer showed the fan-shaped widening, but they presented a marked inclination as compared with the lines at the center of the disc.

The various parts thus had a different radial velocity, by the strict application of Fizeau's principle; this indicates a vortical motion, at least when the inclination persists for a considerable time. But this question, which is a very important one, will be more fully developed later.

These observations and results show clearly that the region of the great spot is still one of great activity, after an entire rotation; they should be compared with a similar observation made by M. Fényi, director of the Kalocsa Observatory, on Feb. 19, when the spot passed over the western limb.

On March 3 the observations were interrupted in the afternoon by bad weather; but on March 4th and 5th the presence of active incandescent masses at the same point on the limb could still be observed, after the *debris* of the great spot had passed over the eastern limb. Moreover, the surroundings of the spot and the entire disc have been studied by the new photographic method mentioned in a former 'note,' which permits the detection of the incandescent gaseous masses projected on the disc.§ A continuous series of prominences surrounding and preceding the spot, and

---

* Dr. Huggins' ten lines are clearly shown, and others more refrangible are suspected.

† This triplet, according to the recent investigations of MM. Kayser and Runge, belongs to a hydrogen series other than that of the green group b of magnesium, and even stronger.

‡ The six preceding lines were also obtained in a prominence on Feb. 19, occupying the same region of the Sun on the eastern limb at noon, Paris MEAN TIME.

§ These last photographs have been obtained with the aid of my assistant, M. Mittau.

forming thus a veritable ring on the surface of the Sun, has been obtained in this manner.

On March 3, at the moment of the appearance of the great spot, the curves of the magnetic recorders of the Observatory, which M. Wolf has kindly placed at my disposal, indicated no exceptional deviation of the magnetic needle.

PARIS OBSERVATORY, Paris, France.

THE NEW STAR IN AURIGA.*

AGNES M. CLERKE.

Through the modest medium of an anonymous post-card, an event of high importance to astro-physical science was, on the 1st of February last, announced to Dr. Copeland, the Scottish astronomer-royal. This was nothing less than the outburst of a new star in the Milky Way. Now such apparitions are not too common, and they are always short-lived. About a score of them have been credibly recorded during two thousand years, beginning with the star which, according to Pliny, determined Hipparchus upon the construction of his epoch-making catalogue. And the "modern Hipparchus" received a similar emphatic summons. Tycho Brahe was, on November 11, 1572, rescued from the quagmire of alchemy, and recalled to his true vocation, by the startling splendor of the renowned "Nova" in Cassiopeia. This extraordinary object was, to begin with, as bright as Jupiter, and by a further rise, placed itself, in a few days, well-nigh on a par with Venus at her best. Neither the glare of the Sun at noon, nor the drifting by night of clouds thick enough to conceal every other sidereal object, availed to blot out its scintillating lustre. Yet it has utterly disappeared. Not even Mr. Robert's searching camera can detect, in the place it once occupied, the faintest glimmer of its pristine fires. They are to all appearance extinct, and there is small probability that they will ever be rekindled. The idea, it is true, got abroad, and even still partially prevails, that the star of 1572 had previously manifested itself at intervals of about three hundred years, and might be expected to show once more towards the close of the present century; but it seems to have originated in pure misapprehension of some vague mediæval notices of comets. Kepler, however, enjoyed the privilege of observing, though in a

---

* *Contemporary Review*, April, 1892. By permission of Leonard Scott Publication Co.

totally different quarter of the sky, a new star scarcely the inferior of Tycho's; and these two have, so far, met no rivals to their surpassing brilliancy.

Our own age has, nevertheless, no reason to complain. It has been on the contrary, exceptionally favored in the unusual number of stellar apparitions presented to it. Half a dozen have been crowded into the comparatively short space of forty-four years, and may, accordingly, all have been witnessed with mature comprehension by many men now living. Eminent among them is Mr. Hind, the discoverer of the first of the series, the "Nova," as such objects are technically called, of 1848, the immediate predecessor of which, separated from it by an interval of 178 blank years, was Anthelm's Nova of 1670. This glaring inequality of apportionment has certainly been for the advantage of science. Astronomers in the last century were ill-equipped for taking advantage of such opportunities, while modern physical appliances are especially adapted for turning them to the best account. They are indeed eagerly welcomed; and the evidence afforded by them is earnestly invoked for the testing of novel theories, and for the decision of various moot questions relative to the constitution of the heavenly bodies. When rapid changes are going on, Nature's secrets are apt to slip out for the instruction of those on the watch for them; and new stars are the intensified embodiment of change. No wonder then that the Edinburgh missive of February, acted as a *reveille* to the astronomical forces in all parts of the northern hemisphere.

The sender turns out to have been a denizen of Auld Reekie, Mr. Thomas D. Anderson, the example of whose success will doubtless kindle the zeal of many another amateur star-gazer. His discovery might indeed have been made a week earlier. Only by degrees, and after several observations, Mr. Anderson came to recognize the novelty of the object sending its straw-yellow beams from a previously empty spot in the southern part of the constellation Auriga. It was found moreover on inquiry to have unobtrusively recorded itself twelve times, from December 10, 1891, to January 20, 1892, on the chart-plates exposed at Harvard College for the purposes of the great spectrographic survey in progress there under Professor Pickering's direction. With the first of these casually secured impressions, its biography begins. No trace of its existence has as yet been pursued further back. Unless totally obscure, it belonged then to the crowd of uncatalogued small stars; and merely swelled by a unit the nameless multitude of the heavens. Nothing indicated the distinction in reserve for it.

For one of its class, however, its growth in light was to an uncommon degree leisurely. Most new stars have leaped upwards from obscurity with bewildering swiftness. They claim as a rule, neither past nor future worth mentioning, and only a brief, if brilliant present. But the star of 1892 attained no strongly emphasized maximum. Although absolutely brightest about December 20, it slowly regained light until February 8, when it was of the fifth magnitude—that is, well within the range of naked-eye vision—entering then upon a gradual, and not perfectly continuous, decline. In aspect it was throughout perfectly stellar. Its rays emanated from a sharp point, and, some incautious remarks to the contrary notwithstanding, were nowise blurred or hazy. And a long exposure photograph, taken by Mr. Roberts with a view to developing possible nebulous surroundings, conclusively demonstrated their absence. A similar result was obtained at South Kensington by Professor Lockyer. To all appearance, then, the object was, and is a star like any other. But let us hear the dictum of the spectroscope in the matter.

The light of Nova Aurigæ, unrolled by prismatic dispersion into a rainbow-tinted riband, presented a dazzling spectacle. Splendid groups of bright lines stood out from a paler background; the red ray of hydrogen, Fraunhofer's C, glowed, as Mr. Espin remarked, like a danger-signal on a dark night; a superb quartet of rays shone in the green; shimmering blue bands and lines drew the eye far up towards the violet; the characteristic blazing spectrum, in fact, of a new star was unmistakably present. Its interpretation left no doubt that hydrogen played a large part in the conflagration; Dr. and Mrs. Huggins at once identified a yellow line with the well-known shining badge of sodium, and more than suspected an adjacent ray to belong to the solar element called "helium;" and a violet line distinctive of calcium imprinted itself strongly on numerous photographs. The substances accordingly ascertained to be glowing in this far-off body, are sodium and calcium, the metallic bases, respectively, of common salt and lime; with hydrogen, the universally diffused gaseous metal indispensable for the production of water. Iron and magnesium are doubtful; but carbon had certainly *not* stamped its sign-manual on the opened scroll of the new star's light.

It was marked, however, by one extraordinary peculiarity in the coupling with dark lines of all the bright rays conspicuous over its entire extent. Each lustrous member of the great hydrogen-series carried a black shadow on its *blue* or more refrangible side; the rays of sodium, calcium, and other unidentified substances being similarly attended. The meaning of this strange appearance was evident, if in the highest degree surprising.

The principle by which motion in the line of sight can be detected through its effect upon the spectrum of the moving body, is now fully recognized. The amount, moreover, of the observed change gives the velocity of the motion, and the *sense* of the change tells its direction. Thus the rays, say, of hydrogen, when they proceed from a luminous mass rapidly approaching the earth, are pushed from their standard places towards the blue end of the spectrum, while they shift towards the red when the movement is one of recession. The result is strictly analogous to the variation of pitch perceived by a stationary listener in the steam-whistle of a rushing engine. The sound is rendered acute, because the air-waves are shortened by the advance of its originating source; it sinks, on the contrary, as they are lengthened by its retreat. And so with the waves of light sent out by the stars. They are physically crowded together by a physical advance, and hence become *more blue*: but because their succession is retarded, they become *more red* when a velocity of withdrawal is in question. Astro-physicists can, accordingly, determine whether a celestial object be moving towards or away from the earth, and at what rate, by simply measuring on a photograph the deviation from its normal position of some known line in its spectrum.

But in Nova Aurigæ two amazing circumstances were disclosed by this method of procedure. First, the speed corresponding to the measured displacements was unprecedented; next, it was apparently pursued, at the same time, in opposite directions. The bright lines unanimously showed to the careful scrutiny of Dr. Vogel at Potsdam recession at the extraordinary rate of 420 English miles a second, while their dark comrades testified to an approach of 300. Plainly, then, both sets were not emitted by the same body; and a twofold spectrum, owning a twofold origin, was at once seen to be under observation. The whole range of bright lines, in short, was obviously marked out as the appurtenance of a mass rushing away from the earth, the dark ones matching them, as proceeding from a mass rushing towards it. And the two were separating at the rate of 720 miles a second, or about sixty-two millions of miles a day!

Moreover, these portentous velocities showed, during at least a month, no perceptible slackening. The coupled lines did not tend to close up, as they should have done if the bodies they served to distinguish relaxed their furious speed, or swerved from their straight course. Hence, these presumably did neither the one nor the other to any considerable extent. They can scarcely then be in mutual circulation: yet a pair of gravitating masses could not possibly have made so close an approach as theirs evidently was, without swaying one another into the description of some kind of orbit. Their orbit, however, may be of the hyperbolic variety; in which case the bodies just now visually conjoined are flying asunder, never to meet again. Their single encounter, if this be so, was what we, in our ignorance, can only describe as casual; and the greater part of their motion must be inherent; it belonged, that is, to themselves, *ab origine*, and was not merely imparted by the pull of their mutual attractive forces. And we should indeed naturally expect the solitary outburst of a "new star" to be associated with precisely such a temporary relationship as comports with hyperbolic traveling. In a permanently organized system, on the other hand, light fluctuations, if they occurred at all, might be looked for periodically. This state of things, in fact, seems actually to prevail in the only known example comparable in any degree with the wonderful star of our present experience. The variable star Beta, in the constellation of the Lyra, has, like Nova Aurigæ, been resolved, through the photographic study of its spectrum,* into a pair, of which one member emits bright, the other shows dark lines on a prismatic background. But here there is clear evidence of revolution in a closed orbit, the bright and dark lines exchanging their relative positions once in nearly thirteen days. Moreover, this same period is observed with strict punctuality by the luminous fluctuations of the star. So that we have here a persuasive argument of identity in nature between continuous stellar variations in brightness, conducted regularly in short periods, and the catastrophic out-break of temporary stars. Nay, we gather a hint that the shape of the orbits traversed by such bodies determines the character of their changes; periodical variability depending upon elliptical movement, ephemeral splendor followed by irrecoverable decay corresponding to a single approach at an excessive velocity, with consequent separation along tracks divergent to infinity.

The star of 1892 has then taught us to regard stellar apparitions as resulting, in some way, from the temporary vicinity of

---

* Conducted at Harvard College by Mrs. M. Fleming and Miss A. C. Maury under the direction of Professor Pickering.

two rapidly moving cosmical masses. All new stars are, it may safely be asserted, during the brief epoch of their visibility, double stars.[*] The light that they send us emanates from a twofold source. Their duplicity, however, might not always be patent to observation. For the spectra of the bodies in conjunction could only be separately distinguished if their motion happened, like that of the components of Nova Aurigæ, to be largely directed towards or from the earth. If they advanced and retired *sideways* or *vertically*—terrestrially speaking—the combined powers of the spectroscope and camera could extract from them no sign by which their separate existence might be inferred. Sidereal science is thus indebted to the present unaccustomed inmate of our skies for the disclosure of a fact which, without the aid of a body so happily circumstanced for the gratification of intellectual curiosity, might have remained for ages undivulged.

But the knowledge that incandescence of the kind first analysed by Dr. Huggins in the star of 1866 is due to external influence, leads immediately to a further question as to how that influence is exerted. Direct collisions are not to be thought of. And for this obvious reason, that the impact of two inelastic bodies either brings them to a stand-still, or reduces them to a unanimity of slackened motion. We know but too familiarly what takes place when oppositely rushing trains crash together. They certainly do *not* proceed onward at express speed to their respective destinations. But this is precisely what the components of Nova Aurigæ are doing. They have beyond question met no serious check in their flying careers. No considerable part of their motion has been sacrificed to produce their increase of light. Elementary though the principle be, yet it is not superfluous to insist upon it, that incandescence through collision implies stoppage, partial or entire. Since the evolved light and heat are only transformed motion, both kinds of energy cannot be present simultaneously. They are correlative. One disappears to furnish the other. Unless the motion be arrested, the blaze will not occur. One might as well expect to get a coat without curtailment of the piece of cloth affording the material for it.

Hence the outburst of the new star in Auriga cannot be attributed to an actual bodily encounter of two dark bodies

---

[*] The compound nature of all variable stars has been advocated for some years by Professor Lockyer; and the merit of the suggestion should be fully acknowledged, although the "meteoritic hypothesis," of which it formed an integral part, has received a fatal blow from the spectroscopic investigations of Nova Aurigæ.

swiftly traversing space. The hypothesis of a grazing collision has more to recommend it. Yet in this case, too, motion should be sacrificed in strict proportion to the development of luminosity. Unless evidence of retardation should be forthcoming, the supposition of outlying entanglements must be abandoned. The two masses, however, spectroscopically observed to be hurrying past at the daily rate of sixty-two million miles, cannot, one would imagine, have surrendered much of their velocity in the process of gaining enhancement to their brilliancy. There is, indeed, a possibility of a *third* body being present, traveling much more slowly than the others. Dr. Vogel, towards the close of February, observed the bright lines on his photographs to be, not only accompanied by dark ones, but themselves double; and he suggested (though with great reserve) in explanation of the phenomenon, the triplicity of the new star. This too, had, very curiously, been surmised by Dr. and Mrs. Huggins as early as February 3, and, if real, could only, one would think, be due to a division of the gaseous body, analogous to the breaking up of some comets in passing the Sun. Yet the circumstance that the bright line spectrum of Beta Lyræ sometimes appears twofold, warns us not to adopt over-hastily, the hypothesis of physical disruption in combination with arrest of movement in the disrupted body.

Masses of matter may, nevertheless, be excited to luminosity by other means besides that primitive one employed in the tinder-box. But before hazarding a conjecture as to how these might be brought into action, let us see what has been learned as to the nature of the bodies concerned in the transient splendor of our Nova. One of them, as giving a spectrum of bright lines, must be of a gaseous constitution. But it is known to be neither a comet on a vast scale, nor a nebula, by the absence of the quality of light distinctive of each of these classes of object. The yellow, green and blue hydro-carbon bands forming the chief part of cometary radiance were clearly shown by Dr. and Mrs. Huggins to have no place in the spectrum of the star, which included conspicuously, on the other hand, the unbroken hydrogen-series of rhythmically disposed rays, from burning red to invisible ultra-violet. But not one of these has ever been observed in a comet. The characteristic nebular spectrum, too, is entirely unrepresented in the Nova, as the eminent investigators just named were the first to point out;* and although affinities are traceable between

---

* The two rays nearest to the chief nebular lines have since been identified by Dr. Vogel with well-known solar-chromospheric groups.

its light and that of the so-called "Wolf-Rayet Stars" in the Milky Way, the resemblance is by no means complete. Thus the gaseous component of Nova Aurigæ belongs really to no established category of celestial objects. It is a body either peculiar in itself, or peculiar through its circumstances.

The second, and most likely the principal, member of the pair is less difficult to classify. It is emphatically a Sun, and an exceedingly hot Sun. An enormously high temperature is implied by the strength and compass of its ultra-violet spectrum, photographed February 22, by Dr. and Mrs. Huggins, at Tulse Hill, with an exposure of one hour and three quarters. As regards the proportionate intensity of its actinic rays, it is, in fact, not outdone by Sirius itself. The details, however, of its spectral hieroglyphics bring it nearer to Rigel than to Sirius; and it may accordingly be ranked with the Orion variety of "white stars."

Now there is good reason to suppose that every such body is in a state of powerful electrical excitement, and creates in its neighborhood a very extensive magnetic field. A second body entering this field, and sweeping with prodigious speed across the lines of force traversing it, must then give rise to powerful electrical agitations. And here, perhaps, may be found the chief source of the amazing displays registered by astronomers as "new stars." Gravitational disturbances, too, of the kind that raise tides in terrestrial oceans, but immensely exaggerated in degree, no doubt come in as auxiliaries, and produce, at any rate, notable effects of bodily distortion, if not of bodily disruption; yet the view that the sudden illuminations in sidereal space exemplified by the apparition of Nova Aurigæ result, in some measure, from the inductive action of highly electrified bodies dashing past each other at excessive velocities, may possibly be substantiated by future researches into the nature of the unmeasured forces thus brought into play.

By its situation in the thick of the Milky Way, our present "guest-star" conforms to a rule almost universal in such cases. The significance of that rule cannot be mistaken, for it is too faithfully observed to be accounted for otherwise than by real physical location; and we are thus assured beyond doubt that "new stars" have their proper place among the "clusters and beds of worlds" collected into the zone of dim light spanning our wintry skies. The conditions then reigning there must be such as to favor in a marked degree stellar conflagrations. And two of these conditions are well ascertained. The galactic region, in the first place, is assuredly one of exceptional crowding;

and it is abundantly stocked, in the second, with bodies of a gaseous nature, and showing gaseous affinities. Rapid and vast developments, accordingly, of gaseous incandescence through quasi-encounters between rushing masses, are much more likely, it would seem, to occur within Milky Way aggregations than elsewhere in sidereal space.

The components of Nova Aurigæ must be added to the list of what are called "runaway stars." Their headlong velocities are altogether beyond the control of any gravitational power which can reasonably be supposed to reside in the sidereal system. What other forces may be acting upon them, it were vain to conjecture; we can only hold to the secure conviction that they pursue no random career, and make no purposeless haste. Yet the revelation is none the less startling of the prevalence of so tremendous an agitation of movement within the seemingly rigid collections of the Milky Way. By their inconceivable remotenesss, the visible effects of displacement there are well-nigh annihilated; the telescopic detection of them may demand centuries of refined observation; only the wonderful faculty by which the spectroscope is enabled, irrespectively of distance, to measure movements in the line of sight, has afforded the bewildering vision now unfolded to us of a mêlée of flying bodies in a realm of apparent immobility.

To this realm Nova Aurigæ properly belongs—a realm so far off that light can hardly spend less, and may spend much more, than a hundred years on the journey thence to our eyes. The blaze then, studied by astronomers with such curious results during the last couple of months, occurred undoubtedly before any of them were born; and may very well date as far back in absolute time as the Battle of the Boyne. Agile light-rays have, meantime, been bearing the news of the event across the portentous intervening gulf at the express rate of 186,000 miles a second. A proportionate magnitude must be assigned to the catastrophe. Our own Sun would make a very poor show if removed to the distance of galactic aggregations. It could certainly not be discerned with the naked eye; it might not even have been thought worth registering in any of our hitherto constructed star-catalogues. So that the new star of 1892 may well have attained to one hundred times the solar brilliancy.

The certainty of the novel and striking disclosures obtained from it was in great measure due to the employment of the chemical method. No object of the kind had previously been investigated with the potent aid of the camera, reliance on which was, in the present instance, amply justified by the upshot. The star was photographed everywhere, under both its simple and its prismatic aspects, on the too rare occasions of favorable weather. The earliest records of its spectrum were secured by Father Sidgreaves at Stonyhurst, and by Professor Lockyer at South Kensington; and the Potsdam series extends from February 14 far into March. From the collation of these various documents, the history of the changes undergone by the remarkable pair of separately invisible bodies, the anomalous relations of which have nevertheless been brought within our sure cognisance, can already be minutely deduced, and may, at any future time, be revised from the higher point of view of freshly acquired knowledge. Thus, stellar science is in none of its various branches, any longer dependent on the fleeting impressions of the fallible human eye. By an unerring process of self-registration, the phenomena it studies are rendered virtually permanent, and can be re-observed at will, long after the immediate witnesses of them have passed away. The application of this powerful engine of research to stars of the temporary class has assuredly borne memorable first-fruits. Their full value can hardly yet be estimated.

A STUDY IN THE VARIATION OF THE SOLAR DIAMETER.*

ORRAY TAFT SHERMAN.

The abnormal variation of the Sun's diameter has been a fruitful field of discussion. The result is summed up by the text writers as (1) the diameter of the Sun itself varies, or (2) the observations are too much disturbed by errors incidental to the solar observation to be profitably discussed in relation to their smaller variations. The first of these statements, save in so far as it becomes gratuitous in the light of our result, we leave without discussion. The second statement may, I think, be confined to the case of the result of a single observer. As far as the disturbances are systematic they tend to remain, as far as the disturbances are accidental they tend to destroy themselves when the work of many observers is gathered into a single mean. We have, therefore, gathered all the observations which could be found. Each has been compared with the value calculated by the gravitational theory. The corrections for each month have been

---

* Communicated by the author.

meaned, converted into arc, and the means of the year taken. The separate yearly values have then been gathered into a general yearly mean. In taking this general mean, those values depending upon a few observations have themselves been joined into a single mean, so that each element of the final mean should depend upon an approximately equal number of observations. When this was impossible the single observation was made the combining unit. This seemed to leave least arbitrary action to the computer. The yearly means, together with the number of observations and observatories involved, are given in the adjoining table.

In No. 234, Jan. 1891, of *The Astronomical Journal* we have given the corrections to the earth's tabular longitude for each year. The same numbers are given in the fifth column after the year 1809. The bar indicates a change in the solar table employed. In the *American Meteorological Journal* for June 1891, we have shown that the auroral numbers for Southern Europe were so connected with the zodiacal light elongations that a maximum in elongation corresponded with a minimum in the auroral number, and a minimum with a maximum. In the fifth column, therefore, we have given Fritz auroral numbers, as an indication of the condition of the zodiacal light. In remarks we have noted the scattered observations of the zodiacal light. If we compare the maximum in the series of yearly means and longitudinal corrections we find maxima agreeing in the following years: 1810-11, '14, '18, '26, '34, '38, '47, '55, '58, '68 '79, '82-'83. All of these maxima may be at once identified as caused by the zodiacal light crossing the Earth's path. In the preceding year we have maxima in 1766 and '94-'96 which, as may be seen from the auroral column, correspond with maximum elongations of the zodiacal light. These are all the maxima the column of Sun-diameters affords. We find minima in the Sun-diameters agreeing with maxima in the corrections to the solar longitudes in the following years: 1820, '23, '26, '41-'43, '51. The minimum in '62 also corresponds to a maximum Sun-spot effect which is masked in the zodiacal column. The rapid decrease in the Sun's diameter from 1814 to 1826 also corresponds to a period during which the corrections to the solar longitude rapidly increased under the influence of the Sun-spots. These are all the minima there are capable of examination. The evidence of the minimum in 1787 tends toward the same end. All of these maxima in the corrections to the longitude may be identified as Sun-spot effects. We have also in 1811, 1821, 1824, 1828, cases in which a comparatively rapid increase in the solar diameter corresponds with records of appearances of the zodiacal light. The whole evidence therefore points to one statement. Maxima in the values of the solar diameter are the effect of the disturbances produced by the zodiacal light. Minima, the effect of disturbances produced by the solar spots.

We may readily understand how this should be. The spectrum of the zodiacal light shows us that it is in part at least composed of solid matter. We are unaware of the density of the matter or of the density necessary to deflect a body traveling with planetary velocities, but there is evidence which indicates that a very slight density is sufficient. The first effect of the meeting of the zodiacal light and Earth may be shown to be a decrease in the Earth's orbital velocity followed by a decrease in the Earth's radius, which again is followed by an increase in the Earth's orbital velocity due to its altered position. But if instead of passing out of the zodiacal light the Earth remains immersed, we have a continuing repetition of the cycle. One effect of which is that the solar diameter is constantly larger than the gravitational theory requires. Accepting Weber's electrodynamic law as at least approximately expressing a fact, the effect of the Sun-spot increases the attraction of the Sun and Earth. Increasing the force it increases the orbital velocity, and hence the radius, when the planet moves toward the Sun, but to a slighter degree, if at all, when the planet moves from the Sun. This is further evidenced by the variations of the diameter in orbit, as is shown by the following examples. 1841–'43 is a period during which the Sun-spot is predominant; 1847, a period when the zodiacal light has been but slightly in force; 1855, a period when the Earth has continued immersed in the zodiacal light.

	1841–43		1847		1855	
	′	″	′	″	′	″
Dec., Jan., Feb.,	32	2.18	32	2.91	32	3.65
March, April, May,		2 20		3 62		3 71
June, July, Aug.,		2 18		3 82		3 96
Sept., Oct., Nov.,		1 70		2 60		3 61

Year.	Observatories.	Observations.	Observed semi-diameter. 16′ +	3 yr. mean. Observed correction to tabular longitude.	Fritz auroral number for middle Europe.
1753	1	288	1.79		68
1754	1	309	1.44	1.59	87
1755	1	299	1.54		43
1756	2	408	2.10		65
1757	2	429	1.99	2.09	87
1758	2	320	2.19		83
1759	1	312	2.53		94
1760	2	284	2.40	2.78	98
1761	2	254	3.40		124
1762	1	227	3.39		120
1763	1	238	3.76	3.29	100
1764	1	244	2.72		119[1]
1765	1	157	3.87		69
1766	1	190	3.55	3.53	40
1767	2	260	3.18		56
1768	2	252	3.66		64
1769	1	211	3.28	3.43	78[2]
1770	1	199	3.36		71
1771	1	214	2.83		96
1772	1	179	2.98	2.70	79
1773	1	192	2.29		96
1774	1	173	2.42		150
1775	1	193	2.39	2.20	88
1776	1	188	1.80		58
1777	1	219	1.21		102
1778	1	217	1.58	1.93	152
1779	1	145	2.00		93
1780	1	176	1.91		130
1781	1	224	1.45	1.52	91
1782	1	181	1.19		103
1783	1	230	1.50		89
1784	1	267	1.36	1.61	85
1785	1	251	1.96		149
1786	1	253	1.20		172[3]
1787	1	210	1.15	1.16	168
1788	2	282	1.14		161
1789	1	249	1.61		134
1790	1	217	1.46	1.81	115
1791	1	211	1.35		109
1792	2	217	2.06		36
1793	2	252	2.01	2.10	35
1794	2	388	2.24		36
1795	2	369	3.30		39
1796	2	387	2.10	2.15	63
1797	2	307	1.05		35
1798	2	352	1.73		29
1799	2	344	2.35	2.02	6
1800	3	443	1.99		6
1801	3	542	1.79		7
1802	3	558	1.91	1.99	11[4]
1803	4	538	2.28		8
1804	4	924	2.49		12
1805	4	848	2.77	2.74	22[5]
1806	4	593	2.95		8[6]

Year.	Observatories.	Observations.	Observed semi-diameter. 16′ +	Observed correction to tabular longitude.	Fritz auroral number for middle Europe.
1807	4	716	3.16		6
1808	5	563	3.18	═══	2
1809	4	530	2.80	+ 0.63	1
1810	3	471	3.11	+ 2.65	1
1811	3	493	3.71	+ 1.65	0
1812	3	509	3.37	+ 0.27	0[7]
1813	4	586	3.53	+ 2.12	2
1814	4	803	4.32	+ 2.89	6
1815	5	806	3.92	+ 2.69	2
1816	6	806 +	3.00	+ 2.98	4
1817	6	879 +	3.27	+ 3.09	26
1818	6	825 +	3.28	+ 3.88	8
1819	7	786 +	2.63	+ 3.89	15
1820	7	849 +	2.18	+ 4.92	8
1821	4	434 +	2.70	+ 4.40	5[8]
1822	4	421 +	2.37	+ 4.40	3
1823	6	578 +	1.39	+ 4.55	1[9]
1824	6	709 +	1.52	+ 3.06	8
1825	7	789 +	1.36	+ 3.89	26
1826	5	549 +	0.86	+ 5.12	29
1827	7	601 +	0.97	+ 4.42	37[10]
1828	8	667 +	1.20	+ 6.11	47
1829	7	702	1.26	+ 4.09?	62
1830	6	708	1.26	+ 4.04?	103
1831	6	1021	1.26	+ 8.56?	69
1832	6	1035	1.34	+ 7.49?	20
1833	7	1104	1.40	+ 0.83	27
1834	7	1135	1.50	+ 2.32	14
1835	8	1222	1.44	+ 2.31	15
1836	8	1090	1.32	+ 1.29	23
1837	9	1510	1.22	+ 1.56	56
1838	8	1170	1.48	+ 1.96	50[11]
1839	8	998	1.37	+ 1.53	85
1840	9	1178	1.55	+ 0.53	76
1841	9	799	1.14	+ 1.73	63
1842	12	1375	1.13	+ 1.62	79
1843	11	1172	1.13	+ 1.68	68
1844	10	1084	1.40	+ 1.58	66
1845	9	850	1.52	+ 0.88	76
1846	8	786	1.87	+ 1.11	80
1847	8	1126	1.94	+ 1.23	87
1848	7	744	1.73	+ 0.55	129
1849	8	636	1.62	+ 1.63	100
1850	8	570	1.52	+ 1.89	89
1851	6	563	1.29	+ 1.58	101
1852	6	620	1.35	+ 1.35	138
1853	5	570	1.66	+ 1.66	116
1854	5	609	1.66	+ 2.39	59
1855	6	667	1.79	+ 2.81	40
1856	5	814	1.52	+ 0.18	43
1857	6	1177	1.43	+ 0.03	20
1858	6	1077	1.53	+ 0.35	66

Year.	Observatories.	Observations.	Observed semi-diameter. 16′ +	Observed correction to tabular longitude.	Fritz auroral number for middle Europe.
1859	5	683	1.26	+ 0.54	91
1860	8	523	1.23	− 0.17	78
1861	8	890	1.27	− 0.29	83
1862	9	868	1.03	− 0.41	99[12]
1863	8	1107	1.12	− 0.55	96
1864	9	1282	1.28	− 0.30	93
1865	9	1293	1.48	− 0.14	109[13]
1866	8	1197	1.32	+ 0.63	105
1867	8	958	1.45	+ 0.71	90
1868	8	1007	1.50	+ 0.45	70
1869	7	615	1.20	+ 0.21	113
1870	6	799	1.33	+ 0.19	143
1871	5	710	1.52	+ 0.40	159
1872	5	713	1.47	− 0.22	140
1873	5	626	1.83	− 0.38	158[15]
1874	5	734	1.55	− 0.23	101
1875	5	737	1.32	− 0.24	87
1876	5	749	1.35	− 0.88	72
1877	4	352	1.46	− 0.92	69
1878	4	332	1.31	− 0.97	85
1879	3	421	1.57	− 0.16	67
1880	4	550	1.53	− 0.44	29
1881	4	590	1.43	− 0.42	53
1882	4	548	1.26	− 0.07	64
1883	4	708	1.57	− 0.60	
1884	3	596	1.12	− 0.77	
1885	3	241	1.14	− 0.82	

[1] Zodiacal light (Perigee). [2] Zodiacal light (Dicquemon). Zodiacal light (Flanzeno). [4] Zodiacal light (Humboldt). [5] Zodiacal light (Huth). [6] Zodiacal light (Bode) (Homer). [7] Zodiacal light (Bode). [8] Zodiacal light (Swiadecki). [9] Zodiacal light (Bode, Olbus). [10] Zodiacal light (Urstphal). [11] Zodiacal light secondary maximum. [12] Maximum Sun-spot effect. [13] Secondary zodiacal light. [14] The zodiacal light crossed the Earth's path though not a maximum.

THE TEMPERATURE OF THE SUN.*

H. LE CHATELIER.

The numerous attempts which have been made to determine the temperature of the Sun have led to the most discordant results; the figures given up to the present time have varied from 1500° to 5,000,000°. The method employed, however, has always been the same (that of Pouillet), and the experimental determinations have always been sufficiently concordant. The divergencies in the final result arise solely, as M. Vicaire has pointed out, from the different laws adopted to connect the radiation of incandescent bodies with their temperature.

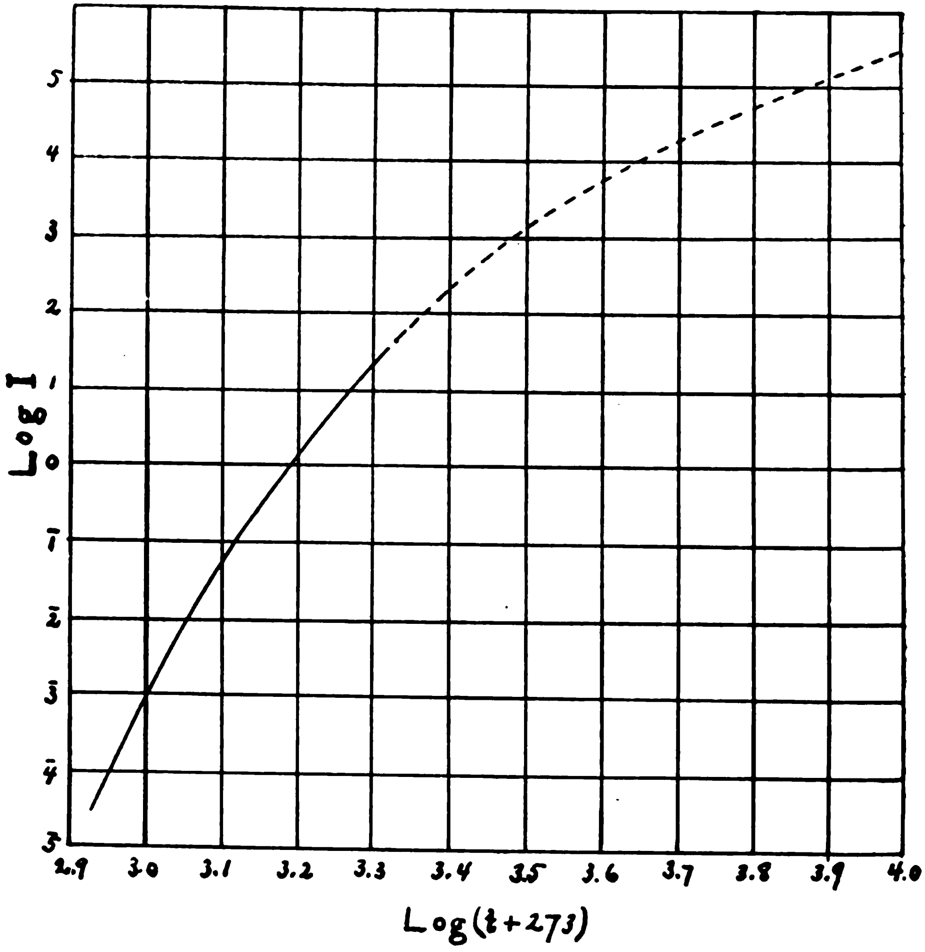
Newton's law, which holds only for an interval of a few degrees, gives for the temperature of the Sun millions of degrees. Dulong's law, which is only exact over a range of 150° at most, gives 1500°. Rosetti's law, established by experiments made between 0° and 300°, gives 10,000°.

The degree of confidence which determinations obtained by

---

* *Comptes rendus* (Paris), March 28, 1892.

means of such extrapolations merit, necessarily increases very rapidly with the magnitude of the temperature interval within which the law of radiation has been submitted to the control of experiment. My investigations, which embrace an interval of 1100° (700° to 1800°), that is to say, four times greater than the most extensive of the experiments here referred to, ought to lead to more certain conclusions.



The intensity of the red radiations emitted by an incandescent body, the emissive power of which is equal to unity, may, according to my experiments, be represented by the formula,*

---

* The numbers which I have given in my former communication were obtained by graphical interpolation. It is preferable to employ the formula, which causes the intensities given for the temperatures 600° and 700° to be modified a little.

$$I = 10^{6.7} . T^{\frac{3210}{T}}.$$

The following table gives the result of my measures:

Intensities observed.	Temperatures Measured.	Temperatures Calculated.	Differences.	Intensities observed.	Temperatures Measured.	Temperatures Calculated.	Differences.
0.00038	680	671	+ 9	0.06	980	982	− 2
0.00074	700	702	− 2	0.105	1020	1026	− 6
0.002	760	755	+ 5	0.19	1080	1078	+ 2
0.0056	810	814	− 4	0.67	1220	1205	+ 15
0.0054	820	817	+ 3	1.18	1270	1265	+ 5
0.01	860	853	+ 7	6.4	1495	1490	+ 5
0.034	940	939	+ 1	1.49	1775	1757	+ 18

The accompanying curve gives, in the unbroken portion of the line, the reproduction of the experimental results, and in the broken portion the extrapolation necessary to reach the temperature of the Sun.

The measure of the intensity of the solar radiations has been made with the photometer which I employed in my previous pyrometric investigations. Three concordant series have given 120,000 for the intensity of the red radiations reaching the Earth (outside of its atmosphere) from the Sun. I give below the most complete of these series:

Observation on March 19, 1892.

Hour.		Elevation of the Sun.		Intensity.	Hour.		Elevation of the Sun.		Intensity.
2^h	^{m}	35°	′	83000	4^h	40^m	14°	′	35000
3		38	30	73000	5		10	30	31000
3	30	25		66000	5	15	8	15	22000
4	12	18		56000	5	25	7		15000
4	30	15		42000					

The intensity of 125,000 which results from these figures indicates an *effective* temperature of 7600°. As M. Violle has proposed, I call the effective temperature of the sun that temperature which a body of emissive power equal to unity must have in order to send us radiations of the same intensity as the Sun. The actual temperature of the photosphere is higher, for a part of its radiations are absorbed by the less highly heated solar atmosphere, and perhaps also, although this seems hardly probable, because the emissive power of the Sun may be less than unity.

It does not seem to me that the uncertainty which attends this temperature of 7600°, on account of errors which may affect the law of radiation, can exceed one thousand degrees.

SOLAR OBSERVATIONS DURING THE FIRST QUARTER OF 1892.*

P. TACCHINI.

The season has been very unfavorable for observations. For the spots and faculæ the number of days of observation has been 56, *i. e.*, 19 in January, 19 in February and 18 in March. The following are the results:

1892.	Relative Frequency of spots.	Relative Frequency of days without spots.	Relative Size of spots.	Relative Size of faculæ.	Number of spot-groups per day.
January	19.63	0.00	79.79	56.58	5.90
February	23.31	0.00	153.61	60.28	5.16
March	13.21	0.00	61.67	86.39	4.28

A considerable increase over the preceding quarter is thus shown. Three periods of greater frequency and extent of spots correspond with the intervals January 16–24, February 5–18 and March 20–25.

We have obtained the following results for the prominences:

1892.	No. of days of observation.	Prominences. Mean number.	Prominences. Mean height.	Prominences. Mean extent.
			″	°
January	13	6.39	39.6	1.6
February	13	7.00	36.0	1.6
March	14	8.14	36.4	2.3

The difference from the preceding quarter is slight, but I believe that the phenomena of the prominences may be considered to have been a little more marked than during the preceding quarter. It should be noticed that while a well-marked maximum of spots occurred in February, the prominences do not show any great differences in the series, and that a maximum took place in March, as was also the case with the faculæ. For the spots, on the contrary, there was a minimum in the month of March.

R. OSSERVATORIO DEL COLLEGIO ROMANO,
Rome, 21 April, 1892.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in ASTRO-PHYSICS, should be addressed to George E. Hale, Kenwood Astro-Physical Observatory, Chicago, U. S. A. Authors of papers are requested to refer to page 544 for information in regard to illustrations, reprint copies, etc.

M. Lecoq de Boisbaudran's Observations on the Electric Spectra of Gallium.—In the *Comptes rendus* (Paris) for April 4, M. Lecoq de Boisbaudran has an interesting Note on his recent studies of the spectrum of gallium. The spectrum obtained when the uncondensed spark produced by a long-wire coil passes between

---

* Communicated by the author.

a metallic electrode and the surface of a solution of chloride of gallium, comprises two characteristic violet lines and a broad, nebulous green band, which seems to be due to the oxide of gallium. If metallic gallium is employed, and a condenser used with the coil, the spectrum becomes much more complicated, and the green band disappears. A small condenser of a few square centimetres surface is sufficient for the purpose. The spark was observed successively in air, carbonic acid gas and hydrogen, in order to be certain that none of the gallium lines were masked by the brilliant lines in the spectra of the enveloping gases. The difficulty of securing perfectly dry gases, and the widening of the red line of hydrogen (C), leaves some doubt as to the exact condition of things in its immediate neighborhood. A list of the wave-lengths of seventeen lines and bands observed is accompanied by notes on various physical characteristics. On taking the spark from a short-wire coil between electrodes of metallic gallium, the spectrum was found to differ materially from that described as produced by the long-wire coil with condenser. Only six important lines were now seen; one of these, very faint in the condensed spark, had become easily visible; another was reduced from a bright to a feeble line; a third appeared in the green, which had not been seen at all with the condensed spark. M. de Boisbaudran remarks in conclusion, "as similar changes occur, in a more or less remarkable manner, with nearly all bodies, it is very necessary to define the conditions under which electric spectra are obtained."

The Aurora of April 25, 1892. Contemporaneously with the return of the great spot (February, 1892) to the eastern limb of the Sun, there appeared an unusually brilliant aurora for these latitudes. I first observed a massing of pale diffuse yellow light 40° W. of N. at 10:5 P. M. (Greenwich M. T.) with two paler streamers of the same color rising from that point perpendicularly to the horizon, and reaching a height of 40°. At 10:15 P. M. the mass of light on the horizon became of an intense pea-green, and the two parallel streamers became so brilliant as to fill in the interspace a fine solid shaft with a somewhat dimmer axis resulting, the structure reaching 50° in height. During and after this, the bank of green light, already extending from 40° to 15° W. of N., gradually passed round the horizon towards N. E., whilst a few faint streamers, at an angle of 80° to 75° to the horizon, brought the display in the N. W. to a close, the inclination being westward.

In the meanwhile, the horizon light had reached as far as 40° E. of N., at which point another maximum occurred at 11:15 P. M., much less brilliant than the former one, but more permanent. Here three or four pale streamers reached up perpendicularly to 30°, dying off at 11:25 P. M. after a few minutes of brighter display.

The diffused light which had been gathering more intensely than ever on the north horizon now became very vivid and continued so, whilst the point of the first display, 40° W. of N., rapidly gained light, until it equalled, if not surpassed that at the N.* At 12:20 A. M. short, well defined and quickly-changing shafts of pale green light shot up from an intense bed of pale grass-green at 40° W. of N, those furthest to the W. appearing to radiate from the centre of the patch. At 12:25 A. M. a massive column, whose width subtended 12° to 15°, ran clear up to the zenith, and almost instantly the quadrant between N. W. and N. E. sent up broad, bright, converging bands of the same green color, there only being two less brilliant streamers about 40° E. of N. which failed to reach the zenith, and which made an angle of about 80° to the horizon, inclining eastwards. The light on the horizon underlying these two streamers was likewise less bright than elsewhere. The whole quadrant was now ablaze to the zenith small white clouds in the zenith taking on a complementary red. That the red was complementary was easily ascertained by looking at them immediately after closing the eyes for a few seconds. I read the time from a dark-faced watch at this time as 12:25 A. M. with perfect ease. During the maximum the horizon-light in the north oscillated vigorously in a horizontal direction for some 15 seconds, with an effect one might obtain by observing many fluctuating parallel surfaces in their own plane, or closely-packed transparent strata under similar conditions. I will not say that corruscation was connected with this oscillatory movement, but I think so.

This last display brought the aurora to a climax and a close, for it had barely subsided when I noticed a general mist covering up what had been till then a clear starry sky, and within 15 minutes from the disappearance of the auroral light, the sky was perfectly overcast, and very fine rain falling.

Stretford, Lancashire, England. J. MACLAIR BORASTON.

Solar Halo and Mock Suns.—On the 30th April, a brilliantly clear day, a fine halo, 50° diameter inside measure, accompanied the Sun from 2:45 P. M. (G. M. T.) to sunset. From S. W. through W. to N. W. the sky was pencilled with delicate parallel striæ of cirro-stratus, the general lie of which was at an angle of 3° to 4° to the horizon, the inclination being northwards. A line passing through the halo and Sun at the same angle bisected a Mock Sun at each point of intersection with the halo. The image on the S. side, as well as the S. side of the halo itself, was brighter than those opposite, though the image on the N. side was better defined. Each image had a corona of diffused light, elongated laterally. The circle enclosed by the halo was of a dusky slate, the Sun being of a dazzling silver white in the centre. The interior edge of the halo was red, the outer edge blue, and beyond the latter was a broad, bright circle of light blue shading off gradually into the darker blue of the surrounding sky.

Throughout the evening a four-days' Moon was encircled by an orange-red corona, coincident with the Moon's edge on the dark limb, and extending a lunar diameter from the bright limb. The earth-shine was coppery.

Stretford, Lancashire, England. J. MACLAIR BORASTON.

Wolsingham Observatory, Circular No. 32.—The star DM. + 55° 1870, XVI^{h} 39^{m} 49^{s}, + 55° 12′ ('55), 9.2, was found 7.3; 7.7, April 26; 29. Variable Spectrum like Mira. T. E. ESPIN.

Kayser and Runge on the Spectra of the Elements.—Professor C. Runge's article on another page "On the Line Spectra of the Elements" is from the pen of one well qualified by long investigation to write on a subject of so great importance. The recent appearance of Part V of Professors Kayser and Runge's series of papers, "Ueber di Spectren der Elemente," is an evidence of progress in a research which promises much toward our knowledge of molecular vibrations. In this last contribution the arc spectra of copper, silver and gold are described in detail. A concave grating of 21 ft. radius and 20,000 lines to the inch (ruled on Professor's Rowland's second machine), made it possible to secure photographs 20 inches in length with a single exposure. It is a pleasure to see the wave-lengths expressed in six figures, and the limiting error given for each line. Other investigators would do well to profit by this example. As in the case of the alkali metals, two secondary series of double lines with constant oscillation differences were found for copper and silver; the principal series seemed to be missing, though a strong double line was noted as possibly forming the first member. No series were found in the case of gold.

The Spectrum of Comet *a* 1892 (Swift).—This morning I obtained an observation of this bright comet with the spectroscope of the 36-inch equatorial. The spectrum is at present of the usual type. The spectrum of the nucleus is apparently continuous and visible from about *C* to *G*. It was made quite broad by the long telescope, and I observed that it was more sharply defined on the east edge than on the west [the slit was parallel to the equator]. Later it was seen that the sharp edge and the diffuse edge corresponded to the sides of the nucleus from and towards the tail.

The three well-known yellow, green and blue bands were present, their intensities being approximately in the ratio 1 : 6 : 2. Their lower edges were quite sharply defined. When the slit was narrowed to 0.004 inches, the bright line on the lower edge of the green band became exceedingly sharp, and could be bisected by the micrometer thread with extreme accuracy. There was apparently no condensation at the point where it crossed the continuous spectrum, except what would be expected from the superposition of the two, thus showing that the bright line is characteristic of the coma rather than of the nucleus.

The wave lengths of the less refrangible edges of the bands were obtained by comparison with nine lines in the iron and magnesium spark-spectra. A 60°-prism was used, there being insufficient time before dawn to change to a higher dispersive power. However, the distances to be measured were short, especially for the middle band, and the settings could be made very accurately; and I give the results to four and five places, as below:

$\lambda = 5630$	$\lambda = 5170.4$	$\lambda = 4722$
31	.4	24
28	.5	22
$\lambda = 5630$	$\lambda = 5170.4$	$\lambda = 4723$

These wave-lengths are not corrected for relative motion of the earth and comet.—*The Astronomical Journal.* W. W. CAMPBELL.

Mt. Hamilton, 1892 April 6.

Photography of The Ring Nebula in Lyra.—Father Denza has recently made a very successful photograph of the ring nebula at the Observatory of the Vatican, and in "*l'Astronomie*" for May a heliotype reproduction, enlarged 78 diameters from the original negative, may be found. Not only is the central star very prominently shown, but there seems to be evidence in addition of a much fainter one, also within the annulus. It is remarkable that this star (if it certainly is a star) should have been obtained by the Roman astronomer with an exposure of only 1^h 50^m, while M. Trépied, using a similar telescope at Algiers in August, 1890, found no certain trace of such an object with an exposure of 6 hours.

A Large New Nebula in Auriga.—The following note by Professor Schaeberle is taken from Pub. A. S. P., No. 22:

On receiving the announcement, February 6th, of the discovery of Nova Aurigæ, Professor Holden requested me to use the Crocker telescope for photographic observations on this star. The same day (February 6th) the Willard lens was therefore strapped to the 6-inch Clarke equatorial, and a series of exposures made that evening. Similar observations have been made on every clear night up to the present time.

On a plate which I exposed for 150^m on the evening of March 21st, I find a large and apparently new nebula in R. A. 5^h $9^m.5$, Dec. + 34° 10′. The north preceding part of this nebula is in the form of a comparatively slender ray which seems to have its origin in the star W. B. 5^h, No. 151. This ray gradually widens—the northern boundary running in an easterly direction for a quarter of a degree or more; the southern boundary runs in a southeasterly direction, passing just a little to the north of the star W. Br., 5^h, No. 162 (a naked-eye star) around which it appears to bend, and then takes a southerly course extending more than a quarter of a degree beyond this star.

In a southeasterly direction the length of the nebula visible on the plate is more than half a degree, while its width varies from a few minutes of arc, at the star No. 151, to twenty or more minutes opposite the star No. 162.

A photograph taken February 27 which I exposed for 90^m shows, less conspicuously, the same object. Since the 21st the weather has been unfavorable so that the possibility of seeing the nebula *visually* is still a question to be decided.

Lick Observatory, March 23, 1892. J. M. SCHAEBERLE.

P. S.—On the evenings of March 24 and 25 I made exposures of 200^m and 195^m respectively. These plates plainly show that the nebula joins the above mentioned stars W. B. 5^h, Nos. 151 and 162. Prints made so as to show only the brightest parts of the nebula reveal the following structure:

A narrow stream of nebulosity issues from the star No. 151 on the east side; a short distance from this star the stream divides into two parts; one running in a southeasterly direction passing the star No. 162 at a distance of two or three minutes of arc, then suddenly curving in towards the star, which it joins in the southeast quadrant. This stream is inclosed by the other branch, which first runs in a more easterly direction until it reaches a point northeast of the star No. 162, where it suddenly curves in towards this star and joins it in nearly the same position-angle as the first branch. From this same point of junction a third stream runs from the star in a southerly direction for a distance of 5′ or more and then turns towards the east. On the original plates several very faint nearly equidistant bands of luminosity are shown in the northern part of the nebula. Taken as a whole a certain resemblance to the Orion nebula is apparent.

J. M. S.

The Portrait Lens in Stellar Photography.—While the above note sufficiently indicates the important part played by the portrait lens in astronomical photography, the varied and valuable results recently obtained by Dr. Max Wolf at Heidelberg with the same means are even more striking. Although Dr. Wolf's portrait lens is only 2½ inches in aperture, he has not only discovered new nebulæ on his long exposure photographs, but new minor planets as well, and several meteors which crossed the field of view left perfectly distinct records of their flight. Dr. Wolf is to be congratulated on the rapid progress he is making in this new field of work.

On the Photography of Colors, by M. G. Lippmann. 1. In the first communication on this subject which I had the honor to present to the Academy, I said that the sensitive films which I then employed were lacking in sensitiveness and isochromatism, and that these defects were the principal obstacles to the general application of the method which I have devised. Since then I have succeeded in improving the sensitive film, and although much yet remains to be done, the new results are sufficiently encouraging to allow me to present them to the Academy.

2. I obtain very brilliant photographs of the spectrum on albumino-bromide of silver films rendered orthochromatic by azaline and cyanine. All the colors appear at once, even the red, without the interposition of colored screens, and after an exposure varying from five to thirty seconds. On two of the plates the colorsby transmission are very clearly complementary to those perceived by reflection.

3. Theory indicates that the compound colors which adorn natural objects

should be obtained in photography in the same way as the simple colors of the spectrum. It is none the less necessary to verify the fact experimentally. The four plates which I have the honor to submit to the Academy faithfully represent objects of various kinds: a stained glass window of four colors, red, green, blue, yellow; a number of flags; a plate of oranges surmounted by a red poppy; a many-colored parrot. They show that the form is obtained as well as the colors. The flags and the bird required five or six minutes exposure in the electric light or sunlight. The other objects were made with several hours exposure in diffuse light. The green of the foliage, the gray of the stone in a building, are perfectly brought out on another plate, the blue of the sky, however, became indigo. It now remains to perfect the orthochromatism of the plate and to considerably increase its sensitiveness. (*Comptes rendus*, April 25, 1892.)

Magnesium as a Source of Light—In an interesting paper on this subject in the *American Journal of Science*, April, 1892, Mr. Frederick J. Rogers sums up the results of his investigation as follows:

1. The spectrum of burning magnesium, as has already been pointed out by Pickering, approaches much more nearly that of sunlight than does the spectrum of any other artificial illuminant.

2. The temperature of the magnesium flame, about 1340° C., lies between that of the Bunsen burner and that of the air blast lamp, although the character of its spectrum is such as would correspond to a temperature of nearly 5000° C., were its light due to ordinary incandescence.

3. The "radiant efficiency" (the ratio of *luminous energy* to total *radiant energy*) is 13½ per cent; a value higher than that for any other artificial illuminant (excepting perhaps the light of the electric discharge in vacuo, for which Dr. Staub of Zürich has found an efficiency of about 34 per cent.)

4. The radiant energy emitted by burning magnesium is about 4630 calories per gram of the metal burned, or 75 per cent of the total heat of combustion; as compared with 15 per cent to 20 per cent in the case of illuminating gas.

5. The thermal equivalent of one candle-power-minute of magnesium light is about 2.4 lesser calories, as against 3.5 to 4.0 for other artificial illuminants.

6. The total efficiency of the magnesium light is about 10 per cent; as compared with .25 per cent (a quarter of one per cent), for illuminating gas.

7. Taking into consideration the greater average luminosity of the rays of the visible spectrum of the magnesium flame, it is certain that *per unit of energy expended, the light-giving power of burning magnesium is from fifty to sixty times greater than that of gas.*

The Magnetic Storm of February in Mauritius.—At a meeting of the Meteorological Society of Mauritius, that took place on April 7, Mr. Meldrum read a short paper on the Sun-spots, magnetic storm, cyclones, and rainfall of February, 1892. The photographs of the Sun that he exhibited, which were taken at the Royal Alfred Observatory from February 5 to 18, showed the very large group of spots, their approximate latitude on the 9th being from 6° to 16° south. Leading on to the occurrence of the great magnetic storm which began at 8^h 55^m on the 13th, he states that its commencement was distinctly recorded on the three curves, the horizontal force suffering the greatest disturbance. Up to 14^h the magnet was in oscillation, the force increasing, and reaching a maximum at 13^h 43^m, after which it began to decrease, the minimum being reached at 0^h 15^m on the 14th. Further abrupt movements occurred at 4^h 30^m on the 14th, the oscillations, as shown by the curves, being very numerous

but at 19^h the magnets became more steady, and were quiet by 3^h on the 15th. The ranges obtained at the Mauritius Observatory were the largest ever recorded there.

Cyclones were not absent during this month. One lasted from the 11th to the 14th, and another from the 25th to the 28th, while a third was also experienced on the 21st and 22d, about 550 miles south of Mauritius. The rainfall for February, as shown by returns from the numerous stations, was from 4.30 to 16.96 inches above the average for periods of 7 to 29 years. At Antoinette the fall for the month amounted to 12.53 inches, while that at Cluny came to 34.37 inches. St. Aubin and Nouvelle France came in for a considerable quantity of rain, the falls in the 24 hours ending at 8 A. M. on the 13th reaching the figures 5.00 and 18.20 inches respectively. Referring lastly to the magnificent displays of auroræ that have been observed both in Europe and America, he mentions that, although at Mauritius the sky was overcast, under similar conditions with respect to solar activity and terrestrial magnetism, a great display was visible in 1872. Mr. Meldrum, in his concluding remarks as to whether "there is a causal connection between solar activity (as indicated by outbursts on the sun) and magnetic disturbances, auroras, cyclones, and rainfall," remarks that with regard to the two former there can hardly be any doubt, but with regard to the two latter he is of opinion that a very close connection does exist, there being a considerable preponderance of evidence in its favor.—*Nature*, May 5, 1892.

On the Periodicity Common to Sun-spots and the Aurora Borealis.—(Extract of a letter from Dr. Terby to M. Faye in the *Comptes rendus* (Paris) March 21, 1892).

"I request of the Academy permission to claim priority on the subject of a question raised by the last aurora borealis and its coincidence with the existence of a very large Sun-spot. Several scientists, among whom I will mention MM. Veeder in America and Marchand in France, no longer hesitate to admit that certain Sun-spots, or, in general, certain disturbed regions of the Sun's surface, are capable of producing on the Earth magnetic perturbations and auroras when the rotation of the Sun brings them to a certain point on the visible disc; from this they have arrived at the conclusion that the *return* of the same solar disturbances, in the same regions, by the effect of rotation, is capable of causing the reproduction of similar phenomena at the surface of the Earth; there would thus be a periodicity of magnetic phenomena and auroras, related to the time of the Sun's synodic rotation.

"I request permission to call attention to the fact that these ideas are only the complete confirmation of those which I expressed in 1883, in a memoir published in the *Bulletins de l'Academie royale de Belgique*, third series, v. VI, No. 7, 1883, entitled: "On the existence and cause of a monthly periodicity of the Aurora Borealis." This paper is based on the study of the solar surface in the photographs obtained at Kew from 1869 to 1871, and on that of the order of succession of the beautiful auroras which appeared at this time, ordinarily at intervals of about a month, the greater part of which I observed myself at Louvain. I agree with M. Marchand in the opinion that the terrestrial phenomena coincide with the passage and *often with the return* of the solar disturbance over the central meridian of the Sun. *It will thus be very interesting to note whether a new aurora borealis is not seen about March 12, after the beautiful phenomenon of February 14 last.*"

"Louvain, March 6, 1892."

It will be remembered that a bright aurora accompanied by a magnetic storm occurred on the predicted date.

On the Connection between Sun-Spots and Magnetic Storms.—The following is from an article on the above subject by Mr. A. C. Ranyard in *Knowledge* for April, 1892:

It is possible that though the Sun itself may not be magnetic, it may act as a magnetic body because it is surrounded by a magnetic envelope or region where its gaseous constituents are precipitated into solid or liquid magnetic particles. During the past year, Professor Dewar has shown that oxygen becomes strongly magnetic when liquefied at a temperature of — 180° Cent. The vapors of iron when precipitated in the comparatively hot lower regions of the corona, would also form a cloud of magnetic fog or dust. There is some evidence, in the forms of the coronal streamers seen in the neighborhood of the Sun's poles, that the coronal particles are magnetic, and tend to arrange themselves along lines of force, as if the whole Sun had a magnetic axis, nearly but evidently not accurately, coincident with the Sun's axis of rotation.

The corona is far from being accurately symmetrical with respect to the Sun's axis of rotation; it is denser in parts, and has projecting rays or structures which extend to a great distance from the Sun, especially in the Sun's equatorial regions. On the above theory we should expect to find the magnetic region similarly unsymmetrical, and a body passing round the Sun, near to the plane of the solar equator, would be subject to very unequal disturbance from the magnetic particles of the corona This seems to tally with the facts observed—for the greatest magnetic storms have generally taken place when a large spot has been seen near to the centre of the Sun's disc. We know very little at present as to the connection between the corona and Sunspots, or as to how far the corona extends—some of its larger structures may extend as far as the earth's orbit, or as far beyond our orbit as the zodiacal light extends. There is no evidence that large coronal structures exist over large Sunspots, but there is evidence of an intimate connection between the general development and arrangement of the parts of the corona and the spottiness of the Sun's surface, as well as between the development of large prominences and Sunspots.

The Great Sun-spot and its Influence.—In a valuable article on the great February Sun-spot in *Knowledge* for April and May, Mr. E. W. Maunder brings forward some important evidence in regard to the connection between Sun-spots and magnetic storms. Mr. Maunder concludes his article as follows.

In a period of nearly nineteen years, therefore, we have three magnetic storms which stand out pre-eminently above all others during that interval. In that same period we have three great Sun spot displays—counting the two groups of April, 1882, together—which stand out with equal distinctness far above all their similar displays. And we find that the three magnetic storms were simultaneous with the greatest development of the spots. Is there any escape from the conclusion that the two have a real and binding connection? It may be direct, it may be indirect and secondary only, but it must be real and effective.

Consider that the period in question is practically some 6,800 days. A magnetic storm does not last many hours, a Sun-spot soon declines from its greatest development, or soon passes away from the center of the apparent disc. Suppose we take an outside limit, and give a period of two days for a great spot to exercise its influence, or a magnetic storm to expend its violence. What are the probabilities against 3 out of 3,400 of such periods of the one phenomenon agreeing with 3 out of 3,400 of the other, if they are not related? If 3,400 numbers were placed in one box, and 3,400 more in a second box, and one from each box were drawn at a time, what is the chance that the three highest numbers would be drawn from the one box, simultaneously with the three highest from the other, each to each, if the matter had not been pre-arranged? Indeed we might legitimately call the coincidence of April, 1882, a double one, and ask the odds against the four highest numbers from each box being so drawn.

Between Sun-spots and storms of the second magnitude it is more difficult to make a satisfactory comparison, because it is not so easy to frame a satisfactory definition as to what constitutes a secondary disturbance. Nevertheless the following brief table of large Sun-spots seen since the beginning of 1881 which were coincident with considerable disturbances may prove of interest. The spotted area is given in millions of square miles:

Date.			Spotted Area. Entire Sun.	Spotted Area. Largest Group.	Date.			Spotted Area. Entire Sun.	Spotted Area. Largest Group.
1881.	Jan.	31	1295	686	1883.	Nov.	1	2100	784
	Sept.	12	2089	917		"	19	3682	1600
1882.	Oct.	2	2480	1234	1884.	March	2	1510	609
	"	5	2065	1198		April	24	2348	1510
1883.	April	3	1545	607		"	30	1746	897
	"	19	2170	670	1885.	Jan.	23	1687	592
	June	30	3650	2210		Feb.	5	1345	571
	July	11	1887	1009		"	13	1569	480
	"	29	1425	1264		May	26*	1923	647
	Sept.	17*	2017	1263		June	24*	2348	1681
	Oct.	16	4730	1733		July	18	1835	504
	"	20	1650	1369	1891.	Nov.	22*	1966	1371

Some of the above, those marked with an asterisk, may fairly be taken as confirming, though with less definiteness, the conclusion drawn from the correspondences between the greatest spots and the greatest storms. But with the others it is not so. Spots as important have been seen upon the Sun, and the magnets have scarcely fluttered, and storms as distinct have occurred when there have been only few spots, and those but small, upon the visible disc of the Sun. The table is important, therefore, not as adding to the weight of the evidence in favor of the connection between Sun-spots and magnetic disturbances, but as emphasizing a point which must not be forgotten. Though the diurnal and annual changes of terrestrial magnetism conclusively prove the solar influence upon it, though the connection between the general Sun-spot cycle and the general magnetic cycle is clearly established, though even in minor irregularities the two curves closely correspond, and though unusually large Sunspots are answered by unusually violent magnetic storms, we cannot, as yet, proceed further and express the magnitude or character of the magnetic disturbances in terms of the spotted area of the Sun, or of its principal groups at the time of observation. The conclusion to my own mind seems to be that though Sunspots are the particular solar phenomenon most easily observed, we must not infer therefore that their number and extent afford the truest indication of the changes in the solar activity which produce the perturbations we remark in our magnetic needles.

Absorption Spectra of Metallic Films.—In the *American Chemical Journal* March, 1892, Mr. W. L. Dudley describes the methods he has employed in forming very thin films of various metals on transparent surfaces. He remarks as follows in regard to the absorption spectra of the films: "Many of the films which corresponded closely in color to the incandescent vapor of the respective metals were examined carefully as to their absorption spectra by throwing a powerful beam of white light through them. If the same molecular condition existed in the film as in the incandescent vapor, we would expect to have the same absorption. In other words, the dark lines of the absorption spectrum of the film should coincide with the bright lines of the emmission spectrum of the incandescent vapor. I found in every case, however, that the films gave simply general absorption, no bands or lines being indicated."

The Visible Spectrum of Nova Aurigæ.—The following letter from Professor Campbell has been received just as we go to press. We regret that the photograph has not arrived in time to appear this month, but it will be used in connection with the article on the spectrum of the Nova which will probably be found in our August number.

MOUNT HAMILTON, May 16, 1892.

My Dear Professor Hale:

I send you by express to-day a photographic copy of a drawing of the visible spectrum of Nova Aurigæ. It is based almost wholly on my observations of Feb. 8, Feb. 9, and March 13. One bright line was observed on March 13 which is not shown in the drawing. Altogether there are thirty bright lines whose positions I determined, two bright lines (at 680 and 432) whose positions were not determined, and ten dark lines.

My visual observations have been reduced a month or six weeks, but I have delayed sending them to you in order that I might send the photographic results with them. But they are not yet ready owing to a pressure of other work, to the very great complexity of the photographs, and to the time consumed in determining the best methods of enlarging, measuring, etc. Spectroscopic photography is still in its infancy here, as you know, and it takes time to determine experimentally the best methods.

Having just noticed that a July number of ASTRONOMY AND ASTRO-PHYSICS is not to be issued, I thought it advisable to send you this note explaining the delay. I hope the photograph (positive, on glass) will reach you unbroken.

Yours very truly, W. W. CAMPBELL.

CURRENT CELESTIAL PHENOMENA.

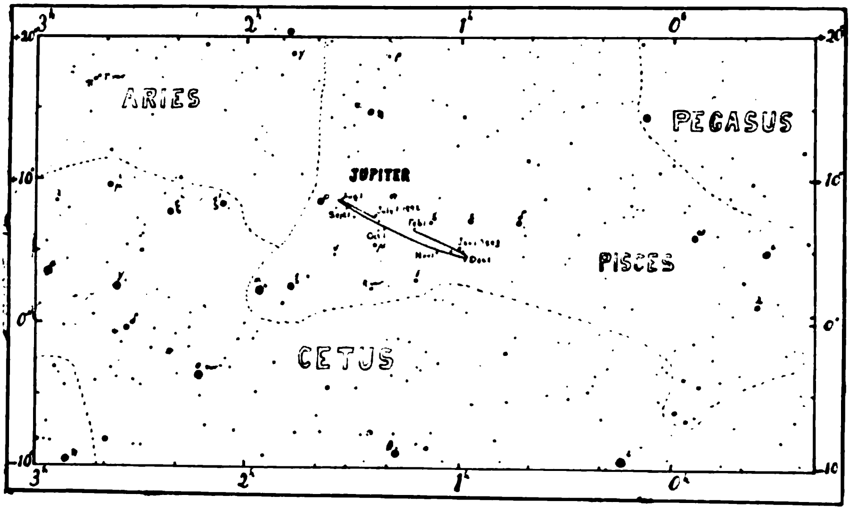
PLANET NOTES FOR JULY AND AUGUST.

Mercury will be at greatest elongation east from the Sun, 27° 14′, July 29. It will, however, in our latitude set only an hour later than the Sun, so that the conditions will not be favorable for naked eye observations. On August 25, at 9 p. m., central time, Mercury will be at inferior conjunction with the Sun, about 4° south of the latter.

Venus will be at inferior conjunction, about 5° south of the Sun, July 9 at a few minutes past noon, central time. Thirty-seven days later she will reach her greatest brilliancy as "morning star."

Mars will be stationary in R. A. July 6, making the turn in the loop of his path through Capricorn (see chart page p. 439). During these two months Mars will be in very favorable position in all respects excepting, in the northern hemisphere, his low latitude. Opposition occurs August 3 at midnight, when his distance will be only 35,000,000 miles. His apparent diameter will then be 27″. This opposition is the most favorable one for observation since that of 1877, when Professor Hall discovered the two satellites, and it will be a good time for the amateur astronomer to see as much as he can of the markings of Mars' surface.

There will be an occultation of Mars by the Moon on the night of July 11, which will be visible throughout the United States. As seen from Washington the occultation will begin at $11^{h}\ 13^{m}$ P. M. and end at $12^{h}\ 15^{m}$ eastern standard time. The Central times of the same would be $10^{h}\ 13^{m}$ and $11^{h}\ 15^{m}$ P. M. respectively. For other localities than Washington the times would vary by several minutes one way or the other, because of different parallax of the Moon. Mars will be again in conjunction with the Moon, 1° 52′ south, Aug. 3 at 21 minutes past midnight.



PATH OF JUPITER AMONG THE STARS DURING THE OPPOSITION OF 1892.

Jupiter will be in good position for observation in the morning during July and August. He will be at quadrature, 90° west from the Sun, July 15; in conjunction with the Moon, 29′ north, July 16 at $5^{h}\ 26^{m}$ P. M., and again, 2′ south, Aug. 13, at $1^{h}\ 26^{m}$ A. M. The last mentioned conjunction will be an occultation, as seen from the southern parts of the United States, Mexico, Central America, and the northern part of South America. The accompanying chart shows the path of Jupiter among the stars during the remainder of 1892 and one month of 1893.

Saturn will be too far down in the west for good observing, although he may be seen during the early evening hours of July.

Uranus will also be pretty low for good seeing by the time that twilight ends in these months. Uranus will be in conjunction with the Moon July 30, at $11^{h}\ 33^{m}$ P. M., central time. This will be an occultation as seen from the southwestern part of the United States and some of the islands of the Pacific.

Neptune is visible in the morning. He is in Taurus about 5° northeast of the bright red star Aldebaran.

MERCURY.

Date. 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
July 5	8 12.7	+ 21 49	5 39 A. M.	1 15.7 P. M.	8 52 P. M.
15	9 19.4	16 37	6 31 "	1 43.0 "	8 55 "
25	10 08.2	10 50	7 05 "	1 52.2 "	8 39 "
Aug. 5	10 39.9	5 29	7 16 "	1 40.7 "	8 06 "
15	10 41.9	3 30	6 46 "	1 03.4 "	7 21 "
25	10 16.1	+ 6 14	5 30 "	11 58.3 A. M.	6 26 "

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			VENUS.		
July 5	7 25.9	+18 15	5 10 A. M.	12 29.0 P. M.	7 48 P. M.
15	6 59.8	17 09	4 10 "	11 23.7 A. M.	6 38 "
25	6 42.7	16 41	3 15 "	10 27.3 "	5 39 "
Aug. 5	6 42.2	16 52	2 30 "	9 43.6 "	4 57 "
15	6 56.9	17 17	2 04 "	9 18.8 "	4 34 "
25	7 22.1	+17 31	1 49 "	9 04.8 "	4 21 "
			MARS.		
July 5	21 25.7	−20 27	9 48 P. M.	2 26.4 A. M.	7 04 A. M.
15	21 23.4	21 40	9 13 "	1 45.0 "	6 17 "
25	21 16.4	22 44	8 32 "	12 58.6 "	5 25 "
Aug. 5	21 05.0	23 48	7 43 "	12 04.1 "	4 26 "
15	20 54.6	24 23	6 56 "	11 14.3 P. M.	3 33 "
25	20 47.0	−24 29	6 10 "	10 27.4 "	2 45 "
			JUPITER.		
July 5	1 25.6	+ 7 36	11 52 P. M.	6 25.8 A. M.	12 59 P. M.
15	1 29.5	7 56	11 16 "	5 50.3 "	12 25 "
25	1 32.4	8 10	10 38 "	5 13.8 "	11 50 A. M.
Aug. 5	1 34.2	8 18	9 56 "	4 32.4 "	11 09 "
15	1 34.6	8 17	9 17 "	3 53.5 "	10 30 "
25	1 33.7	+ 8 10	8 38 "	3 13.3 "	9 49 "
			SATURN.		
July 5	11 44.2	+ 4 09	10 27 A. M.	4 46.7 P. M.	11 06 P. M.
15	11 46.8	3 50	9 52 "	4 10.0 "	10 28 "
25	11 49.9	3 29	9 17 "	3 33.8 "	9 51 "
Aug. 5	11 53.7	3 02	8 39 "	2 54 2 "	9 10 "
15	11 57.6	2 36	8 05 "	2 18.7 "	8 32 "
25	12 01.6	+ 2 09	7 32 "	1 43.5 "	7 55 "
			URANUS.		
July 5	13 59.9	−11 43	1 45 P. M.	7 01 9 P. M.	12 17 A. M.
15	13 59.9	11 43	1 04 "	6 22.7 "	11 38 P. M.
25	14 00.3	11 45	12 27 "	5 43.8 "	11 00 "
Aug. 5	14 01.0	11 50	11 46 A. M.	5 01.6 "	10 18 "
15	14 02.1	11 56	11 07 "	4 22.9 "	9 38 "
25	14 03.4	−12 03	10 30 "	3 45.0 "	9 00 "
			NEPTUNE.		
July 5	4 34.7	+20 28	2 09 A. M.	9 38.3 A. M.	5 08 P. M.
15	4 36.0	20 30	1 30 "	9 00.3 "	4 30 "
25	4 37.1	20 32	12 52 "	8 22.1 "	3 52 "
Aug. 5	4 38.2	20 34	12 10 "	7 39.9 "	3 10 "
15	4 39.0	20 35	11 27 P. M.	6 57.5 "	2 28 "
25	4 39.5	+20 36	10 48 "	6 18.7 "	1 49 "
			THE SUN.		
July 5	7 01.2	+22 42	4 22 A. M.	12 04.4 P. M.	7 46 P. M.
15	7 42.0	21 23	4 31 "	12 05.8 "	7 41 "
25	8 21.9	19 28	4 40 "	12 06.3 "	7 32 "
Aug. 5	9 04.7	16 43	4 53 "	12 05.7 "	7 19 "
15	9 42.6	13 46	5 04 "	12 04.1 "	7 04 "
25	10 19.6	+10 27	5 16 "	12 01.7 "	6 48 "

Occultations Visible at Washington.

Date 1892.	Star's Name.	Magnitude.	IMMERSION Washington M. T.	IMMERSION Angle f'm N pt.	EMERSION Washington M. T.	EMERSION Angle f'm N pt	Duration.
			h m	°	h m	°	h m
July 6	25 Scorpii	6.5	12 47	101	14 02	271	1 15
9	B.A.C. 6666	6	7 40	41	8 23	324	0 43
11	35 Capricorni	6	8 50	72	9 55	262	1 05
11	MARS		11 05	35	12 07	286	1 02
18	13 Tauri	6	12 43	119	13 14	195	0 31
Aug. 2	19 Scorpii	5	8 37	59	9 37	334	1 00
5	τ Sagittarii	4	6 59	60	8 06	307	1 07
10	B.A.C. 8274	7	8 10	77	9 06	233	0 56
15	ν^2 Tauri	6	12 41	112	13 20	204	0 39
31	3 Sagittarii	5	7 58	70	9 20	294	2 12

Mr. Marth's Ephemerides of the Satellites of Saturn.

[From *Monthly Notices*, March 1892.].

In this table the times have been changed from Greenwich Mean Time to Central Standard Time. The abreviations *Rh.*, *Te.*, *Di.*, *En.*, and *Mi.* stand for the names of the satellites Rhea, Tethys, Dione, Enceladus, and Mimas The letters *a*, *b*, *c*, *d*, and *e*, stand for conjunctions of the satellites in order as follows: With the preceding end of the outer ring; with preceding end of planet's equatorial diameter; with center of planet; with following end of planet's diameter; with following end of ring. The letters *n* and *s* signify that the satellite at the time of conjunction is north or south of the point designated by the preceding letter; *Sh.* means that the shadow of a satellite is near the central meridian of the planet; *Ecl. D.* and *Ecl. R.*, the disappearance and reappearance of a satellite at beginning and end of an eclipse.

Day	Time	Phenomenon
June, 1892.		
20	6.8 pm	Te Ecl. R
	7.4	En s Te n + 1.8
	7.5	Te n Di s + 1.9
	8.2	Te en
	9.0	Di ds
21	3.9	Mi en
	4.0	Te Sh
	4.8	Te bs
	5.5	En en
	6.8	Te as
	9.3	Mi es
22	4.1	Te Ecl. R
	5.5	Te en
	7.7	Rh s Titan n — 5.7
	8.0	En en
23	2.2	Te bs
	2.7	Di ds
	3.7	Titan dn
	4.2	Titan as
	5.2	Di Sh
	6.0	Di bs
	6.5	Mi es
	6.8	En as
	7.6	Titan en
	8.2	Di as
24	2.2	Te en
	5.1	Rh Ecl. R
	5.1	Mi es
	6.5	Rh en
	8.0	En s Rh n + 3.1
	9.3	Di an
	9.4	En es
25	3.8	Mi es
	8.1	En en
26	1.9	Di as
June, 1892.		
26	2.4 pm	Mi es
	3.7	Rh es
	5.1	Di s En n — 4.0
	6.3	Rh ds
	8.3	Mi as
	9.7	Rh Sh
	10.2	Rh bs
27	3.1	Di an
	3.1	En es
	5.3	Di bn
	6.9	Mi as
	9.3	Di Ecl. R
	9.5	En as
	10.8	Di en
28	5.5	Mi as
	6.6	Di s Te s + 4.9
	9.7	Di s En s + 3.4
	10.0	Rh an
29	4.2	Mi as
	4.5	En an
	9.6	Mi an
	10.8	En en
30	3.0	Di Ecl. R
	3.3	En as
	3.5	Di en
	6.9	Di n Titan s + 2.6
	8.2	Mi an
	10.2	Te s Titan s + 2.5
	10.2	Rh s Di n + 5.1
	10.6	Ti es
	10.8	Titan es
July, 1892.		
1	3.0	Rh s Titan s — .2
July, 1892.		
1	3.3 pm	Di n En n + 3.6
	5.3	Rh s Te n — 4.3
	5.6	Di es
	5.7	Te n Titan s — 4.1
	5.8	En es
	6.8	Mi an
	7.8	Di ds
	9.2	Ti an
	10.3	Di Sh
2	7.9	Te es
	9.9	Te ds
3	6.0	Rh Ecl. R
	6.5	Te an
	7.5	Rh en
	8.5	Te bn
4	1.6	Di ds
	4.8	Di bs
	5.2	Te es
	7.0	Di as
	7.2	Te ds
5	3.9	Te an
	4.7	Rh es
	5.9	Te bs
	7.3	Rh ds
	8.2	Di an
	9.3	Te Ecl. R
6	2.5	Te es
	4.5	Te ds
	7.4	Te bs
	9.2	Te as
7	3.4	Te bn
	6.6	Te Ecl. R
	8.1	Te en
	11.0	Rh an
8	1.9	Te ds
July, 1892.		
8	1.9 pm	Di an
	4.1	Di bn
	4.8	Di bs
	6.8	Te as
	8.1	Di Ecl. R
	9.6	Di en
9	3.3	Titan dn
	4.0	Te Ecl. R
	5.4	Te en
	7.2	Titan en
10	2.1	Te bs
	2.2	Rh as
	4.1	Te as
11	1.3	Te Ecl. R
	1.8	Di Ecl. R
	2.7	Te en
	3.4	Di en
12	1.4	Te as
	2.0	Rh bn
	4.5	Di es
	6.7	Di ds
	6.9	Rh Ecl. R
	8.5	Rh en
14	5.7	Rh es
	8.3	Rh ds
15	3.7	Di bs
	5.9	Di as
16	7.1	Di an
	9.3	Di bn
	10.6	Titan es
17	12.1	Titan as
19	3.3	Rh as
21	3.1	Rh bn
	7.8	Rh Ecl. R
	9.5	Rh en
23	6.8	Rh es
	8.4	Rh ds
25	3.3	Titan dn
	7.1	Titan en

Configuration of Jupiter's Satellites.

Day	Configuration
July	
1	3 4 1 ○ 2
2	3 4 ○ 1 2
3	4 2 1 3 ○
4	4 2 ○ 1 3
5	4 1 ○ 2 3
6	4 2 ○ 1 3
7	4 2 3 1 ○
8	♃ 3 4 ○ 2
9	3 1 ○ 2 ●
10	2 3 1 ○ 4
11	2 ○ 1 3 4
12	1 ○ 2 3 4
13	♃ ○ 1 5 4
14	♃ 2 1 ○ 4
15	3 ○ 1 2 4
16	3 ○ 1 2 4
17	3 2 1 ○ 4
18	4 2 ○ 3 1
19	4 1 ○ 2 3
20	4 ○ 2 1 3
21	4 2 1 ○ 3
July	
22	4 3 ○ 1 2
23	4 3 ○ 2 ●
24	4 3 2 1 ○
25	4 2 ○ 3 1
26	1 ○ 4 2 3
27	○ 2 1 4 3
28	2 1 ○ 3 4
29	3 ○ 1 4 ●
30	3 1 ○ 2 4
31	♃ 3 2 ○ 4
Aug.	
1	2 ○ 1 4 ●
2	1 ○ 2 4 3
3	○ 4 2 1 3
4	2 4 1 ○ 3
5	4 3 2 ○ 1
6	4 3 1 ○ 2
7	4 3 2 ○ 1
8	4 2 3 ○ ●
9	4 1 ○ 2 3
10	4 ○ 1 2 3
Aug.	
11	2 1 4 ○ 3
12	3 2 ○ 4 1
13	3 1 ○ 2 4
14	♃ 3 ○ 1 4
15	2 3 1 ○ 4
16	1 ○ 2 3 4
17	○ 1 2 3 4
18	2 1 ○ 3 4
19	2 3 ○ 1 4
20	♃ 3 1 ○ 2
21	3 4 ○ 2 1
22	4 2 3 1 ○
23	♃ 4 ○ 2 3
24	4 ○ 1 2 3
25	4 2 1 ○ 3
26	♃ 4 2 ○ 1
27	3 4 1 ○ 2
28	3 4 ○ 2 1
29	2 3 1 ○ 4
30	○ 2 1 3 4
31	○ 2 3 4 ●

Jupiter's Satellites.

July 1	9	39	P. M.	I	Tr. In.
	10	31	"	I	Sh. Eg.
	11	53	"	I	Tr. Eg.
3	3	38	A. M.	II	Sh. In.
4	1	25	"	III	Ec. Dis.
	3	51	"	III	Ec. Re.
	10	49	P. M.	II	Ec. Dis.
5	1	21	A. M.	II	Ec. Re.
	1	36	"	II	Oc. Dis.
	4	07	"	II	Oc. Re.
6	10	16	P. M.	II	Te. Eg.
7	3	42	A. M.	I	Sh. In.
	11	32	P. M.	III	Tr. Eg.
8	12	52	A. M.	I	Ec. Dis.
	10	10	P. M.	I	Sh. In.
	11	35	"	I	Tr. In.
9	12	23	A. M.	I	Sh. Eg.
	1	48	"	I	Tr. Eg.
	10	56	P. M.	I	Oc. Re.
12	1	25	A. M.	II	Ec. Dis.
13	10	09	P. M.	II	Sh. Eg.
	10	24	"	II	Tr. In.
14	12	53	A. M.	II	Tr. Eg.
	10	10	P. M.	III	Sh. Eg.
15	1	25	A. M.	III	Tr. In.
	2	46	"	I	Ec. Dis.
16	12	04	"	I	Sh. In.
	1	29	"	I	Tr. In.
	2	19	"	I	Sh. Eg.
	3	42	"	I	Tr. In.
17	12	50	"	I	Oc. Re.
	8	49	"	II	Sh. In.
	10	11	P. M.	I	Tr. Eg.
20	10	08	"	II	Sh. In.
21	12	45	A. M.	II	Sh. Eg.
	12	59	"	II	Tr. In.
	3	27	"	II	Tr. Eg.
	11	33	P. M.	III	Sh. In.
22	2	08	A. M.	III	Sh. Eg.
	10	34	P. M.	II	Oc. Re.
23	1	58	A. M.	I	Sh. In.
	3	22	"	I	Tr. In.
24	9	50	"	I	Tr. In.
	10	42	"	I	Sh. Eg.
	12	03	"	I	Tr. Eg.
28	12	44	"	II	Sh. In.
	3	21	"	II	Sh. Eg.
	3	33	"	II	Tr. In.
29	3	34	"	III	Sh. In
	10	24	P. M.	II	Ec. Re.
	10	39	"	II	Oc. Dis.
30	1	05	A. M.	II	Oc. Re.
	3	52	"	I	Sh. In.
31	1	02	"	I	Ec. Dis.
	10	21	P. M.	I	Sh. In.
	11	42	"	I	Tr. In.
Aug. 1	12	35	A. M.	I	Sh. Eg.
	1	55	"	I	Tr. Eg.
	11	03	P. M.	I	Oc. Re.
	11	07	"	III	Oc. Dis.
2	1	04	A. M.	III	Oc. Re.
	8	23	P. M.	I	Tr. Eg.
4	3	20	A. M.	II	Sh. In.
Aug. 5	10	29	P. M.	II	Ec. Dis.
6	12	50	A. M.	II	Ec. Re.
	1	07	"	II	Oc. Dis.
	3	34	"	II	Oc. Re.
7	2	56	"	I	Ec. Dis.
	9	45	P. M.	II	Tr. Eg.
8	12	14	A. M.	I	Sh. In.
	1	34	"	I	Tr. In.
	2	29	"	I	Sh. Eg.
	3	46	"	I	Tr. Eg.
	9	25	P. M.	I	Ec. Dis.
	9	30	"	III	Ec. Dis.
	11	49	"	III	Ec. Re.
9	12	54	A. M.	I	Oc. Re.
	2	56	"	III	Oc. Dis.
	8	57	P. M.	I	Sh. Eg.
	10	13	"	I	Tr. Eg.
13	1	04	A. M.	II	Ec. Dis.
	3	33	"	II	Ec. Re.
	3	35	"	II	Oc. Dis.
14	9	47	P. M.	II	Tr. In.
	9	52	"	II	Sh. Eg.
15	12	13	A. M.	II	Tr. Eg.
	2	08	"	I	Sh. In.
	3	23	"	I	Tr. In.
	11	19	P. M.	I	Ec. Dis.
16	2	32	A. M.	III	Ec. Dis.
	2	43	"	I	Oc. Re.
	3	49	"	III	Ec. Re.
	8	37	P. M.	I	Sh. In.
	9	50	"	I	Tr. In.
	10	51	"	I	Sh. Eg.
17	12	02	A. M.	I	Tr. Eg.
	9	11	P. M.	I	Oc. Re.
19	8	41	"	III	Tr. In.
	10	30	"	III	Tr. Eg.
	3	39	"	II	Ec. Dis.
21	9	53	"	II	Sh. In.
22	12	14	A. M.	II	Tr. In.
	12	29	"	II	Sh. Eg.
	2	39	"	II	Tr. Eg.
	4	02	"	I	Sh. In.
23	1	14	"	I	Ec. Dis.
	9	36	P. M.	II	Oc. Re.
	10	38	"	I	Sh. In.
	11	38	"	I	Tr. In.
24	12	44	A. M.	I	Sh. Eg.
	1	50	"	I	Tr. Eg.
	10	59	P. M.	I	Oc. Re.
25	8	17	"	I	Tr. Eg.
26	10	07	"	III	Sh Eg.
27	12	18	A. M.	III	Tr. In.
	2	05	"	III	Tr. Eg.
29	12	30	"	II	Sh. In.
	2	39	"	II	Tr. In.
	3	06	"	II	Sh. Eg.
30	3	08	"	I	Ec. Dis.
	11	57	P. M.	II	Oc. Re.
31	12	24	A. M.	I	Sh. In.
	1	26	"	I	Tr. In.
	2	38	"	I	Sh. Eg.
	3	38	"	I	Tr. Eg.
	9	37	P. M.	I	Ec. Dis.

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A.................$0^h\ 52^m\ 32^s$
Decl.................$+81^\circ\ 17'$
Period............$2d\ 11^h\ 50^m$

July	3	2 A. M.
	8	1 "
	13	1 "
	18	1 "
	22	midn.
	27	"
Aug.	1	"
	6	11 P. M.
	11	11 "
	16	11 "
	21	10 "
	26	10 "
	31	10 "

ALGOL.

R. A.................$3^h\ 01^m\ 01^s$
Decl................. $+40^\circ\ 32'$
Period............$2d\ 20^h\ 49^m$

July	9	4 A. M.
	12	1 "
	14	10 P. M.
Aug.	1	3 A. M.
	3	midn.
	6	9 P. M.
	21	5 A. M.
	24	2 "
	26	10 P. M.

δ LIBRÆ.

R. A................$14^h\ 55^m\ 06^s$
Decl................. $-8^\circ\ 05'$
Period............$2d\ 07^h\ 51^m$

July	1	7 P. M.
	15	6 "
	25	1 A. M.

U CORONÆ.

R. A...............$15^h\ 13^m\ 43^s$
Decl ....$+\ 32^\circ\ 03'$
Period............$3d\ 10^h\ 51^m$

July	1	1 A. M.
	7	10 P. M.
	14	8 "
	21	6 "
Aug.	8	1 A. M.
	14	11 P. M.
	21	9 "
	28	6 "

U OPHIUCHI.

R. A..............$17^h\ 10^m\ 56^s$
Decl..................$+\ 1^\circ\ 20'$
Period. ....$0d\ 20^h\ 8^m$

July	1	4 A. M.
	1	midn.
	2	8 P. M.
	6	5 A. M.
	7	1 "
	7	9 P. M.
	12	2 A. M.
	12	10 P. M.
	17	3 A. M.
	17	11 P. M.
	22	4 A. M.
	22	midn.
	23	8 P. M.
	27	4 A. M.
	27	midn.
	28	8 P. M.
Aug.	1	5 A. M.
	2	1 "
	2	9 P. M.
	7	2 A. M.

U OPHIUCHI CONT.

Aug.	7	10 P. M.
	12	3 A. M.
	12	11 P. M.
	17	3 A. M.
	17	11 P. M.
	22	4 A. M.
	22	midn.
	23	8 P. M.
	27	5 A. M.
	28	1 "
	28	9 P. M.

Y CYGNI.

R. A...............$20^h\ 47^m\ 40^s$
Decl................$+\ 34^\circ\ 15'$
Period............$1d\ 11^h\ 56^m$

July	2	3 A. M.
	5	3 "
	8	3 "
	11	2 "
	14	2 "
	17	2 "
	20	2 "
	23	2 "
	26	2 "
	29	2 "
Aug.	1	2 "
	4	2 "
	7	2 "
	10	1 "
	13	1 "
	16	1 "
	19	1 "
	22	1 "
	25	1 "
	28	1 "
	31	1 "

Occultations of Stars by the Planets.

[From *Astr. Nach.*, No. 3073.]

	Date		Central Time of Conjunction.		Diff. of Decl.	Maximum Duration.	Magnitude of Star.
			h m		"	m	
			STARS NEAR MARS.				
1892.	July	9	8 06	A. M.	+ 19	98	9.0
		24	1 00	A. M.	+ 8	43	9.2
			STARS NEAR JUPITER.				
	July	2	9.8	A. M.	− 67	2.1	9.1
		13	2.4	A. M.	+ 20	2.7	8.9
			STARS NEAR SATURN.				
	Aug.	2	7.8	P. M.	+ 32	1.1^h	9.5
		4	4.9	"	+ 115	1.1	9.5
		6	12.5	A. M.	− 60	1.1	9.5
		15	6.8	P. M.	+ 95	1.0	9.1

Brightness of Asteroid No. 324 (Palisa Feb. 24.)—Herr Berberich (*Astr. Nach.* 3088) finds that the Asteroid No. 324, which was of the 11th magnitude when discovered in February last has an average magnitude, at opposition, of 9.7, and that at perihelion its magnitude would be 8. The late discovery of so bright a planet is quite remarkable and is to be explained by the great inclination of its path, 33° 25', to the equator.

Phases and Aspects of the Moon. Central Time.

		d	h	m	
First Quarter	July	1	8	13	P. M.
Apogee	"	3	6	12	A. M.
Full Moon	"	9	7	44	P. M.
Last Quarter	"	16	7	48	"
Perigee	"	17	8	30	"
New Moon	"	23	5	31	"
Apogee	"	31	12	30	A. M.
First Quarter	"	31	1	45	P. M.
Full Moon	Aug.	8	5	57	A. M.
Perigee	"	12	4	30	"
Last Quarter	"	15	12	37	"
New Moon	"	22	4	59	"
Apogee	"	27	7	18	P. M.
First Quarter	"	30	7	29	A. M.

Twenty-two Asteroids Discovered in 1891.—We take the following data from the *Vierteljahrschrift der Astronomische Gesellschaft*, J. 27, 1:

No.	Name.	Date of Discovery.	Discoverer.	Place.
303	Josephina	Feb. 12	Millosevich$_1$	Rome
304	Olga	Feb. 14	J. Palisa$_{76}$	Vienna
305		Feb. 16	A. Charlois$_{15}$	Nice
306	Unitas	March 1	Millosevich$_2$	Rome
307		March 5	A. Charlois$_{16}$	Nice
308		March 31	Borrelly$_{16}$	Marseilles
309	Fraternitas	April 6	J. Palisa$_{77}$	Vienna
310		May 16	A. Charlois$_{17}$	Nice
311		June 11	A. Charlois$_{18}$	Nice
312		Aug. 28	A. Charlois$_{19}$	Nice
313	Chaldea	Aug. 30	J. Palisa$_{78}$	Vienna
314		Sept. 1	A. Charlois$_{20}$	Nice
315	Constantia	Sept. 4	J. Palisa$_{79}$	Vienna
316		Sept. 8	A. Charlois$_{21}$	Nice
317		Sept. 11	A. Charlois$_{22}$	Nice
318		Sept. 24	A. Charlois$_{23}$	Nice
319		Oct. 8	A. Charlois$_{24}$	Nice
320		Oct. 11	J. Palisa$_{80}$	Vienna
321		Oct. 15	J. Palisa$_{81}$	Vienna
322		Nov. 27	Borrelly$_{17}$	Marseilles
323		Dec. 22	M. Wolf$_2$	Heidelberg
324		Dec. 1	M. Wolf$_1$	Heidelberg

The last two were discovered photographically. No. 324 although discovered earlier than 323 was at first thought to be identical with an older planet, hence was numbered later. The subscript numbers after the name of each discoverer indicates the number of the asteroids discovered by that person.

COMET NOTES.

The weather during the past month has been unusually bad so that we have had but few opportunities to observe the comets. Swift's comet is growing rapidly fainter but is yet a conspicuous telescopic comet with a faint tail about 5° long. It ought to be followed, with large telescopes at least, a couple of months longer. It is moving northeast through the constellation Andromeda. Winnecke's comet reaches its theoretical maximum brightness July 8. It is now quite conspicuous in a five-inch telescope. It is moving rapidly south and west and will pass, during June and July, through the constellations Leo Minor, Cancer, Gemini, and Orion, into Eridanus. The two comets Brooks, 1886 IV, and Tempel, 1867 II, have not been found. We continue the search ephemeris for the former, but there is little probability that it will be [illegible] Denning's comet is in Perseus andmoving slowly southeast. It is extr

Orbit of Comet *a* 1892 (Swift).—Since the publication of my orbit of this comet as derived from my own observations in the May number of this periodical,* I have made another approximation with the following result.

ELEMENTS.

$$
\begin{aligned}
T &= 1892 \text{ Apr. } 6.64066 \text{ Gr. M. T.}\\
\omega &= \ \ 24^\circ \ \ 29' \ \ 29''\\
\Omega &= 240 \ \ \ 55 \ \ \ 1\\
i &= \ \ 38 \ \ \ 42 \ \ \ 19\\
\log q &= 0.01162
\end{aligned}
$$

O. C. WENDELL.

Harvard College Observatory, May 16, 1891.

Ephemeris of Comet a 1892 (Swift).

(Calculated from Mr. Wendell's elements by H. C. Wilson and Miss F. E. Harpham.)

Gr. M. Noon		App. R. A.			App. Decl		log Δ	log r	Br.
1892 June	16	0	23	08	+ 42	39.7	0.2090	0.1870	0.27
	20		29	49	43	49.1	0.2156	0.1996	0.24
	24		36	00	44	53.9	0.2217	0.2121	0.22
	28		41	35	45	54.3	0.2272	0.2243	0.20
July	2		46	36	46	50.5	0.2321	0.2363	0.19
	6		51	02	47	42.8	0.2365	0.2481	0.18
	10		54	49	48	31.4	0.2404	0.2596	0.16
	14	0	57	59	49	16.3	0.2439	0.2708	0.15
	18	1	00	29	49	57.7	0.2470	0.2818	0.14
	22		02	18	50	35.5	0.2496	0.2926	0.13
	26		03	23	51	09.5	0.2520	0.3031	0.13
	30	1	03	46	+ 51	39.5	0.2541	0.3133	0.12

Ephemeris of Winnecke's Periodic Comet 1892.

[From *Astr. Nachr.* No. 3083, continued from page 444.]

Berlin Midnight		App. R. A.			App. Decl.			log Δ	log r	Br.
		h	m	s	°					
1892 July	1	8	22	54	+ 30	37	08	9.1562	9.9477	57.89
	2	8	10	46	29	01	43	9.1425	9.9479	
	3	7	58	11	27	15	36	9.1294	9.9482	66.04
	4	7	45	14	25	18	45	9.1181	9.9486	
	5	7	32	03	23	11	36	9.1086	9.9491	73.56
	6	7	18	44	20	55	04	9.1010	9.9498	
	7	7	05	26	18	30	34	9.0956	9.9506	79.16
	8	6	52	15	16	00	02	9.0926	9.9515	
	9	6	39	19	13	25	44	9.0920	9.9526	81.62
	10	6	26	44	10	50	04	9.0939	9.9537	
	11	6	14	36	8	15	25	9.0981	9.9550	80.30
	12	6	02	58	5	44	01	9.1044	9.9565	
	13	5	51	54	3	17	46	9.1128	9.9580	75.54
	14	5	41	25	+ 0	58	05	9.1227	9.9596	
	15	5	31	33	− 1	14	00	9.1341	9.9614	68.43
	16	5	22	17	3	17	53	9.1466	9.9632	
	17	5	13	37	5	13	20	9.1600	9.9652	60.29
	18	5	05	31	7	00	24	9.1740	9.9673	
	19	4	57	58	8	39	24	9.1884	9.9694	52.17
	20	4	50	55	10	10	41	9.2031	9.9717	
	21	4	44	21	11	34	43	9.2179	9.9740	44.72
	22	4	38	14	12	52	03	9.2327	9.9764	
	23	4	32	32	14	03	13	9.2474	9.9789	
	24	4	27	12	15	08	48	9.2619	9.9815	
	25	4	22	13	16	09	18	9.2762	9.9841	32.60
	26	4	17	33	17	05	14	9.2903	9.9868	
	27	4	13	11	17	57	02	9.3040	9.9896	
	28	4	09	03	18	45	07	9.3174	9.9924	
	29	4	05	10	− 19	29	50	9.3306	9.9953	24.00

Berlin Midnight	App. R. A.			App. Decl.			log Δ	log r	Br.
	h	m	s	°	'	"			
July 30	4	01	30	− 20	11	30	9.3433	9.9982	
31	3	58	02	20	50	26	9.3558	0.0012	
Aug. 1	3	54	43	21	26	53	9.3678	0.0043	
2	3	51	35	22	01	09	9.3796	0.0073	18.02
3	3	48	34	22	33	25	9.3911	0.0105	
4	3	45	40	23	03	54	9.4022	0.0138	
5	3	42	54	23	32	44	9.4130	0.0168	13.81
6	3	40	13	24	00	06	9.4236	0.0200	
7	3	37	37	24	26	06	9.4338	0.0233	
8	3	35	06	24	50	52	9.4438	0.0265	
9	3	32	39	25	14	29	9.4535	0.0298	10.80
10	3	30	15	25	37	05	9.4630	0.0332	
11	3	27	54	25	58	43	9.4722	0.0365	
12	3	25	35	26	19	30	9.4812	0.0398	
13	3	23	18	26	39	28	9.4899	0.0432	8.59
14	3	21	02	26	58	41	9.4985	0.0466	
15	3	18	48	− 27	17	11	9.5069	0.0499	

Search Ephemeris for Comet Brooks, 1886 IV.

[From Astr. Nach. 3064, continued from page 443]

	Perihelion, March 31.					Perihelion, April 30.				
	R. A.		Decl.		Light.	R.A.		Decl.		Light.
	h	m	°	'		h	m	°	'	
July 9	20	27.5	− 42	00	0.32	17	5.7	− 48	52	0.72
19	21	14.7	− 43	35	0.29	17	52.7	− 48	30	0.52
29	21	58.2	− 44	56	0.27	18	01.6	− 47	35	0.37
Aug. 8						18	12.2	− 46	25	0.26
18						18	23.9	− 45	09	0.19
	Perihelion, May 30.					Perihelion, June 29.				
July 9	14	05.8	− 25	46	0.64	12	33.2	− 5	07	0.32
19	14	35.3	− 29	47	0.49	13	01.7	− 10	26	0.29
29	15	06.5	− 32	57	0.37	13	31.9	− 15	28	0.25
Aug. 8	15	38.5	− 35	16	0.27	14	03.6	− 20	05	0.22
18	16	11.0	− 36	53	0.20	14	36.7	− 24	05	0.18
	Perihelion, July 29.									
July 9	11	37.3	+ 6	42	0.16					
19	12	04.1	+ 2	00	0.15					
29	12	32.2	− 2	47	0.15					
Aug. 8	13	01.5	− 7	37	0.15					
18	13	32.1	− 12	16	0.14					

Observation of Saturn.—At 10:30 P. M., Central standard time. I detected one of the satellites of Saturn apparently moving along the needle-like appendage to the planet, which is now presented by the rings. The apparent diameter of the satellite so far exceeded the apparent thickness of the ring, that it gave the appearance of a beautiful golden bead moving very slowly along a fine golden thread. I followed it for an hour during which time the change of position was perceptable without micrometric measurement. At 11:35 A. M. the satellite had moved off the thread and stood with three others to the west of the ring, as seen in the inverting telescope. L. W. UNDERWOOD.

Underwood Obervatory, Appleton, Wis.

At Goodsell Observatory we happened, with some students, to be looking at Saturn with a 16-inch telescope at about $9^h\ 30^m$ P. M. central time on the same night as the above. The satellite Titan was a little below, *i. e* north of, the ring, just in contact with it, on the east side [illegible]he planet. The diameter of the satellite appeared to be about three time[illegible]s of the rings. H. C. W.

NEWS AND NOTES.

Readers of this journal will please remember that our next issue will be for the month of August, as July is one of our vacation months.

During the last month the observers at Goodsell Observatory have been unable to do any work with the instruments on account of rain and persistent clouds.

Total Solar Eclipse, April 15-16, 1893., as presented elsewhere by Professor H. S. Pritchett, Observatory, Washington University, St. Louis, is an excellent setting forth of all the important facts connected with the event. Astronomers everywhere will be interested in this article, not only on account of the local information given, but also in the suggestions made concerning co-öperation of different observing parties along the path of the eclipse. We wish to call special attention to this latter highly important feature of the paper.

The Milky Way by Otto Bœddicker.—The crowded space of our last number made it impossible to speak of the four plates of the Milky Way, in portfolio form made by Otto Bœddicker, and published by Messrs. Longmans, Green & Co., as fully as they deserve. So we call attention to them again.

The drawing was begun in October, 1884, by Dr. Bœddicker, Astronomer at the Earle of Rosse's Observatory at Birr Castle Parsontown, the object being to obtain an accurate representation of the Galaxy as it appears to the naked eye. In an accompanying note, the details of the plan of work are stated quite fully, and will show how faithfully and laboriously it was carried forward to completion. First he copied the maps of Argelander's *Uranometria Nova* which contained parts of the Milky Way. Then excluding all extraneous light he examined a part of the Galaxy until satisfied that he had made out some feature, then by the aid of an incandescent light details observed were inserted on the map. Results were verified on consecutive nights and further details added until a large number of nights was given to one section. The next step was to construct a large chart in stereographic projection to 100° north polar distance, and thereon insert the parts of the Milky Way, as furnished by the sections, in order to deduce a true picture of the gradation of light in the different sections. Three different ways were employed to determine the uniform scale of light. First, different spots and parts of the Galaxy were numbered, and written down directly from the sky in order of brightness; then notice was taken of the order in which the different portions of it appeared from first twilight to complete darkness and, lastly, the order in which they disappeared with the rising Moon. To be free from bias, in carrying the work forward, the author avoided all pictures of the Milky Way which had been previously made until the drawings were completed. The last stage of the work consisted in the three enlarged sections covering the whole of the Milky Way, and the general chart as they appear in the finished work.

The best way to see the fainter details of these plates is to view them at a distance of five or ten feet, for the evident reason that the contrast between faint nebulosity and the surrounding white ground is lessened the larger the area of the retina of the eye, that is covered by the image of the nebulosity. Celestial photographers are taking advantage of this physiological fact in the use of wide angled lenses to vary the area of the field of view to get contrast, for the study of details in the grouping of the stars.

The comparison of these drawings with the excellent ones by Heis, at once shows that the details of the former are more full and varied. Bœddicker does not attempt to give the faint luminosity surrounding the Milky Way proper as Heis does, because he does not feel sure that it is confined to it. To his eye the sky is covered by irregular patches of faint luminosity, and hence is not everywhere uniformly black. The attempts to represent the lunes and rifts with true light scale has proved a very hard task as every artist knows, but it is agreeably surprising to notice how well it is done in this new work. Astronomers interested in this kind of study will find these drawings a great help in studying the Galaxy which, without much doubt, is the key to the structure of the universe.

The size of these plates is 18 inches by 23 inches, and the price in folio is $10.00.

Aurora at Mt. Hamilton.—Up to the present observations, I had never seen the aurora at Mt. Hamilton.

On May 18*d* 8^h 35^m standard Pacific time (8 hours slow of Greenwich), while comet seeking on the roof of the Observatory, my attention was attracted to the northeast by two rather slender yellowish beams of light shooting vertically from the horizon near the star Alpha Cephei. I at once recognized in these the characteristic auroral streamers. The two beams were each about one degree in diameter and extended to an altitude of some 20°, the distance between them being about 3° or 4°. They were conspicuous then for a few minutes but finally merged into a single broad beam which faded quite rapidly. By 8^h 45^m no trace of the display remained, nor did it return again up to as late as moonrise.

E. E. BARNARD.

Mt. Hamilton, May 19th, 1892.

Aurora at Providence, Rhode Island.—A most beautiful and brilliant display of aurora borealis occurred here last night. It was first seen at our Observatory soon after eight o'clock. At that time it was not very brilliant, but consisted of long streamers which shot up from the north and northwestern horizon, to a point near the dipper in the Great Bear. At nine o'clock it faded away. About ten o'clock it quickly brightened up again, and consisted of two distinct arches extending from the northwest near Venus, Castor and Pollux to a point in the northeast near the Cross in Cygnus. On the horizon the so-called dark segment was easily seen, and the stars of Cassiopiea shone as through a thick fog. The most brilliant part of the Aurora was between Cassiopiea and Polaris. This was of a most dazzling yellow light. About eleven o'clock the aurora was at its height and consisted of the two arches which were broken up into streamers, some of the streamers extending as far south and west as α Virginis. The light was very bright and resembled a moonlight night. At times the streamers seemed almost to unite at a point near Arcturus to form a crown, but no well defined crown was formed. From half-past eleven until after two o'clock the aurora gradually faded, and by two o'clock nothing was left of it but a few patches of white light near the northern horizon. The display of last night was one of the finest of the year, none equaling it except the one of Feb. 13. The color of this Aurora was white and yellow, the red color which usually accompanies brilliant displays being absent. At the time of greatest brilliancy, and when it broke up into streamers, the horizontal magnetic needle was greatly disturbed as usual. No observations were taken here with the spectroscope. The observations with the magnetic needle were made by C. Bates Johnson.

Providence, May 19, 1892. F. E. SEAGRAVE.

Occultation of Uranus, April 12, 1892.—At Toronto this occultation, which took place at 11h 51m 4s Eastern standard time, was well seen. Sky clear, air steady, definition good. Uranus was picked up at 11h 15m and easily followed up to bright limb of the Moon. Approach seemed rapid; and disappearance almost instantaneous, though planet was shown with appreciable disc. At distance of about Moon's breadth, Uranus seemed to be of same color as Moon when eye has become accustomed to her glare, but as the planet approached, his disc took on a greenish tinge which deepened until occultation; same tint was seen on emergence at 1h 10m A. M. Tint faded, until 2 o'clock, normal color was restored. Observation made with ten and one-quarter inch With-Browning reflector, power of 144, and Barlow lens. Planet picked up with Kelner eye-piece, power, 60; all powers showed disc. G. E. LUMSDEN.

At the Seagraves Observatory the planet was well seen even in contact with the Moon's bright limb near the emersion. The time of emersion is very uncertain as light clouds covered the Moon at that time.

IMMERSION.

	h	m	s
First contact	*12	5	7.5
Second contact	12	5	11.0

EMERSION.

	h	m	s
Mean of both contacts	13	32	21

F. E. SEAGRAVES.

Proceedings of Harverford College Observatory, 1891.—This volume contains an Investigation of the Parallax of the double star δ Herculis = Σ 3127, the Results of Double Star measures, Observations of Comet Wolf, made during 1891, and Sun-spot observations from April 1890 to Dec. 31, 1891. The first mentioned work is by the Director of the observatory, F. P. Leavenworth, and depends upon micrometrical measures of position angle and distance of the companion from the principal star on 45 nights from June 20, 1889, to Nov. 30, 1891. Mr. Leavenworth has taken great pains to determine the effect of personal equation depending upon the position of the eyes relative to the line joining the stars and the angle from the meridian. The measures of position angle were taken with the eyes in three different positions, viz.: normal, that is perpendicular to the line joining the stars, parallel to the same, and horizontal. The position angle for 1891.0 was approximately 187° and the distance 16″. The results indicate that the personal equation varies considerably both with the position of the eyes and with the hour angle and that, in this case, the measures with the eyes normal are the most accurate. The final value obtained for the parallax of δ Herculis is $\pi = + 0.050'' \pm 0.014''$. H. C. W.

Annual Report of the Observatory of Paris.—The report of the Director, Admira Mouchez, as usual indicates a large amount of work being done at the Observatory. We notice that the number of meridian circle observations for the year 1891, by nine observers, foots up to 19,458. Messrs. Loewy and Puiseux have been engaged a large part of the time in the adjustment and study of the instrumental constants of the new equatorial *coude*. The Messrs. Henry began in September the regular work of charting by photography their assigned zone of the sky, and obtained during the year 133 plates. M. Deslandres has been actively at work in the new department of the Observatory devoted to spectroscopy and has achieved marked success in photographing the chromosphere and prominences of the Sun. Considerable space in the report is given to the meeting of the International Committee on the Photographic Chart of the sky, which was held at Paris in March and April of last year. H. C. W.

---

* Very uncertain by several seconds.

The Opposition of Mars in 1892.—A circular prepared by Professor Eastman of the U. S. Naval Observatory contains the following information: The determination of the solar parallax by means of meridian observations of Mars at opposition was attempted in 1862 and again in 1877. The results obtained in those years have been generally considered by astronomers as numerically too large.

The opposition of Mars, early in August, 1892, will afford another opportunity for employing the method used in 1862 and 1877. The observations and results obtained in 1877 indicated the probability of a systematic error in the observations of Mars, or of the comparison stars, or perhaps of both. It is believed that a modification of the usual method of observing would eliminate, at least, one probable source of systematic error in observing. For this reason, and for the purpose of testing the reality of the apparent coincidence of the values of the parallax obtained in 1877, and by Mr. Stone in 1862, it is earnestly hoped that all observatories having the necessary equipment, and especially all those in the southern hemisphere, will cordially coöperate in the proposed observations of Mars and the comparison stars according to the following program:

METHOD OF OBSERVING.

1. It is essential that all the observatories in the southern hemisphere that are provided with meridian circles of more than 4.5 inches aperture, and at least an equal number of northern observatories, should participate in the observations.

2. Each meridian circle used in the observations should be provided with a small reversing prism placed in a short cap, or cell, fitted to slide over the outer end of the eye-piece. The prism should be mounted on the end of a lever pivoted at one side of the cell, with the longer end of the lever projecting from the side of the cell about half an inch. With this adjustment of the lever, the prism can be quickly placed at will in the emergent pencil of rays before it reaches the eye, and the image of the object reversed. As soon as the bisection is made a slight pressure on the lever throws the prism out of the line of sight. Half of the bisections of Mars and of each star should be made each night in the ordinary way, and half when the object is viewed through the prism. It must be borne in mind that the use of the prism is absolutely essential to the success of the work.

3. In order to eliminate all errors depending on the positions of the comparison stars, every observer should, in every instance, observe the stars selected for the given night, and in no case depart from this rule.

4. The observations should begin on June 20, and continue on every favorable night until September 23.

5. One bisection, and two, if possible, should be made on each side of the center of the field. No observations of right ascension, except one transit over the central thread, should be attempted unless a chronograph is used.

6. The method used in 1877, for obtaining the position of the center of Mars, is so well adapted to secure the desired result that it is adopted, with the modifications described in paragraph 2 of this paper, for the work of 1892. The method is as follows: Two threads of equal size are inserted in the movable declination system of the field of the telescope, the distance between them being about 3″ or 4″ less than the minimum diameter of Mars during the proposed period of observation.* This distance will be about 16″ for the opposition of 1892. The observation consists in moving these threads until the two small segments of the planet, outside of the threads, are seen to be exactly equal. If the thread nearest the micrometer head be disignated as thread *a* and the other as thread *b*, then the comparison stars should be observed by bisecting the *first*, *foruth*, *fifth*, and *eighth* stars w[illegible]ad *a*, and *second*, *third*, *sixth*, *seventh* [illegible]

stars with thread *b*. This order should be reversed on alternate nights; but in all cases the thread used in the observation should be carefully recorded for each star.

7. The inclination of the threads used should be carefully determined during the progress of the work.

8. The division errors of the circles should be invested, at least in the vicinity of those divisions used in the observations.

9. Whenever the circle microscope threads are moved more than half the distance between the adjacent divisions they should be read on each division.

10. In making the bisections the telescope micrometer thread should be moved in all cases towards the spring against which it acts.

11. The periodic errors of all the micrometer screws should be investigated.

12. It is desirable that an ocular of a power of 150, at least, be used on all the smaller instruments, the larger ones using a power of from 150 to 200.

THE OBSERVING LIST.

The comparison stars have been so selected that the transit of four in each group takes place *before* that of the planet and four *afterward*, and, also so that the mean declination of the group is nearly the same as the mean declination of Mars for the time each group of eight stars is used.

The positions of the stars in the following list are the approximate places for 1892.0; and the positions of Mars are given for the time of transit at Washington.

The time is divided into three periods and the positions of Mars are given for the beginning and end of each period, and also for those days when the maximum and minimum right ascensions occur in each period.

OBSERVING LIST.

OBJECT.	Mag.	α			δ	
		h	m	s	°	
From June 20 to July 26.						
O. Arg. S. 20970	7.0	20	50	38	−22	25.1
η Capricorni	5.0	20	58	15	20	16.8
27 Capricorni	6.5	21	3	23	20	59.2
ϕ Capricorni	5.5	21	9	30	21	5.9
Mars, June 20		21	19	32	20	6.8
Mars, July 6		21	25	41	20	51.7
Mars, July 26		21	15	29	22	49.9
Lacaille, 8851	6.0	21	29	5	23	56.2
41 Capricorni	5.8	21	35	51	23	45.0
D. M. −20°, 6923	7.5	21	41	42	20	4.3
Lalande, 42700	7.2	21	49	37	21	38.8
From July 27 to August 10.						
Lacaille, 8463	6.2	20	23	11	−22	45.1
Lacaille, 8506	7.0	20	31	41	24	36.2
17 Capricorni	5.9	20	39	54	21	54.3
Lacaille, 8612	7.0	20	46	42	24	11.2
Mars, July 27		21	14	32	22	56.2
Mars, Aug. 10		20	59	41	24	9.0
Lacaille, 8813	6.0	21	19	36	24	17.2
Lacaille, 8832	7.8	21	24	12	25	40.0
Lacaille, 8851	6.0	21	29	5	23	56.2
O. Arg. S., 21562	7.8	21	35	24	22	25.3
From August 11 to September 23.						
O. Arg. S., 20429	7.0	20	15	6	−23	49.1
Lacaille, 8463	6.2	20	23	11	22	45.1
Lacaille, 8506	7.0	20	31	41	24	36.2
17 Capricorni	5.9	20	39	54	21	54.3
Mars, August 11		20	58	38	24	12.5
Mars, September 4		20	44	19	24	3.0
Mars, September 25		20	53	57	22	6.7
Lacaille, 8734	7.0	21	7	1	25	17.2
Lalande, 41404	7.5	21	14	32	22	50.7
ζ Capricorni	4.0	21	20	30	22	52.8
37 Capricorni	6.2	21	28	47	−20	34.0

U. S. NAVAL OBSERVATORY, April 29, 1892.

BOOK NOTICES.

An Elementary Treatise on the Differential Calculus with Applications and Numerous Examples. By Joseph Edwards, M. A., Formerly Fellow of Sidney Sussex College, Cambridge, England. Second Edition, Revised and Enlarged. Publishers, Messrs. McMillan & Co., London and New York, 1892, pp. 521. Price $3.50.

Not having examined the previous edition of this book we are only able, in a general way, to indicate the changes made in the revision before us. The author claims that it is considerably enlarged, that the chapters have been added on maxima and mimima of several independent variables, on elimination; on Lagrange's and Laplace's theorems; on changing the independent varible, one chapter giving a short account of the principal properties of the best known curves which may be convenient for reference. And many sets of easy examples especially illustrative of theorems and methods proved or explained in the immediately preceding book-work.

The author uses mainly the method of limits and has prepared the revision with care, extending the scope of the book as originally written to meet the requirements of the best teachers who claim that the standard of work in the Calculus should be materially raised.

The first two chapters are devoted to definitions and fundamental propositions, the third gives the standard forms, and then follow the topics of successive differentiation, expansian, partial differentiation, tangents and normals, asymptotes, singular points, curvatures, envelopes, curve tracing, some well-known curves.

The final chapters on application treat of undetermined forms, maxima and minima with one or two variables, elimination, expansions continued, and the change of the independent variable.

The matter and the plan of the text seem to be very good, and the publishers have done their part neatly and well.

Logarithmic and other Mathematical Tables by William J. Hussey, Assistant Professor of Astronomy in the University of Michigan. Second Edition. Ann Arbor, Michigan. The Register Publishing Co., 1892, pp. 148.

This is a book of five place tables and it is very conveniently arranged. The first is a table of common logarithms from 1 to 1000 with auxiliaries for sine and tangent in seconds of arc, the second is for addition and subtraction of natural numbers, and the third and fourth are for trigonometric functions, the fifth gives the natural trigonometric functions, sixth squares, cubes, square roots and cube roots from 1 to 1020. The figures of the tables are old style, with an easy, clear face, and the page is conveniently divided by heavy and light rule, so that the computer can instantly find what he wants. If the tables are accurate (we have no reason to believe they are not), this book will prove to be a popular one. The three pages of astronomical and mathematical constants at its end contain very useful matter.

An Elementary Course in Theory of Equations By C. H. Chapman, Ph. D., Associate in Mathematics in Johns Hopkins University. Messrs John Wiley & Sons, Publishers, 53 East Tenth St., New York, 1892. 12 mo. cloth pp. 90. Price $1.50.

This small book interests us at sight. In ninety pages the author has brought together the principles of Determinants and the Theory of Equations in such a way as to suppose only, on the part of the student, a good knowledge of algebra and some acquaintance with trigonometry and calculus, and is therefore suitable for a college text-book or for private study. We are sure he is right in saying that a knowledge of Determinants and the Theory of Equations is necessary to those beginning the study of the modern higher mathematics, and it is also true that most texts on these subjects are too extended and exhaustive for the College student. It has been the aim of this author to introduce only such parts of the themes as are most profitable for actual practice in the mathematical investigation. The first twenty pages treat of Determinants in elemental way, furnishing a variety of examples to illustrate the principles and the operations. The second part of the book treats of algebraic equations and embraces forty pages, and the third part is devoted to the computation of the real roots of numerical equations.

It will be an advantage to the student to be somewhat acquainted with the elementary processes of Determinants to read the first part of this little book easily. If not so acquainted, he may find it so condensed in statement and limited in illustration, that progress will be slow.

A Hand-Book of Practical Astronomy for University Students and Engineers. By W. W. Campbell, formerly Instructor of Astronomy in the University of Michigan; Astronomer in the Lick Observatory. The Register Publishing Company, Ann Arbor, Michigan, 1891. pp. 166.

The fact that the larger treatises on practical astronomy can not be used satisfactorily with undergraduate students is the reason that the author has prepared another new book better adapted to the wants of the considerable number of students in colleges and universities who are now turning their attention to Astronomy more generally than heretofore. This book is the outgrowth of a system of instruction in the form of lecture notes to large classes in practical Astronomy in use at the university of Michigan.

The order of topics is the same as that found usually in handbooks of this kind. The twelve chapters treat respectively of the following subjects:—The celestial sphere, time, transformation of cöordinates, correction of observations, precession, nutation, etc., angle and time measurement, the sextant, the transit instrument, the zenith telescope, astronomical azimuth, the surveyor's transit, the equatorial and an appendix giving hints on computing, combination and comparison of observations, list of objects for the telescope, refraction tables and reductions to the meridian and elongation.

In presenting these topics the formulæ are given with references usually to Chauvenet's trigonometry. They are briefly explained, illustrated by examples in which the form of work and solution are made prominent. Many of the figures, in illustration of the topics are new and seem to us well chosen. If the engraver had done his work better, in some instances, it would have materially added to the good appearance of the page. This text seems to be well considered in detail, and we think it well adapted to the place for which it is prepared.

PUBLISHER'S NOTICES.

The subscription price to ASTRONOMY AND ASTRO-PHYSICS in the United States and Canada is $4.00 per year, in advance. For foreign countries it is $4.40 per year which is the uniform price. Messrs. Wesley & Son, 28 Essex Street, Strand, London, are authorized to receive subscriptions. Payment should be made in postal notes or orders or bank drafts. Personal checks for subscribers in the United States may be used.

Currency should *always* be sent by registered letter.

Foreign post-office orders should be drawn on the post-office in St. Paul until July 1, 1892; after that date, on the office in Northfield, Minnesota, U. S. A.

All communications pertaining to Astro-Physics or kindred branches of Physics should be sent to George E. Hale, Kenwood Astro-Physical Observatory, Chicago, Ill.

All matter or correspondence relating to General Astronomy, remittances, subscriptions and advertising should be sent to Wm. W. Payne, Publisher of ASTRONOMY AND ASTRO-PHYSICS, Goodsell Observatory of Carleton College, Northfield, Minn.

Manuscript for publication should be written on one side of the paper only, and *special care should be taken to write proper names and all foreign names plainly*. All drawings for publication should be *smoothly* and *carefully* made, in *India ink* with lettering well done, because such figures are copied exactly by the process of engraving now used. If drawings are made about double the size intended for the printed page, better effect will be secured in enrgaving than if the copy is less in size. As a rule the publishers have had to re-draw the figures sent during the last year at considerable expense. We hope to avoid this in the future. It is requested that manuscript in French or German be type-written. If requested by the authors when articles are sent for publication, *twenty-five* reprint copies, in covers, will be furnished free of charge. A greater number of reprints of articles can be had if desired, at reasonable rates.

Rates for advertising and rates to news agents can be had on application to to the publisher of this magazine.

Astronomy and Astro-Physics.

NEW SERIES No. 7. AUGUST, 1892. WHOLE No. 107.

GENERAL ASTRONOMY.

COLORS EXHIBITED BY THE PLANET MARS.[*]

WILLIAM H. PICKERING.

In my former paper upon this subject,[†] attention was called to the important effect of our own atmosphere in misleading our judgment as to the true colors exhibited by the heavenly bodies. A good illustration of this effect may be obtained from a mountain summit upon a slightly cloudy day. The distant greens of the landscape, which are by no means as brilliant as when viewed close at hand, are at once changed to grays either by the passing over them of a cloud shadow, or by the passing of a very thin mist between them and the eye. In the former case they become darker, and in the latter lighter, but in either case the greenish tint entirely disappears.

The sudden changes of color exhibited by some of the smaller areas upon the planet Mars are sometimes almost startling. A recent view was obtained shortly before sunrise, when the snowy region about the south pole appeared of a most brilliant green, quite equalling in color the rather narrow green band situated just to the north of it. Later as the Sun came up, the color of the snow changed to bright yellow, the rest of the disc changing in the mean time to orange. Later the seeing improved, several of the canals became visible, and the snow became as colorless as that upon our surrounding mountains. The two former effects were probably due to bad seeing, the fluctuations of our own atmosphere superposing the colors of the surrounding regions upon the snow. We have laid it down as a rule never to rely greatly upon our color observations unless the snow caps of the planet appear perfectly colorless, and the canal system is well defined. These conditions we find always combined with the best seeing. For these delicate color observations it will therefore be seen, that not only do we require a telescope of the very first quality, but also the very best obtainable atmospheric conditions.

---

[*] Communicated by the author.

[†] See page 449, No. 6.

In studying the smaller dark regions, such as the northwestern part of the Syrtis major, great differences of color have been noted from night to night, and I have colored sketches in my possession, taken at different times, in which it is represented as grey, as green, as blue, as brown and even as violet. The latter color was so extraordinary that I endeavored to make that portion of the planet appear to my eye of some other color, but it was impossible, and no other color but violet lake could be made to match it. This color upon the planet has only been seen by me upon one occasion since. The brown color above noted was undoubtedly due to bad seeing. At one time I felt convinced that the real color of the darkest spots upon the planet was a deep blue, and this may in reality be the case, but of late, under the most favorable circumstances, they have appeared to me of an absolutely colorless dark grey. Probably this point can be settled at the present opposition.

Before describing the colors of particular regions more at length, it may be well to give a description of the general characteristics of different longitudes, as observed during the opposition of 1890. For this purpose we may divide the surface of the planet into six sections, each sixty degrees of longitude in breadth, the first leaving the 0° meridian central. The times of transit of the 0° meridian of the planet may be readily computed, but the amateur will find those given in convenient shape in the excellent ephemerides published by Mr. Marth in the *Monthly Notices*. The only pity is that these ephemerides cannot appear about six months earlier in order to be of the most use to astronomers outside of the British Islands.

The most striking marking upon the planet, and that most readily seen with a small telescope, is the Syrtis Major, or Y mark. This is nearly central in the sixth position of the planet, with the 300° meridian in the middle of the disc. Owing to the period of rotation of Mars being 37 minutes longer than that of the Earth, in about six nights Mars will be found at the same hour in the fifth position with the 240° meridian central. This region in 1890 was interesting as containing the most conspicuous canals visible upon the planet, excepting the large one which terminates the Syrtis Major upon the north. At this opposition these canals will all be too far north to be well seen. The fourth and third regions of the planet were both extremely uninteresting as showing very little detail of consequence. The second position with the 60° meridian central was interesting as showing the great southern ocean, which is nearly as conspicuous as the

Syrtis Major itself. In the first position with the 0° meridian central the ocean is disappearing and the Syrtis Major coming into view.

We now come to a curious feature of the observations, namely, the actual changes in color which, eliminating all probable sources of error, the surface of the planet really seems to undergo. When the Syrtis Major is central, before the autumnal equinox of the northern hemisphere, the region to the east is seen to be distinctly more greenish than that to the west. As the season wears on the difference in color becomes less marked, and the greenish hue is confined more closely to the region immediately bordering the Syrtis on the east. In most of my drawings made in 1890 the two arms of the Syrtis are shown of equal breadth. This appears to be the case also upon Green's map published in Chambers' Astronomy, although this point is not well shown by him. At present there is no doubt but that the eastern arm is much the wider of the two, perhaps twice as wide. Early in 1890 the entire region enclosed between the arms of the Syrtis Major, as far as the snow cap, was of a brilliant green color. On June 27 however, or eleven days before the vernal equinox of the southern hemisphere, a yellow spot appeared at the extreme northern point of the triangular area. As the season advanced this yellow spot increased in area, till it covered the whole region as far south as could be seen. This year when first observed, this area was entirely green, but on May 9, or seventeen days before the vernal equinox, the yellow or perhaps reddish spot appeared in the same place, and it will be interesting to determine if, as the season advances, this color again progress towards the pole. Changes to the east of the Syrtis Major have also been noticed by Schiaparelli. These he ascribes to extensive floods. On June 8, 1890, thirty days before the autumnal equinox in the northern hemisphere, there was a large greenish area visible in longitude 180°, latitude 30° north. By July 16, or eight days after the equinox, this spot could not be found, the whole region appearing of a yellow tint. In longitude 10°, latitude 40° north, is a large crescent-shaped area. In June and July, 1890, it was well seen and appeared quite as dark as the great southern ocean. This was noted upon a number of occasions. It was however painted green, and the ocean to the south of it blue, the difference in color on one evening being very clear, as seen by my assistant, Mr. A. E. Douglass, and myself. On March 22 of the present year the crescent was well shown, but was markedly fainter than the ocean, which was again [illegible] of being blue, but the color could not be satisfactorily confirmed. This crescent is now too far north, owing to the motion of the planet, to be satisfactorily studied.

While these indications of change of color upon the planet are too few and isolated at present to enable us to form a satisfactory explanation of their causes, they still hold out a promise that should these observations be carefully repeated at future oppositions, under suitable conditions, we may in time be able to deduce the laws affecting them, and perhaps even predict their changes in advance. Too much stress however cannot be laid on the danger of optical illusion in this matter. It is generally considered that a very good instrument, and some practice is required, before an observer can certainly see the canals even, but in order that satisfactory results in this branch of the research may be achieved the more important canals must be seen with distinctness, and the snow caps, if present, must appear perfectly colorless.

AREQUIPA, Peru, May 13, 1892.

THE DOUBLE STAR, π^2 URSÆ MINORIS (Σ 1989.)*

S. W. BURNHAM.

But few measures have been made of this pair, although it is in a position to be observed at all observatories in the northern hemisphere on every night of the year. It is always moderately difficult with ordinary refractors, and the distance is still slowly decreasing. It is certainly a binary, but the period must be very long, as the angular motion in sixty years has been but about twenty degrees. With so small an arc it would of course be useless to attempt to obtain even an approximate period. It should be measured more frequently than heretofore to furnish the requisite data. It is probable that for some time to come the larger refractors will be necessary for this work.

The following are all the measures since the discovery of this pair by Struve:

	°	″		
1832.68	24.1	0.71	Σ	3n
1836.76	23.9	0.53	Σ	3n
1840.95	28.1	0.70	OΣ	3n
1841.46	23.0	0.85	Ma	1n
1858.59	21.1	0.60	Se	2n
1881.43	14.9	0.49	β	4n
1884.20	2.5	0.33	En	6n
1892.30	3.6	0.24	β	3n

---

* Communicated by the author.

The place of this star (1880) is:

R. A. $15^h\ 46^m\ 13^s$
Decl. $+80°\ 23'$

The magnitudes of the components are 7.1 and 8.1 in Struve. It seems to have been overlooked in the Harvard photometric Catalogue.

THE PROPER MOTION OF Σ 1603.*

S. W. BURNHAM.

This wide pair of bright stars has been known since 1783 when it was observed by Sir William Herschel. It was subsequently incorporated in Struve's great catalogue, and has been frequently measured by later observers. From these observations it appears that the components are relatively fixed. Stumpe in his catalogue of proper motions (*A. N.* 3000) assigns different proper motions to the components. This is probably based upon meridian observations, but it does not appear why data of this kind should be used when the micrometrical observations, so much superior to anything which could be derived from meridian circle work, are available for a comparison of the motion of the companion with that of the primary. Of course these measures give only the relative movement, and as no third star has been connected by observations with micrometer, the meridian position must be used to give the general drift of the system. The proper motion of A is given as 0″.189 in the direction of 259°.7, and of B, 0″.220 in 257°.9. This would imply a system similar to that of 61 Cygni. The direct measures, however, do not justify this conclusion.

The following is a complete list of all the measures down to the present time, including my recent observations at Mt. Hamilton:

	°	″		
1783.26		14.78	Herschel I	1n
1783.34	79.8	19.25	Herschel I	1n
1830.	81.5	20. ±	Herschel II	1n
1830.26	80.6	23.01	Herschel II	1n
1831.00	81.1	22.80	Herschel II	1n
1832.18	80.6	22.42	Struve	5n
1846.43	81.5	22.49	O. Struve	4n
1851.29	81.5	22.47	Dawes	1n
1858.28	81.5	22.26	Dembowski	1n
1863.25	78.7	22.94	Radcliffe	1n
1866.39	81.6	22.24	Dembowski	3n
1877.38	81.4	22.45	Hall	6n
1880.82	80.5	22.23	Bigourdan	1n
1883.20	82.0	22.33	Engelmann	5n
1892.37	81.7	22.30	Burnham	4n

---

* Communicated by the autho

The magnitudes according to Struve are 6.9 and 7.3, and it is, therefore, one of the easiest pairs in the sky to measure. It is evident that all of the measures prior to Struve, by the Herschels, and that at a later date made at the Radcliffe Observatory, are affected by large errors, and cannot be used at all in reference to relative motion. When the other measures are taken together it is absolutely certain that these stars have remained fixed with reference to each other from the first accurate positions by Struve in 1832 down to the present time, and that whatever the real proper motion may be, it is the same for each star. There is no need of further measures of this pair for many years.

NOTE ON THE HISTORY OF THE COLOR OF SIRIUS.*

T. J. J. SEE, BERLIN.

CONCLUDING NOTE.

Since my paper was finished in January last, I have had the benefit of the friendly criticism of several astronomers, and have ascertained the views of a number of others respecting the colors of the stars. Suffice it to say that as the result of this experience, I am the more fully convinced that if we are to believe the ancients in anything, we ought to believe them respecting the color of Sirius. For we must adhere to the evidence, unless there is reason to suspect its trustworthiness; and this being true, we could more logically conclude that Antares was white in antiquity than that Sirius was. All the different bits of evidence cited appear to be independent, for when any evidence of copying has been found, it has been pointed out; moreover, the research is a *comparative* one, since attention was given not only to what the authors say of Sirius but also what they say of other stars, and when the words seem to be loosely used attention is called to the uncertain value of the evidence. The summary on page 384 gives the authors in something like the order of their importance and probable trustworthiness; hence it will be observed that the poets are placed last on the list. Since the poets agree with the astronomers and philosophers it does not seem that they ought to be excluded; for if they had declared that Sirius was white, many would regard their testimony of great value and perhaps nearer the truth than that of "professional" observers. Therefore the present agreement ought to be

---

* Communicated by the author.

regarded as strongly confirmatory of the records left by Ptolemy, Geminus, Seneca, Pliny, Cicero, Aratus, Germanicus, Horace and Festus.

To those who ask whether the ancients did not observe the stars near the horizon, the answer is clear:—This was indeed true of some of the ancients, such as the (ancient) Egyptian priests, who wished to determine the place of the Sun among the stars; but *not true* of those who studied the constellations, charted the heavens, formed star-catalogues and traced the motions of the planets and Moon among the stars. Ptolemy and Geminus were professional astronomers, and Ptolemy has himself recorded in the Almagest that "we make our observations on the meridian of Alexandria." Among the ancient astronomers after the time of Timocharis (300 B. C.) the custom of observing on the meridian seems to have been in common use; we know positively that it was followed by Hipparchus; and Geminus, his contemporary and associate, must have followed the same method.

Moreover, we know perfectly well on general principles that the ancients, in studying the constellations (which they knew far better than the average even of intelligent moderns, because they lived more under the open sky and because their ideas of the gods naturally led them to be continually contemplating the stars) would, in the nature of things, come to know the appearance of the stars not when they were on the horizon but when high in the heavens. The ancients do not call Vega and Jupiter red, neither have I seen any case in which they are called fiery. Cleomedes says* Aldebaran and Antares are of the same size and color as Mars; moreover the very name Antares means "rival of Mars," and the body is spoken of by a number of writers as a "burning star" (ardenti astro).

Mars was given the name *πυρόεις*, and connected with the god of war, because its color suggested blood. In the same way (in the opinion of the writer, at least), the Dog Star was named *Sirius* because its deep red color suggested "burning."[†] Venus was named from her beauty, and Jupiter (originally the god of the clear sky) from his clear, brilliant light ("salutary influence") and stately motion; Saturn from his pallid color and very slow motion among the stars, and Mercury because of his swiftness and appearance at dusk. Hyginus (reflecting, no doubt, the observation of some astrologer), says Saturn and

---

* Discovered since writing my paper on Sirius.

[†] Aratus says the star "most fiercely burns" and mortals call him Sirius."

Betelgeux, Jupiter and Vega, Mars, and fire are of the same color. Pliny assigns correct colors to all the planets, and distinguishes between the color of the Sun when rising and when high in the heavens; calls Sirius "burning" and says Canopus is "huge and bright." Seneca says Sirius was redder than Mars, and that Jupiter has no color at all. Cicero says the Dog Star "shines fervidly with a ruddy light;" and, speaking intelligently of the planets, declares that Mars is "ruddy and terrible to the earth." Germanicus says Sirius is "hurled in a ruddy course through the sky," and alludes to Antares as burning in the breast of the Scorpion; Manillius says the "Dog rages in its fire" and speaks of the "shining Scorpion with a burning star." Hesiod says Sirius "burns the face and knees," and Homer says it is an "evil omen, bringing much fever (something fiery) to wretched mortals." Euripides alludes to Sirius as sending "flames of fire" from the heavens, and Ap. Rhodius speaks of the star as "burning the Islands of Minos" (meaning some of the Cyclades). Aratus calls the Dog Star "colored" and Horace refers to the "red Dog," while Virgil speaks of both Sirius and Antares as "burning." At the Floralia Ovid tells us dogs were offered up on account of the Dog in the sky, and Festus says they were of a ruddy, nearly red, color, and sacrificed to placate the (angry) Dog Star in order that the blooming fruits might be brought to maturity. Columella compares roses to Tyrian purple, the rising Sun, ruddy Mars, and "Sirius fire;" while Eratosthenes says Venus and Vega are white, and that Mars is of the "nature of fire." Geminus says all stars have the same influence on the earth, and (indirectly) that the great multitude are "clear" while Sirius is "fiery." Lastly, Ptolemy says Aldebaran, Arcturus, Betelgeux, Pollux, Antares and Sirius are "fiery red." Do these facts indicate that the ancients were ignorant, careless, or color-blind, or that they observed the heavenly bodies on the horizon? There is evidently not the least logical ground for such a supposition, and those who adhere to the facts and follow the legitimate principles of historical research will reach the correct conclusion respecting the ancient color of Sirius.

ROYAL OBSERVATORY, Berlin, May 24th, 1892.

NOTE.—Some corrections and changes by the author will be found under Notes and News.—[ED.]

ON A PRETENDED EARLY DISCOVERY OF A SATELLITE OF MARS.

RALPH COPELAND, PH.D.

In the Crawford Library of the Edinburgh Royal Observatory is a quarto pamphlet of ten leaves, the complete title of which is: "Eberhard Christian Kindermanns, Königl. Pohl. und Churfürstl. Sächszl. Hof-*Math.* und *Astronomi*, Astronomishe Beschreibung und Nachricht von dem Cometen 1746. Und denen noch kommenden, welche in denen innen besagten Jahren erscheinen werden.—Dreszden, zu finden bey Gottlob Christian Hilschern, Hof-Buchhändler, 1746." Although Kindermann* thus held the post of astronomer to the King of Poland, who was at the same time Electoral-Prince of Saxony, the few observations he has placed on record have hitherto proved of very little value. Doubts, indeed, have at various times been expressed as to their general trustworthiness; nor is it quite certain that the comet of which the little book under consideration professes to treat ever really existed, although Kindermann gives the names of two persons and mentions a third by whom he alleges it to have been seen, as well as by himself. Dr. Hind, however, has suceeded in deriving a rough orbit from the fuller particulars given by Struyck, to whom Kindermann had communicated them. The tract also contains predictions of the return of three several comets, amongst them that of 1661, of which the elements, computed long previously by Halley, resemble those of the comet of 1532. Probably it was this resemblance which led Kindermann to assume their identity with a period of 129 years and a consequent return in 1790, a conjecture which, it is needless to say, was never realized.

These particulars are now of little moment, except in so far as they characterize the writer of the book, the frontispiece of which is sufficiently striking, containing, as it does, a little figure professing to show the orbit of a satellite of *Mars* discovered by the author. The encircling legend runs: "Via Luna (*sic*) Martis entdecket vom Autore den 10. Iul: 1744." On the face of the planet are various distinct markings, amongst which it is easy to recognize the long "dumb-bell," drawn by Divini and Cassini, and figured in the first volume of the *Philosophical Transactions*. The satellite is only removed about 2½ radii of *Mars* from the

---

* The Pulkowa Library contains three of his books, including the one described above.

centre of the planet. The satellite is nearly four-tenths of the diameter of the primary, and both bodies are liberally provided with atmospheres.

It may be mentioned that *Gulliver's Travels* were given to the world in 1726-7, while Voltaire's *Micromegas* seems to have been published about 1752. The statements they contain about the moons of *Mars* are widely known through Professor Hall's memoir. Kindermann's "discovery" is thus intermediate, in point of date, between the felicitous conceptions of the great satirists.—*Monthly Notices, May, 1892.*

PHOTOGRAPHIC SEARCH FOR A PLANET BEYOND THE ORBIT OF NEPTUNE.

ISAAC ROBERTS, F.R.S.

The hypothesis that one or more planets exist beyond the orbit of *Neptune* has been long entertained by astronomers, and Professor Forbes, in a remarkable paper on "Comets and ultra-Neptunian Planets," which he read before the Royal Society of Edinburgh at the beginning of the year 1880, predicted with considerable confidence that one or two such planets exist, and in the paper referred to he gave very fully his reasons.

The prediction was based upon the recorded positions of the aphelia of a number of comets. He said,* "That there could be no longer a doubt but that two planets revolve in orbits external to that of *Neptune*, one about 100 times, the other about 300 times the distance of the Earth from the Sun."

In 1887, November, I wrote to Professor Forbes to ask him if he had further considered the hypothesis concerning the supposed planets, and that I was prepared to make a search for them by photographic methods. In his reply he stated that the present position of one of the hypothetical planets is $11^h\ 48^m$ R. A. and 3° N. Declination, and he believed that a range of 5° each way in R. A. and of 2° or 3° in Declination ought to find the planet if it is there. The motion of the planet he computed at one degree in 2.96 years.

I thereupon commenced the search, but soon found that the climate of Maghull was so unfavorable for celestial photographic work of this character that my task was nearly hopeless; but since the removal of my Observatory to Crowborough I re-

---

* *Memoir*, p. 3.

sumed the search under conditions sufficiently favorable to complete the work, which was conducted on the following plan:—

A chart was made of the region indicated by Professor Forbes between R. A. $11^h\ 24^m$ and R. A. $12^h\ 12^m$ with Declination 0° 0′ to 6° 0′ North. This region was covered by eighteen photographic plates, each of more than four square degrees in area, and allowed of sufficient overlap to show a number of the same stars on two or more contiguous plates. Two sets of photo-plates of the region were taken with an interval of not less than seven days between the exposures, which were of ninety minutes duration, and the dual photographs were subsequently compared three times over by superposition, in order to see if any star appeared on one plate which was not on the other, or to see if change in the position of any star had taken place in the interval between the dual exposures. In this way the whole of the plates covering the region were very carefully examined, and it now only remains for me to report that no planet of greater brightness than a star of the 15th magnitude exists on the sky area herein indicated, nor is there on the plates any abnormal appearance to which it is necessary here to draw special attention. It is a region where the stars are not exceptionally numerous, and they are mostly faint. *Monthly Notices, May, 1892.*

CROWBOROUGH HILL, Sussex, 1892, April 12.

PHYSICAL OBSERVATIONS OF MARS.*

DR. TERBY, LOUVAIN, FRANCE.

On the 13th of May, from $8^h\ 7^m$ to $9^h\ 40^m$, I again saw the black thread; my drawings again show the displacement of the satellite polar spot by rotation; I satisfied myself that the companion spot was less brilliant and less white than the polar spot properly so-called; in other words the white light was at its maximum in the larger polar spot, and about which the satellite spot effected its movement of rotation. At $9^h\ 3^m$ the western extremity of the smaller spot was near the central meridian which corresponds to a longitude of 185°.6.

These observations then give us as approximate results: Martian longitude of the western extremity of the satellite polar spot, 185°.6. Martian longitude of the eastern extremity, 215°.3. Mean, or longitude of the middle, 200°.45. Martian

---

* Continued from No. 106, page 480.

longitude of the middle from direct observation, 204°.3 We must not forgot that these data are deduced from our drawings and not from observations made directly to this end. The agreement between the mean of the results obtained for the two extremities of the spot and the result obtained by the drawing for the middle of the supplementary snowy mass is nevertheless very remarkable; and we can attribute to the middle of the satellite spot, as a close approximation, the longitude of about 200°.

On the 18th, I again observed the little companion of the polar spot, always less white and less brilliant than the principal spot. On the 20th of May, it was even visible with the power of 180 diameters.

Whenever Elysium or the Trivium Charontis occupy the eastern half or right of the apparent disk, I have always perceived on the western or left limb, and on the prolongation of Erebus, some points or little white dots more or less brilliant, to the number of three under the most favorable conditions, occupying the vertices of a triangle; these points figure in twelve of my drawings.

These brilliant points have only been seen when they approach the west limb of the disk, and they become more and more visible, more and more white and shining, in proportion as they approach it more, until they end by passing beyond it by irradiation like the polar spot. We have not observed them in the vicinity of the central meridian, nor on the east limb, and I only know how to fix their position in a very approximate manner by the following process: on the 9th of May, from $9^h\ 10^m$ to $9^h\ 29^m$, these brilliant points were found on the extreme limb when the longitude of the central meridian was 225°.5; they could then have an approximate longitude of 135°. Further the prolongation of Erebus crosses this longitude in a Martian latitude of about + 40°. These snowy points are then found in a region near enough to that where M. Schiaperelli, in 1879, proved the existence of a snowy and brilliant prolongation of the polar spot and even an isolated snowy spot which he called Nix Olympica.

We find that in 1888 we have verified at Louvain the existence of the following canals, properly so-called; some canals remain ing doubtful are marked with an interrogation point.

Artusapes, Phison, Typhonius, Orontes, Protonilus, Deuteronilus, Callirhœ, Euphrates (below Lake of Ismenius), Hiddekel and Gehon (traces), Indus, Oxus, Tanais, Jaxartes, Ganges, Nilokeras, Nilus, Ceraunius, Agathodæmon, Nectar, Gigas (?), Phlegethon (?), Acheron (?), Pyriphlegethon (?), Hades, Erebus, Cerberus, Styx, Eunostos, Hyblæus, Antæus, Cyclops (?), Triton, Lethes, Nepenthes, Thoth.

I observed Phison three times; the 29th of April, the first of June, and the second of June. The first time the canal appeared as a large rosy ribbon, very pale, perfectly straight; this observation, though difficult, did not leave the slightest doubt. The second and third time the ribbon appeared divided into two finer parts, perfectly straight and parallel; the difficulty of the observation gave rise to a slight doubt, but nevertheless such was the impression received.

As a proof of the impartiality with which these observations have been made, I will mention here that M. Schiaparelli, by a letter of the 28th of May, informed me of the existence of a very marked doubling in his 18-inch, that of the Euphrates, asking me to verify it. I expended every effort, after that date, to succeed in seeing the doubling of the Euphrates, but the canal itself has totally escaped me, with the exception of a piece of it which I saw under the Lake Ismenius on the 31st of May, and further, I have only identified this last in studying my drawings long afterwards and in beginning the preparation of this memoir.

The results deposited in this memoir are very small if one compares them to those which M. Perrotin has obtained at the Observatory of Nice, by the aid of the mammoth 30-inch telescope, the second instrument of the world, and to those which M. Schiaparelli has himself realized at Milan with his admirable 18-inch, especially in what concerns the doubling of the canals. I have said at the beginning that, in conditions so unfavorable, one could only hope for less still when using a simple 8-inch, however excellent it may be. But these results have an incontestible value in the presence of the incredulity with which certain astronomers still consider the beautiful discoveries of Milan. Who would believe it? In spite of the beautiful drawings of M. Perrotin, one reads still that the discoveries of M. Schiaparelli have not been confirmed by the largest instruments.*

We are then happy to bring our mite to the defense of the truth. Our excellent equatorial, comparable to that with which M. Schiaparelli made his first discoveries, has permitted us to verify the existence of a sufficiently great number of canals, and to get a glimpse of the doubling of one of them, in spite of the combination of deplorable circumstances which annihilated a great part of its power; above all it has caused us to even admire the general exactitude of the chart, to prove, for example, that not a

---

* English Mechanic, Jan. 1889, page 368.

single one of the white and brilliant spots which we have remarked on the limbs of the planet, as all observers have done for a long time, remained inexplicable to one who was provided with this almost infallible guide.

After what we have seen we dare to affirm that henceforth the progress of areography will be in the hands of those alone who, freeing themselves from the shackles of doubt, will resolutely engage in the way traced by the celebrated astronomer of Milan: A new era is begun in the study of Mars by the discovery of canals and of their doubling, and by the micrometric determination of 114 fundamental points of the map, an era succeeding to that which was inaugurated a half century ago by the construction of the first two hemispheres of Mars and by the approximate fixing of fourteen points by Mædler.—*Translated from the French by Roger Sprague, Berkley, Cal.*

THE NEW ENLARGING PHOTOGRAPHIC LENS.*

S. W. BURNHAM.

The proposed new lens by Dallmeyer for making an enlarged picture on the plate has attracted considerable attention. It has been given, somewhat in advance of any practical test of its usefulness, the rather complicated name of "telephotographic lens." Briefly stated it consists in the use of a double concave lens through which the light is passed, after transmission through the usual photographic objective, and distributed over a greater area of the plate, and thus giving an enlarged image, the scale of which will depend upon the relative focal lengths of the two lenses and the distance between them.

In the first place there is nothing new in the proposed device. A great many people who have gone into photographic experiments, the writer among the number have tried, with more or less success to get enlarged pictures of distant objects by photographing with an eye-piece placed between the principal lens and the plate. The most common instruments used in this way have probably been the ordinary lens with an eye-piece of some form, and the ordinary pocket telescope or spy-glass with its correcting eye-piece. The late Dr. H. D. Garrison and the writer tried a good many experiments with instruments of the last named form, but as the pictures were never quite sharp, the matter was aban-

---

* From *The Beacon*, April, 1892.

doned as not worth following up. We did not try, so far as I now remember, the double concave eye-piece. The proposed Dallmeyer lens is simply an objective fitted with a double concave eye-piece; in other words, an opera glass, and nothing else. Doubtless a skillful optician will be able to figure these lenses so that the resulting picture will be some sharper than that which would be made with a field or opera glass. How far any such combination will stand a severe test remains to be seen, but there is nothing new in the idea, and probably nothing new in the attempt to put it in practical shape.

In the second place, anyone who chooses to take a little trouble can at least roughly test the principle for himself at practically no expense at all. There is no reason why such a photographic lens, made in the usual way by manufacturing opticians, should cost much, if any, more than the ordinary rectilinear combination, and especially if a single achromatic can be used, as is probably the case, in place of the more expensive doublet.

I have tried a few experiments in the last day or two with my ordinary Laverne lens, which I have used in the camera for all purposes during the past five or six years. This has a focal length of about 8½ inches. I found among my possessions two double concave lenses, one which was formerly the eye-piece of a cheap opera glass, and the other a lens out of which I made some years ago a finder for my camera. This was before finders of this form were to be had in the market. A measurement of these lenses gave for the respective foci—1.6 and + 2.0 inches. A trial of the first showed that it was inferior to the other, for the reason that its diameter was so small only a small part of the plate was covered, and therefore the other trials were made with the second lens. I send with this a print from a negative made with the Laverne lens in the regular way, and attached to it a print from an enlarged view of a small portion of the other picture. This was made placing the double concave lens at the proper distance behind the other lens for this enlargement. This gives a magnifying power of about seven diameters, and is therefore equivalent in size to a picture made with an ordinary lens of sixty inches focus. This was the maximum enlargement which could be made with the bellows extension of my camera. A greater enlargement probably could have been made without sensibly affecting the sharpness of the picture. The plate in this picture was about nineteen inches from the principal lens.

Of the success of the experiment it is unnecessary to speak, as the reproduced positive will show for itself. As a crude attempt, with no accurate adjustment of the axes of the two lenses, to say nothing of the best relative foci, it is perhaps not unsatisfactory.

Anyone wishing to try his lens in this way can easily do it by getting at any optician's or dealer in lenses a double concave lens of one-half to one-fourth the focal length of that of the other lens to be used with it. This will only cost a dollar or two, and is all the outlay required. It will be better to set the photographic lens forward of its usual place in the front board by nearly its focal length, and use the cone or projecting tube as a support for the concave lens, which should be arranged to slide for a limited distance toward or from the front lens. As will be seen hereafter, a slight change in the position of the former will make a great difference in the scale or magnification of the image.

My friend, Dr. Henry Crew, of the Lick Observatory, who is an authority on all theoretical and practical questions relating to optics, has calculated the formulæ which govern the combination and use of lenses of this character. From these formulæ anyone with very little mathematical training can find for himself what lenses to use, and how they should be combined to produce a given result. This will be clear from the following:

A = focal length of the combination, that is, of a lens which would give a picture on the same scale as the enlarged picture.
F = focal length of the front double or single lens.
f = focal length of the concave lens.
d = distance between the two lenses.

Then,

$$A = \frac{F \times f}{F + f - d}$$

By substituting the known values of F and f, and assuming a value for d, we get at once the focal length of a single lens which would give a picture of the same size as that made by the new combination, and by dividing that quantity by the focal length of the front lens, we have the magnification given by the concave lens at this particular distance from the other. It must be remembered that the focal length of the concave, or negative, lens is a negative or minus quantity, and the resulting value of A must always be a positive or plus quantity. The practical use of the formula will be apparent from the following example, based upon the lenses which I have used in the experiments referred to, where F and f are respectively + 8.5 and — 2 inches. Let the assumed distance between the lenses be 7 inches and we have:

$$A = \frac{(+8.5) \times (-2)}{8.5 - 2 - 7} = \frac{-17}{-0.5} = +34$$

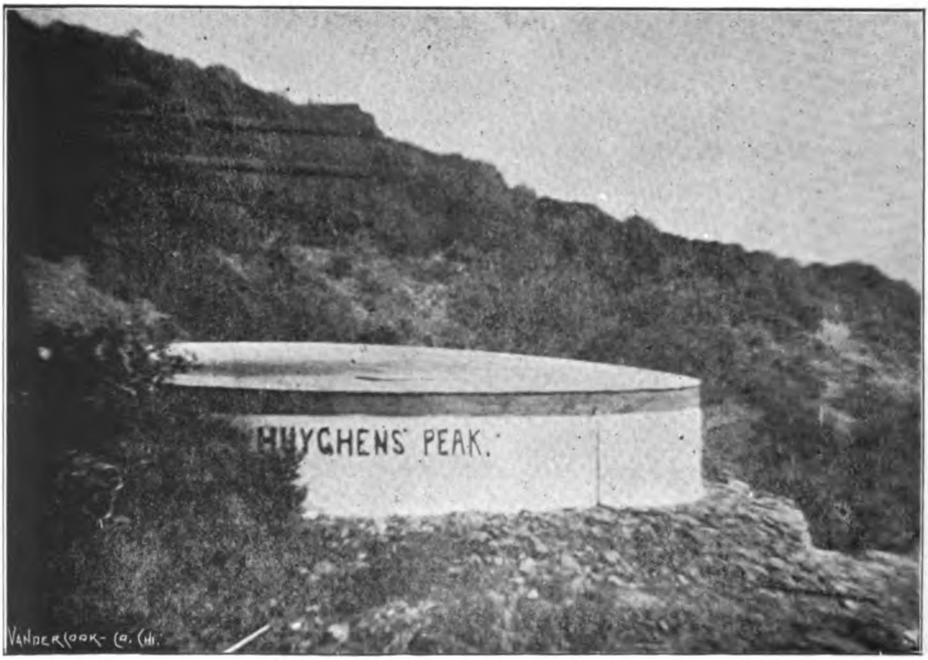
the [illegible] lenses must

[illegible]

rt, the [illegible]
eale theore[illegible]
es focus. I[illegible]
ed, but I am
ven lens be-
[illegible]
ed picture
s conne[illegible]
the front
Y = the

PLATE XX.

Photographed with Ordinary Rectilinear.



Photographed with Added Negative Lens.

ILLUSTRATIONS OF M NHAM'S PAPER.

[illegible] ent that the distance between the [illegible] lenses must [illegible] greater than the difference between the [illegible] focal [illegible] this case more than 6½ inches [illegible] arrangement will be when the separation [illegible] ever may be the relative focal length [illegible] the photographic image [illegible] If the assumed distance between [illegible] the result [illegible] would have [illegible] magnifying power [illegible] In the accompanying [illegible] where the power is seven [illegible] the [illegible] separated about [illegible] It will be seen [illegible] of the concave lens [illegible] in the scale [illegible] also be observed that a [illegible] by reducing the difference [illegible] lenses. For example, if I had used [illegible] focus, instead of two, and placed them [illegible] 36 apart the picture on the ground glass would have [illegible] same scale theoretically, as if a single lens had occupied [illegible] inches focus. In practice, of course, the range [illegible] limited, but I am unable to say how far it could be [illegible] lens before the image would become [illegible] Doubtless the optician, by figuring the [illegible] combination, will be able to [illegible]

Another of the formulæ mentioned [illegible] tion in order to determine the distance [illegible] whether the extension of the camera [illegible] distance from the plate to the rear [illegible]

$$Y = A\left\{\frac{F - f}{F}\right\}$$

Substituting the values of these quantities [illegible] ment referred to, we have,

$$Y = 60\left\{\frac{8.5 - 6.8}{8.5}\right\} = 12 \text{ inches}$$

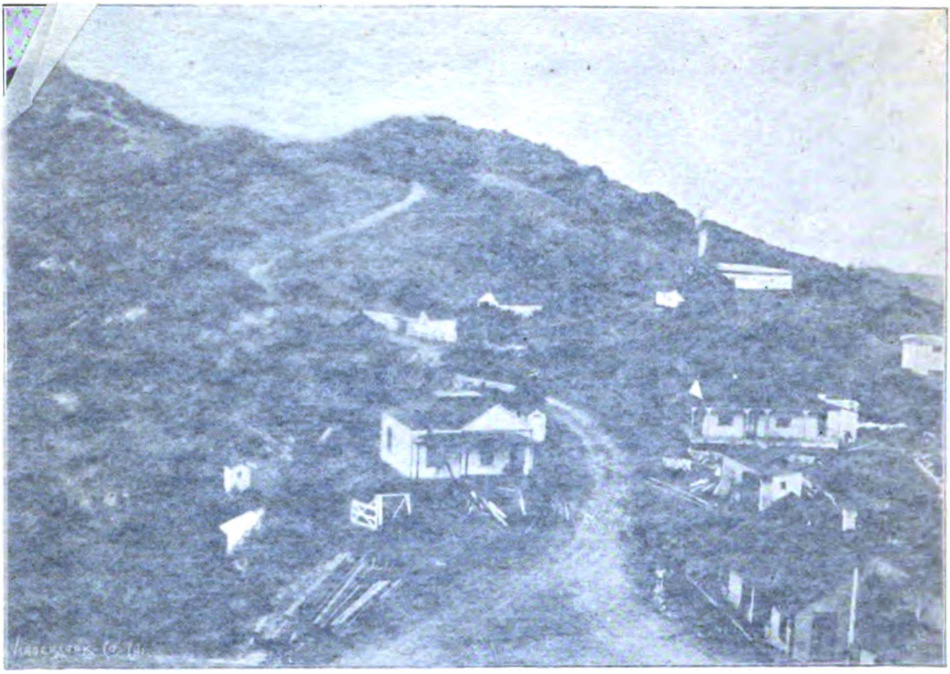
Therefore the concave lens was 12 inches from the [illegible] course, the front lens 6.8 inches farther.

In making these enlarged pictures it is hardly necessary to say that the time of exposure is much increased. [illegible] shown the exposure was about four or five seconds on a slow plate, with the front lens stopped down to $\frac{1}{22}$. Without

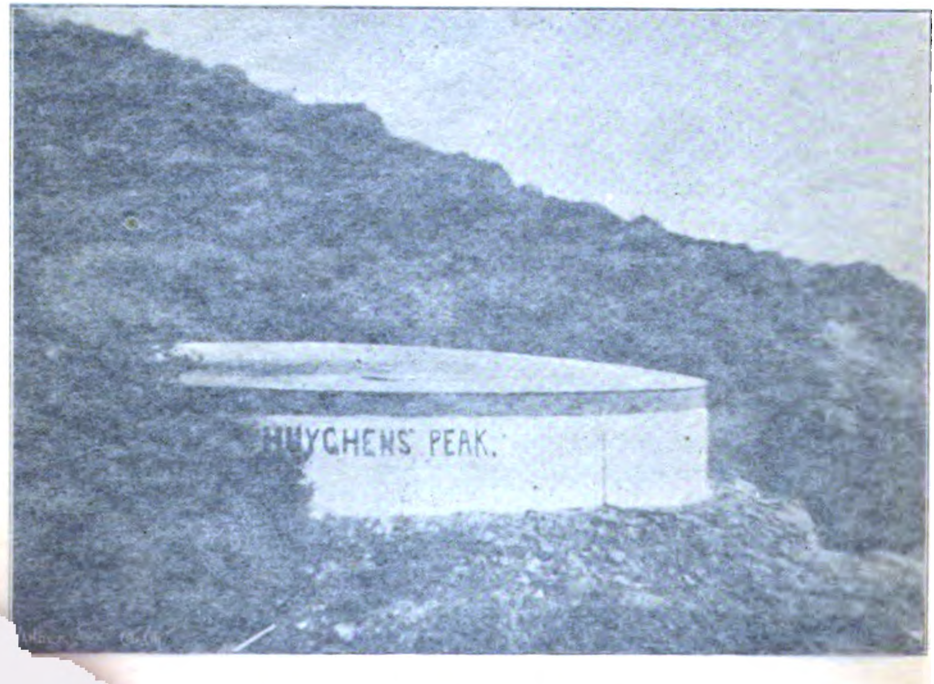
---

* Frontispiece in *The Beacon* [illegible] 1892.

E XX.



Photographed with Ordinary Rectilinear.



Photographed with Added Negative Lens.

ILLUSTRATIONS OF MR. BURNHAM'S PAPER.

ro-Physics, No. 107.

It is evident that the distance between the two lenses must always be greater than the difference between the two focal lengths, or, in this case more than 6½ inches; and that the maximum enlargement will be when the separation is nearest this limit, whatever may be the relative focal lengths of the two lenses. In the above example the photographic image would be magnified four times. If the assumed distance between the lenses had been 6.6 inches, the resulting value would have been 170 inches, giving a magnifying power of twenty. In the accompanying picture,* where the power is seven diameters, the lenses must have been separated about 6.8 inches. It will be seen that shifting the position of the concave lens by only one-tenth of an inch produces a large difference in the scale of the picture on the plate. It will also be observed that a highly magnified image can be obtained by reducing the difference between the focal length and the two lenses. For example, if I had used a concave lens of six inches focus, instead of two, and placed the lenses 2.6 apart, the picture on the ground glass would have been on the same scale theoretically, as if a single lens had been used of 500 inches focus. In practice, of course, the range of power would be limited, but I am unable to say how far it could be carried with any given lens before the image would become too indistinct and blurred. Doubtless the optician, by figuring these lenses with reference to their combination, will be able to produce a sharper magnified picture.

Another of the formulæ mentioned is important in this connection in order to determine the distance of the plate from the front whether the extension of the camera will be sufficient. If Y = the distance from the plate to the rear lens, then,

$$Y = A\left\{\frac{F-d}{F}\right\}$$

Substituting the values of these quantities as used in the experiment referred to, we have,

$$Y = 60\left\{\frac{8.5-6.8}{8.5}\right\} = 12 \text{ inches.}$$

Therefore the concave lens was 12 inches from the plate and, of course, the front lens 6.8 inches farther.

In making these enlarged pictures it is hardly necessary to say that the time of exposure is much increased. In the picture shown the exposure was about four or five seconds on a slow plate, with the front lens stopped down to $\frac{f}{22}$. Without

---

* Frontispiece in *The Beacon* for April, 1892.

the concave lens probably half a second was about the time for the other picture with the same aperture and light. By using a larger lens in front, if the necessary definition can be obtained in that way, the time can be considerably reduced.

The most useful and practical application of this principle would seem to be in fitting a properly corrected double concave lens to the rear of the ordinary rectilinear lens commonly used by all photographers. The former should be attached to a tube which could be screwed into the rear part of the mounting of the doublet. The concave lens should have a sliding motion in this tube to give the desirable range of magnifying power, which would be indicated by a graduated scale. As I have shown, this change in the position of the rear lens would be limited to a small distance. A system of lenses arranged in this way would possess the great advantage of allowing the doublet to be used in the usual way, and when the increased focal length was desired the rear lens could be screwed into place in a moment.

THE TOTAL SOLAR ECLIPSE, APRIL 15-16, 1893.*

The total eclipse of the Sun, which will take place during the month of April next year, will most probably be very widely observed, not only because the shadow of the moon passes over such a great stretch of land, but because the phenomenon occurs at the period when a sun-spot maximum is approaching, at which time, of course, the disturbed state of the atmosphere of the Sun is on the increase. The maximum time of totality is also in this case considerable, amounting to as much as $4^m\ 46^s$.

Path of Shadow.—The general trend of the path of the shadow will be gathered from the accompanying diagram (Fig. 1). This track cuts through Chili, passes to the north of the Argentine Republic, skirts the provinces of Bolivia and Paraguay, and runs through the heart of Brazil. The centre of the shadow leaves South America near the town of Ceara or Fortaleza, and travels across the Atlantic Ocean, striking the African coast between Cape Verde and Bathurst.

Probable Points for Observations.—The special points for observations may be said roughly to be three, viz.: the region about Chili, the northeast corner of Brazil, *i. e.*, the region of Ceara, and the Senegambian coast. These localities are so situated on the line of central and total eclipse that photographs of

---

* From *Nature*, June 30, 1892.

the corona taken at Chili will precede those taken in Africa by about 3½ hours; while those obtained in the northeast of Brazil will be intermediate between the two.

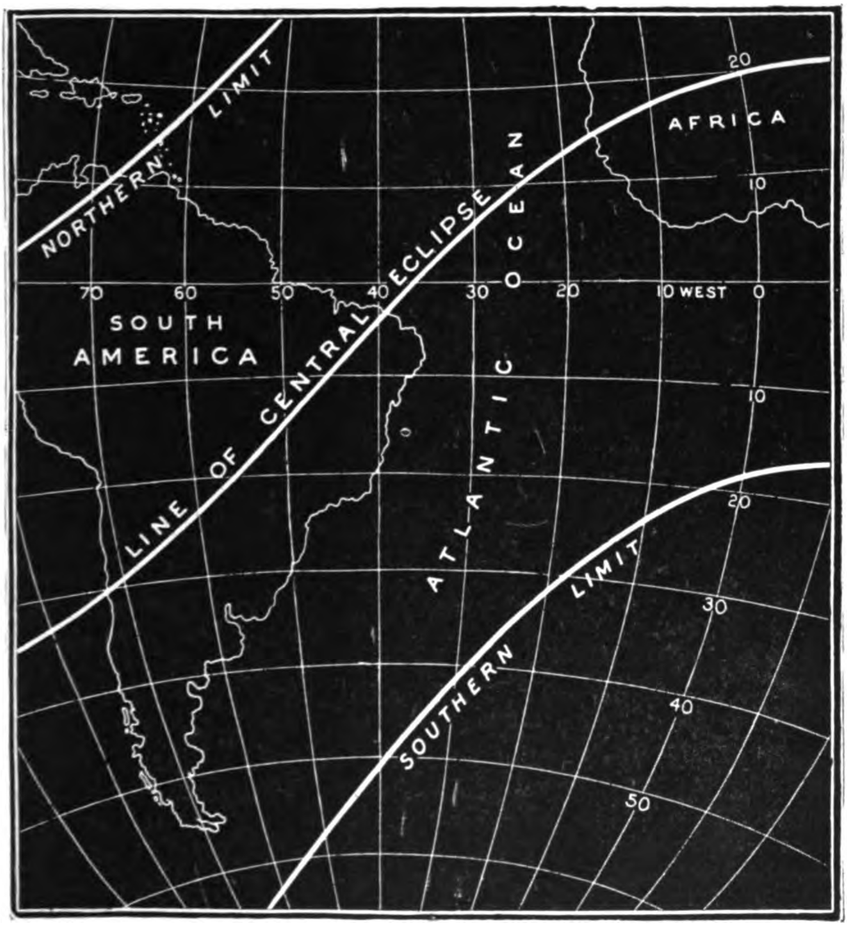


FIGURE 1.

Let us deal first with the Chilian district; this, we learn, will be occupied by the American astronomers. So far as we know at present, the Lick Observatory will send a party to Chili under the direction of Mr. Schaeberle, while Professor Pickering will also direct other observers somewhere about the same spot. To the north of the Argentine Republic, and on the Railway which runs up from Buenos Ayres, there seems to be another spot which would be available. This place, Rosario de la Frontera, lies to the north of Tucaman, and to the south of Jujuy, its approximate position being longitude 65° 7′, latitude 25° 48′ S. The duration of totality here amounts to 3^m 8^s, the local time of its commencement being April 15, 20^h 40^m. This place should, if possible, be made use of, for, besides being easily accessible, the probabilities from all accounts seem to be in favor of fine weather. From observations gathered from the nearest meteorological station, Salta, the mean annual temperature is found to be 63°.6 F., and the rainfall 22.8 inches; the chances for clear weather at this season being estimated at two-thirds.*

Following the track of the shadow across Brazil, no suitable spots are reached until the coast is approached; the most favorable place here is no doubt Fortaleza or Ceara, the capital of the province of Ceara, and a city of 20,000 inhabitants. Para Curu is also another very favorable point, lying nearly in the centre of the line of central eclipse; its position is longitude 38° 30′, latitude 3° 42′ S., and the local time of the beginning of the eclipse is April 15, 23^h 40^m, the time of its duration being 4^m 44^s.

With regard to the weather in this neighborhood, the chances for clear skies seem unfortunately, very small. The rainfall is reckoned as over 100 inches per annum, while even in April 10 inches has been usually recorded. For the last five years fifteen days on an average in this month have been rainy, the number in one year reaching twenty-one.

Taking into account the easy accessibility of the place, and its important position on the line of totality, it seems desirable that at any rate there should be some observers there.

Following the shadow over the Atlantic Ocean, we arrive at the shores of West Africa, on which, probably both French and English expeditions will take up their respective positions. The accompanying map (Fig. 2) shows the coast-line of this region; AB, CD, and EF indicating the line of central eclipse and the northern and southern limits. The places which seem at present to be the most favorable are Joal and Palmerin, on the coast, if observations there are more convenient than others made inland.

The prospect of fine weather seems to be more probable here than in America. December, January, and February are the cloudy months, the weather during March and April being usually fine; the rains begin about May; sometimes tornadoes occur at intervals of five or six days, being accompanied by

---

* The information for the most part concerning the American stations is gathered from Mr. H. S. Pritchett's article, "The Total Solar Eclipse, April 15-16, 1893," in the June number of ASTRONOMY AND ASTRO-PHYSICS.

Fig. 2.—Showing the region on

om one to two hours, leaving the
t and clear. The wind called the
t three months of the year is gen-
l dry. It comes from the Sahara
sequently minute particles of sand,
re a yellowish tint. In April the
northwesterly, and not usually

expedition will take has up to the
led. Several lines of steamers run
ry, and if one of Her Majesty's
p at Teneriffe and carried them
to the Salum River, the matter
ing this the only available route
sh and African Steam Navigation
touching at Madeira, Teneriffe,
ar, naturally require much time to
n conditions it seems impossible to
t.

essibility and proximity to the line
and other places on the same river
test advantages. The bar at the
revent a man-of-war of deep draft
. As the region here is all under
sary official letters will of course

points relating to this region if it
imately settled upon. Luxuries in
condensed), cocoa and milk, condi-
r, biscuits, soups, and preserved
from England; rice, fowls, sheep,
ays procurable from the native vil-

o be taken out, and it seems proba-
truments should be constructed at
n pieces. The necessary housing of
ny) would not prove very difficult,
nd in the villages, or bamboo and
run up by the natives; it might be
o small tents, as they might prove
ding.

ing of the necessary instruments, it
s' loads vary from 40 to 65 pounds;

heavy rain, lasting generally from one to two hours, leaving the atmosphere afterwards bright and clear. The wind called the "Harmattan" during the first three months of the year is generally from the northeast and dry. It comes from the Sahara Desert, and brings with it consequently minute particles of sand, tending to give the atmosphere a yellowish tint. In April the prevailing wind is westerly to northwesterly, and not usually very strong.

The route which the English expedition will take has up to the present not been definitely settled. Several lines of steamers run to Teneriffe and Grand Canary, and if one of Her Majesty's ships picked the expedition up at Teneriffe and carried them either to Bathurst or directly to the Salum River, the matter would be simplified; but failing this the only available route seems to be that by the British and African Steam Navigation Company. These steamers, touching at Madeira, Teneriffe, Grand Canary, Goree, and Dakar, naturally require much time to get to Bathurst. Of the return conditions it seems impossible to get any information at present.

Taking into account the accessibility and proximity to the line of totality, perhaps Palmerin and other places on the same river (River Salum) offer the greatest advantages. The bar at the mouth of the river would prevent a man-of-war of deep draft from proceeding up the river. As the region here is all under French protection, the necessary official letters will of course have to be obtained.

There are one or two other points relating to this region if it should by any chance be ultimately settled upon. Luxuries in the way of tea, sugar, milk (condensed), cocoa and milk, condiments, wine or spirits, flour, biscuits, soups, and preserved meats, should all be brought from England; rice, fowls, sheep, goats, and bullocks being always procurable from the native villages.

Cement and lime should also be taken out, and it seems probable that the huts for the instruments should be constructed at home and carried out there in pieces. The necessary housing of the observers (and escort, if any) would not prove very difficult, for either room could be found in the villages, or bamboo and grass huts could be quickly run up by the natives; it might be advisable to take one or two small tents, as they might prove very serviceable just after landing.

With regard to the packing of the necessary instruments, it may be said that the carriers' loads vary from 40 to 65 pounds;

a case capable of being slung on a bamboo can weigh as much as 250 pounds, while to carry a weight of one hundredweight the services of two men would be required. Their wages would, of course, depend on whether they were obtained from Bathurst or the trading wharf on the river at the point of disembarkation, as in the latter case they could be discharged as soon as the selected spot had been reached.

NOTES ON NEW AND OLD NEBULÆ.*

LEWIS SWIFT.

In the February number of *Observatory* Mr. Denning published an article with the above caption to which I immediately replied, but for some unknown reason my answer has never appeared in that journal. Speaking of a bright nebula he had discovered about 2°. S. E. of Gamma Camelopardis, of which the New General Catalogue contains no record, he says, "There is probably not another nebula so plain as this remaining to be discovered north of the equator." I began comet-seeking in 1857 with my present 4½-inch telescope, and constantly encountered nebulæ which, as I possessed no catalogue, I inferred were, of course, well known. From the start I marked their places by estimation on an old Burritt's Astronomical Atlas, for future reference, and from that date until my assumption of the directorship of the Warner Observatory in 1883, I had recorded some two hundred and fifty of these objects with no suspicion that a single one of them written down before 1879 was new. Consulting this map I find forty-eight recorded within 25° of the pole, one being nearly 2° S. E. of Gamma of the constellation named. I cannot recall its appearance or brightness or the year of its record, but to have been seen with so small a telescope it could not have been very faint. In comet sweeping for so many years I must have run across it many times. Some ten years since when comet seekers allotted to themselves a certain region for their quest, I notified them that I would mark their Burritt's maps with all the nebulæ I had discovered during more than twenty years, which I did, and on all the fifteen or more Atlases thus treated, including Professor Barnard's, the above nebula will be found. As a twenty-two foot equatorial is an inconvenient instrument for sweeping the polar regions, and as I supposed all of the forty-eight objects alluded to

---

* Communicated by the author.

were old, I have attempted to verify but few of them. These remarks have been suggested by a paper in *Astronomische Nachrichten*, No. 3097, by Professor Barnard on, "Two probably variable nebulæ," one of them being the identical one under discussion. After mentioning Mr. Denning's discovery on Nov, 7, 1890, he says, "I had previously discovered this nebula on August 23, 1889. It is 1′ in diameter, round, and in appearance is very much like a comet. . . . From its brightness it is not possible that it has been so conspicuous for any great length of time, or it would have been found by Swift and others. The fact that Mr. Denning and I independently found it within a little over a year is another proof that it must be brighter than in previous years." He gives the place of the nebula for Jan. 1, 1890, as Right Ascension $3^h\ 56^m\ 17^s$, Declination north 69° 30′ 38″.

I can conceive of no cause for the variability of nebulæ, and find no real evidence that any such exist, though, provided the purity of the atmosphere were the same on all occasions, the variability of his second suspect seems plausible. A slight change in this respect, which in a bright nebula would not be noticeable, could easily be detected in a very faint one. The same applies to bright and faint stars suspected or known to be variable.

I find some twenty or more nebulæ marked on my Burritt's chart in the vicinity of his second nebula, though none in the exact place of the object discovered by him on Nov. 30, 1888, in R. A. $0^h\ 37^m\ 55^s.71$; Decl. south 8° 48′ 6″.5.

WARNER OBSERVATORY, Rochester, N. Y., July 13, 1892.

THE NEBULAR HYPOTHESIS.[*]

When we look up at the clear sky at night, the stars and the planets seem to be equally distant, for the judgment of the eye is at fault for objects so remote; but astronomy teaches us that the Sun is a star, like the stars that we see in the sky, and that the planets, including the earth, revolve around him in obedience to the laws of gravitation, at distances which are insignificant in comparison with the vast intervals which separate the stars from one another. The Sun and planets, therefore, form a closely connected system isolated in space; they are members of one family, and their contiguity alone points to an identity of origin. We shall find many other facts bearing out the conclusion which we thus anticipate.

---

[*] A lecture by James E. Keeler, Allegheny Observatory, delivered before the Academy of Science and Art, of [illegible] on Nov. 6, 1891.

So far as we can know the manner in which the works of God are perfected, it is by a slow process of evolution rather than by special creation. The nebular hypothesis, which is our subject for this evening, seeks to explain the origin of the solar system, not by referring it to a special creative act of the Deity, but by regarding the Sun and planets as the result of development from a pre-existing form of matter, by the action of forces which are still in operation. The origin of matter is a mystery which the nebular hypothesis makes no attempt to solve.

It is evident that we are here outside the province of astronomy considered as an exact science, and are in the realms of hypothesis and speculation; but our speculations must be held tightly in check; they must be well within the bounds of probability, they must contradict no single natural law, and they must run in harmony with the whole course of the teachings of physical science; hence they can be profitably indulged in only by those profoundly versed in the laws of nature, and not by any one who chooses to give a loose rein to his imagination.

We have seen that the Sun is a star. Let us then look to the heavens above, to see if among the thousands of his compeers we can find something which will assist us in tracing the history of his past.

If, when you go out-doors this evening,* you will look up at the sky overhead, you will see in the constellation Andromeda at a point which I will presently describe more definitely, a very faint, almost imperceptible, patch of light. If you will look at this object with an opera glass, or better yet, with a large field glass, you will find that it is elongated, bright in the center, and fading gradually away at the edges until it is lost in the sky. This is the nebula of Andromeda, type of one of the two great classes into which the singular objects known as nebulæ may be divided.

Faint as this nebula appears to the naked eye, it is one of the brightest and largest in the heavens, so that it is sometimes called the "Queen of the Nebulæ." It is the only real nebula which was known before the invention of the telescope. Its real dimensions must be enormous. If we suppose the distance of the nebula to be no greater than that of the nearest star we see, its length must be more than 30,000 times the distance from the Earth to the Sun, so that the whole orbit of Neptune is insignificant compared with it. How much larger the nebula actually is than this, we have no means of telling. Professor G. P. Bond,

---

* Nov. 6, 1891.

one of the early directors of Harvard College Observatory, discovered two dark rifts or channels running along one side of the nebula, at places which are indicated in this diagram.

What is this nebula? It is the first and most natural question which it would occur to any one to ask; I must tell you at once that this question cannot yet be definitely answered, but I shall try to tell you some of the interesting facts that are known about the nebulæ. The last few years have added very much to our store of information.

It was once supposed that the nebulæ were aggregations of stars, so immensely distant that with the largest telescopes the individual stellar components could not be distinguished. In the constellation Hercules is an object which with a field-glass looks exactly like a nebula, but on employing a larger telescope it is resolved into a globular cluster of something like two thousand minute stars. It was thought that all nebulæ, if sufficient optical power could be brought to bear on them, would be similarly resolved into stars, but this was an error, for we now *know* that many of the nebulæ are not made up of stars at all.

No telescope revealed to the eye much more of the nature of the Andromeda nebula than what I have indicated in the diagram.* The principal reason for this is that the field of view of a large telescope is limited, so that the whole nebula cannot be seen at once. It was reserved for photography to reveal the true structure of this great nebula. We will project a view of it on the screen, and at the same time illustrate the disadvantage of a small field.

The first photograph which showed the structure of the Andromeda nebula was made by Mr. Roberts, of England. The one which we have in the lantern was taken by Mr. Barnard, of the Lick Observatory, with a comparatively small telescope, but it is of such exquisite sharpness that it shows everything on the larger photographs. Over the slide I have placed a piece of tin, in which there is a round hole. You therefore see upon the screen only a small part of the nebula, but the size of the hole is such that the small circle of light on the screen contains as much of the sky as can be seen at once with the great Lick Telescope. By moving the piece of tin about we can bring different parts of the nebula into view, but you see that in this way it is difficult to form an idea of the true shape of the object behind it. We now remove the tin, and the whole magnificent object is visible at a glance. Only one of the thousands of stars dotted over the screen is visible to the naked eye. Here are Bond's dark lanes, which you now recognize as elliptical, or rather spiral, rifts, extending completely around the nebula. At this place, near the center, a new star

* See Chambers' Astronomy, Vol. III, page 70. Also Young's General Astronomy, page 504.

suddenly appeared in 1885, evidence of some tremendous cosmical convulsion which perhaps actually occured long before the discovery of America.

Andromeda Nebula from aPhotograph by Mr. Roberts, copied from *Himmel und Erde*. See, also, *Sidereal Messenger*, Vol. IX, Frontispiece. Cut does not show small field of the Great Lick Telescope.

You will notice that the whole aspect of the nebula suggests condensation toward the center, and that the arrangement of many stars in lines following the outlines of the nebula leaves little room for doubt that these stars and the nebula are in some way related.

[TO BE CONTINUED.]

ASTRO-PHYSICS.

ON NOVA AURIGÆ.*

WILLIAM HUGGINS, F.R.S., AND MRS. HUGGINS.

We had the honor in February last of communicating to the Royal Society a short preliminary note on the remarkable spectrum of this temporary star. We beg now to present a fuller account of our observations, together with two maps of the spectrum of this star, and some theoretical suggestions as to its nature. One map represents the result of our work by eye in the visible region; the other map has been drawn from a photograph of its spectrum, taken without its light having passed through glass, and which extends into the ultra-violet nearly as far as the absorption of our atmosphere permits even the solar rays to pass.

On the Visible Region of the Star's Spectrum.

The kindness of Professor Copeland in sending us a special telegram on February 1 enabled us to commence our observations of the star on February 2, when it was of about the 4.5th magnitude. These observations were continued on the following evening, and on the 5th, 6th, 22nd, and 24th February, and on the 15th, 18th, 19th, 20th, and 24th March, when the sky was more or less sufficiently clear for further observations to be made by eye. On the two ends of the spectrum the observations were usually made with a spectroscope containing one dense prism of 60°, but the comparisons in the brighter parts of the spectrum were observed with a more powerful spectroscope containing two compound prisms.

Comparisons with Hydrogen.—Three bright lines of great brilliancy, about the positions $H\alpha$, $H\beta$, and $H\gamma$, left little doubt that they were due to hydrogen. The corresponding lines of a hydrogen vacuum tube were found to fall upon these lines, showing that they had their origin in this gas; but the line in the star at F, which could be best observed, showed a large shift of position towards the red. The line from the vacuum tube fell not upon the middle of the line, but near its more refrangible edge. The star line was brighter on the more refrangible side, so much so, indeed, that our first impression was that this side of the line only might be truly $H\beta$, and the less bright part towards

---

* Communicated by the authors.

the red, a line of some other substance falling near it. Subsequent observations of the hydrogen lines in the star left no doubt that though they presented the unusual character of being double, and sometimes triple, they were due wholly to hydrogen. These lines were rather broad, but defined, especially so on the more refrangible edge. Similarly to what is observed in the spectrum of terrestrial hydrogen, C was narrower than F, which again was less broad than Hγ near G.

The remarkable phenomenon presented itself that all the bright hydrogen lines and some other of the bright lines were doubled by a dark line of absorption of the same gas on the blue side. The shift of the dark hydrogen lines towards the blue showed a velocity of approach of this cooler gas somewhat greater than the recession of the gas emitting the bright lines. Our estimates of the relative velocity would place it at about 550 miles a second, which is in good accordance with the result obtained by Professor Vogel from the measurement of his photographs.

So far as our instruments enabled us to determine the point under the unfavorable condition of the rapidly waning light of the star, no material change in the relative motion of the gases producing the bright and dark lines took place from February 2 to about March 7, when the star's light became too faint for such observations—a result which we believe to be in accordance with successive photographs taken at Potsdam, Cambridge (U. S.), Stonyhurst, and some other observatories.

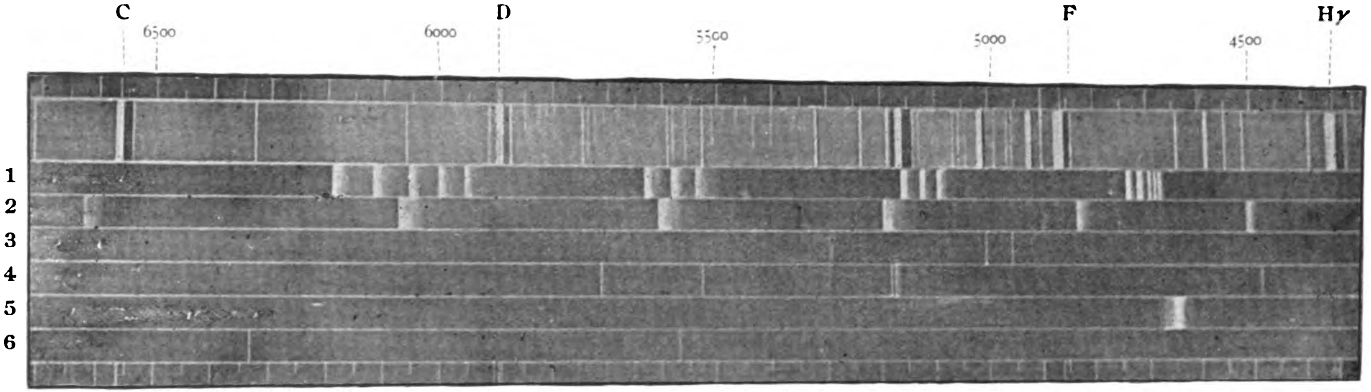
Comparison with Sodium.—A bright line, which on one occasion we glimpsed as double, appeared about the position of D.

Direct comparisons with a sodium flame, while leaving no doubt that the line was due to this substance, showed that it was shifted, similarly to the bright hydrogen lines, towards the red. Perhaps we should state that at the time we had the impression that this line was not shifted to so large an amount relatively to sodium as was the F line relatively to hydrogen. As the comparison was more difficult at this part of the spectrum, and one prism only was used, we do not attach importance to this observation.

Comparisons with Nitrogen and Lead.—There can be little doubt that one of the four brilliant lines in the green is the same line which appeared in the Nova of 1876, and was at that time suspected of being the chief nebular line. Very great pains were taken to ascertain its exact position and character.

For this purpose, on February 2, and again on February 3, direct comparisons were made with the more powerful spectro-

PLATE XXI.



"*1. Hydrocarbon. 2. C. Oxide. 3. Nebula. 4. Mg. 5. Wolf-Rayet Stars. 6. Aurora.*"

scope of the star's line with the brightest double line of [illegible] trogen spectrum, and also with a line of lead, to which [illegible] their relative position of the nebular line is accurately [illegible] Comparisons on both nights, and with both lines, showed [illegible] the star line was certainly less refrangible than the chief nebular line, and by a much larger amount than the shift of F relative to hydrogen. A similar conclusion has been [illegible] rived at by [illegible] Professor Young, Professor Vogel, Professor [illegible] all at the [illegible] Observatory, Father [illegible] greaves, Dr. Beck [illegible] Bel [illegible] at [illegible] ikova. The position of the line in the [illegible] and the line may well be one about this position [illegible] quently seen bright at the sun's limb.

It may be added that though three [illegible] seen in the star's spectrum not far [illegible] nebulae, no one of [illegible] be regarded [illegible] certain evidence [illegible] out the second line. [illegible] cases of [illegible] the nebulae which I [illegible] spectrum lines [illegible] I [illegible] since with [illegible] instrument [illegible] and [illegible] lines as [illegible] the origin of [illegible] that [illegible] the nebulae [illegible] not known [illegible] second [illegible] line is not [illegible] of [illegible] which [illegible] near it.

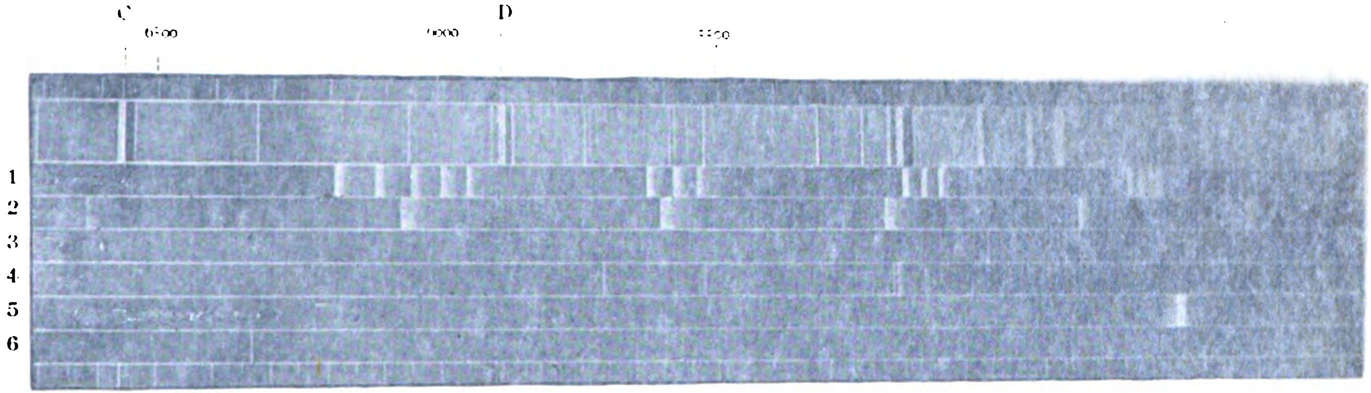
[illegible] conclusion [illegible] the spectrum of the Nova [illegible] ship [illegible] t lines [illegible] nebulae would be [illegible] further [illegible] the absence [illegible] we [illegible] of the [illegible] of a very [illegible] which is [illegible] found [illegible] spectrum of [illegible]

[illegible] mparison [illegible] h the [illegible] carbon [illegible] and C [illegible]

— [illegible] bright [illegible] in the [illegible] um of [illegible] tion [illegible] tail [illegible] edge [illegible] by [illegible] flame [illegible] sons [illegible] fell a [illegible] for a [illegible] the star [illegible] r, tho [illegible] not co [illegible] with [illegible]

The character of the st [illegible] es, [illegible] points [illegible] it is [illegible] with [illegible] on the blue side contrary to [illegible] red side, and gradually falls off [illegible] tainty could be supposed still to re [illegible] when we found no brightenings in [illegible]

PLATE XXI.



"1. *Hydrocarbon.* 2. *C. Oxide.* 3. *Nebula.* 4. *Mg.* 5. *Wolf-Rayet Stars* 6. *Aurora.*"

scope of the star's line with the brightest double line of the nitrogen spectrum, and also with a line of lead, to which line the near relative position of the nebular line is accurately known. Comparisons on both nights, and with both lines, showed that the star line was certainly less refrangible than the chief nebular line, and by a much larger amount than the shift of F relatively to hydrogen. A similar conclusion has been arrived at by Professor Young, Professor Vogel, Professor Campbell, at the Lick Observatory, Father Sidgreaves, Dr. Becker, and M. Bélopólsky, at Pulkova. The position of the line in the star is about λ 5014 and the line may well be one about this position which is frequently seen bright at the Sun's limb.

It may be added that though three faint bright lines are to be seen in the star's spectrum, not far from the place of the second nebular line, no one of them can be regarded as that line. Indeed no certain evidence exists that the chief nebular line occurs without the second line. In some cases of my early observations on the nebulæ in which I recorded the spectrum as consisting of one line only, I have since with better instruments been able to see the second and third lines as well. The origin of the second, as well as that of the chief nebular line, is not known. Professor Keeler has shown that the second nebular line is not coincident with the double line of iron, which is very near it.

The conclusion that the spectrum of the Nova has no relationship with that of the bright-line nebulæ would be strengthened, if further confirmation were needed, by the absence in a photograph we took of the spectrum of the New Star of a very strong ultra-violet line which is usually found in the spectrum of the nebula of Orion.

Comparison with the Hydrocarbon Flame and Carbon Oxide. —The brightest line in the spectrum of the Nova, with the exception of F, falls near the brightest edge of the green fluting of the hydrocarbon flame. Direct comparisons showed the star line to fall a little to the red side of the edge of the fluting; but, allowing for a shift of the star's spectrum, the place of the line would be near, though not coincident with, the brightest edge of the fluting.

The character of the star line leaves, however, no doubt on this point, for it is multiple with the brightest and most defined line on the blue side, contrary to the fluting which is defined on the red side, and gradually falls off towards the blue. If any uncertainty could be supposed still to remain, it was wholly removed when we found no brightenings in the star's spectrum corresponding to the other flutings of the hydrocarbon flame. A bright band in the blue falls just beyond the fluting in this region. This band may have the same origin as a similar band in certain of the Wolf-Rayet stars.

We conclude that the spectrum of the Nova has no relationship with the usual spectrum of comets.

We found from direct comparison that the different set of flutings characteristic of the carbon oxide spectrum was not represented by any corresponding brightenings of the spectrum of the Nova.

Comparison with Magnesium.—It was not unreasonable to suppose that the star line might have its origin in magnesium, the triple line of which at *b* falls almost at the same place. The comparison showed the stellar line falling upon the more refrangible pair of the magnesium triplet, and to overlap it slightly on both sides, but rather more on the blue side. Considering that with the resolving power used the three lines of the triplet were well separated, and that we sought in vain for a similar triplet in the star; and, further, that if the probable shift of the star's spectrum towards the red be taken into account, the star line would fall rather more to the blue side of the more refrangible pair of the triplet, we consider it probable that the star line has some other origin. The stellar line is multiple, but it was found difficult to observe it with a sufficiently narrow slit. A thin and defined bright line was clearly seen at the blue side of the rather broad stellar line, but the remaining and less bright part of the line was not certainly made out, but on one occasion it was more than suspected of consisting of several lines.

We consider the evidence to be against the star line having its origin in magnesium, especially as no correspondingly bright lines were observed in the Nova at the positions of the other strong lines of the spark spectrum of magnesium, nor in our photograph at the position of the strong magnesium triplet a little more refrangible than H.

The third bright line in the green of the Nova which is nearest to F, and the least brilliant of the lines in this region, was found to have a wave-length of about λ 4921. A large number of bright lines were seen in the spectrum besides those which have been entered on the map.

The lines only of which we were able to fix the position with approximate accuracy are drawn across the spectrum. The places of the lines drawn partly across the map are from estimations only.

We observed a line a little more refrangible than D, of which the position when corrected for the shift of the spectrum, is at or very near that of D_3. Also a bright line below C, and others between C and D.

On February 2 and February 3 groups of numerous bright lines crowded the spectrum between *b* and D, which were less easily seen as the star waned.

The continuous spectrum extended, when the star was brightest, below C, and as far into the blue as the eye could follow it, at this time to a little distance beyond G.

The visible spectrum of the Nova, and especially the reversal of H and K, and of the complete series of the hydrogen lines in the ultra-violet, together with the probable presence of D_3, suggests strongly a state of things not unlike what we have in the hotter erupted matter at the solar surface. In a photograph of a prominence taken on March 4, 1892, which I have received from M. Deslandres, not only H and K and the complete series of hydrogen lines are reversed, but three bright lines appear beyond which may be more refrangible members of the same series.*

Photograph of the Ultra-Violet part of the Spectrum.—On February 22 and March 9 we took photographs of the star with mirror of speculum metal and a spectroscope of which the optical part is made of Iceland spar and quartz.

The photographs taken on February 22 with an exposure of 1¾ hour surprised us in showing an extension of the star spectrum into the ultra-violet, almost as far as the limit imposed upon the light of celestial bodies by the absorption of our atmosphere.

Not only the hydrogen lines near G and at *h*, but also H and K, together with the complete series which appear dark in the white stars, came out bright, each with its corresponding absorption line on the blue side. There are some inequalities of brightness in these lines, especially in the line δ, which is brighter than γ or β, which probably arises from lines of other substances falling near them. On this night K was followed by a strong absorption, which was less intense than the absorption at H.

Beyond the hydrogen series the spectrum is rich in bright lines, which, in most cases, are accompanied by lines of absorption. Necessarily, from the long range of spectrum included on the plate, the scale is small, and for this reason, and from the faint-

---

* M. Deslandres informs me that his measures of the position of the three lines falls into Balmer's formula for the hydrogen series. We must regard them, therefore, as members of that series, and due to hydrogen. June 1.

ness of the more refrangible portion of the spectrum when observed under the measuring microscope, the positions given to the stronger groups, which alone have been inserted in the map, must be regarded as approximate only.

Below the spectrum of the Nova, the spectrum of Sirius has been drawn for comparison. The group near the more refrangible limit of the spectrum* has been drawn in. Numerous other lines between this group and the end of the hydrogen series have been detected in our photographs of Sirius, but have not yet been measured with sufficient accuracy to justify us in putting them into the map.

In this map the shift of the spectrum of the Nova has not been attempted to be shown. The bright lines in the star have been put at the places of the hydrogen lines.

To the extreme limit of the spectrum a faint continuous spectrum shows itself.

The photograph of March 9, exposed for 1½ hour, was rather faint, as the state of the sky was unfavorable.

The apparently Multiple Character of the Lines.—On February 2 we noticed that the F line was not uniform throughout its breadth, and soon came to the conclusion that it was divided, not quite symmetrically, by a very narrow dark line. The more refrangible component was brighter, and rather broader than the other. Later on in February we were sure that small alterations were taking place in this line, and that the component on the blue side no longer maintained its superiority. We suspected, indeed, at times that the line was triple, and on towards the end of February and in the beginning of March we had no longer any doubt that it was occasionally divided into three bright lines by the incoming of two very narrow dark lines.

Similar alterations, giving a more or less apparent multiple character to the lines, are to be seen not only in the bright lines, but also in those of absorption in contemporary photographs taken of the spectrum of the star. I may mention those taken at Potsdam, Stonyhurst, and the Lick Observatory. They were specially watched and measured by M. Bélopólsky at Pulkova.

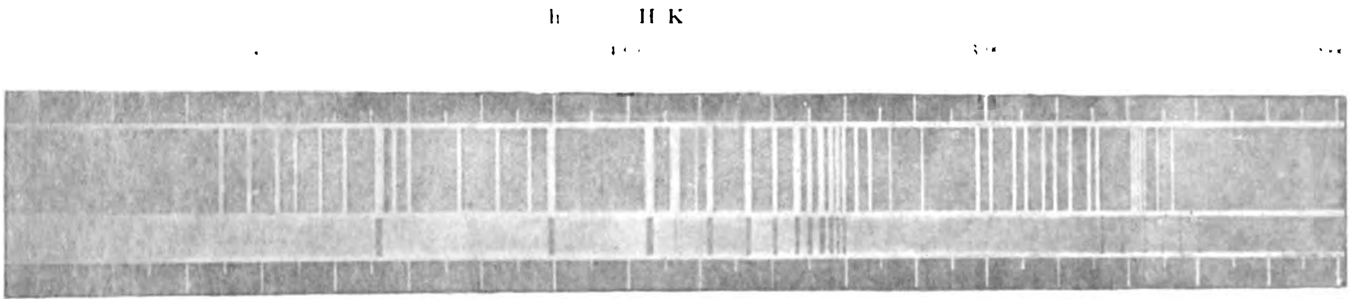
Professor Pickering informs me that on a photograph taken at Cambridge, U. S., on February 27, H, K, and α are triple, and that Miss Maury recorded, "the dark hydrogen lines rendered double, and sometimes triple, by the appearance of fine bright threads superposed upon the dark bands."

To explain these appearances on the assumption that each com-

---

* *Roy. Soc. Proc.*, vol. 48, p. 216.

PLATE XXII.



ASTRONOMY AND ASTRO-PHYSICS No. 107

ponent of the bright and dark lines is produced by the emission or absorption of hydrogen moving with different velocities would require a complex system of six bodies all moving differently.

A much more reasonable explanation presents itself in the phenomena of reversal, which are very common on the erupted solar surface and in the laboratory.[*]

Professor Liveing informs me that he and Professor Dewar, in their researches with the arc-crucible, met with cases in which, through the unequal expansion of the bright line on the two sides, the narrow reversed dark line did not fall upon the middle of the broader bright line, but divided it unsymmetrically. This effect was notably shown in photographs which they took of the spectrum of zinc. Unsymmetrical division of the lines by reversal would also come in, if the cooler and hotter portions of the gas were possessed of relative motion in the line of sight.

These observers met also with double reversals which gave a triple character to the expanded single line. In one experiment, when sodium carbonate was introduced into the arc, the reversed D lines were seen as a broad dark band with a bright diffuse band in the middle. As the sodium evaporated the band narrowed, and the bright line in the middle showed a second reversal within it. This was a case of threefold reversal.

There would seem to be little doubt but that the more or less divided character—sometimes unsymmetrically—of the bright and dark lines of the Nova, which appeared to be undergoing continual alterations, was due to the incoming upon the broader lines of narrow reversed lines, bright or dark, as the case might be. Provision must therefore be made for conditions favorable for such reversals in any hypothesis which is suggested to account for the phenomena of the new star.

Waning of the Star.—The first record of this star was its appearance as a star of the 5th magnitude on a plate taken at Cambridge, U. S., on December 10, 1891. No star so bright as the 9th magnitude was found at its place on a plate taken by

---

[*] M. Deslandres permits me to quote the results of his recent observations on this point. "Lorsque l'on dirige sur la fente d'un spectroscope de grande dispersion l'image d'une facule du Soleil on a invariablement avec les raies H et K du calcium un renversement triple. Même, lorsque les facules sont larges et intenses, on obtient encore un renversement triple avec les raies brillantes centrales, plus faibles il est vrai, si l'on envoie dans le spectroscope la lumière de tous les points du Soleil, comme c'est le cas pour les étoiles; par example en dirigeant le collimateur vers le Soleil sans l'intermèdiaire d'aucun objectif, ou encore en le dirigeant vers un point quelquonque du ciel. Si elles sont au centre la raie centrale est à sa place normale, si elles sont à l'est ou à l'ouest la raie centrale est deplacée légèrement (2 kil. au plus) mais deplacée surement. Au point de vue pratique cette propriété fournit un moyen de reconnâitre l'état général de la surface solaire lorsque le Soleil est caché par les nuages."

Dr. Max Wolf on December 8. Combining the photographic magnitudes obtained at Greenwich with the visual ones made at the University Observatory, Oxford, and by Mr. Stone and Mr. Knott, we find that throughout February and the first few days of March the light of the star declined very slowly, but with continual and considerable fluctuations, from about the 4.5th magnitude down to the 6th magnitude. After March 7, the remarkable swayings to and fro of the intensity of its light, set up probably by commotions attendant on the causes of its outburst, calmed down, and the star fell rapidly and with regularity to about the 11th magnitude by March 24, and then down to nearly the 14.4th magnitude by April 1. On April 26, however, it was still visible at Harvard Observatory as a star of the 14.5 magnitude on the scale of the meridian photometer.

We observed its spectrum for the last time on March 24, when it had fallen to nearly the 11th magnitude. We were still able to glimpse the chief features of its spectrum. The four bright lines in the green were distinctly seen, and appeared to retain their relative brightness; F the brightest, then the line near *b*, followed by the lines about λ 5015 and 4921.

Traces of the continuous spectrum were still to be seen. Considering the much greater faintness of the continuous spectrum when the star was bright on February 2 than the brilliant lines falling upon it, we are not prepared to say that the falling off of the continuous spectrum was greater than might well be due to the waning of the star's light.

Professor Pickering informs me that in his plates "the principal bright lines faded in the order K, H, *α*, F, *h*, and G, the latter line becoming much the brightest when the star was faint." The calcium lines, K and H, showed signs of variation during the whole time of the star's visibility, and I may remark that the order of the other lines agrees with the relative sensitiveness of the gelatine plate for these parts of the spectrum. Professor Pickering's photographic results appear to us to agree with those we arrived at by eye, in not showing any material alteration in the nature of the star's light, notwithstanding a very large fall of intensity.

General Conclusions.

Among the principal conditions which must be met by any theory put forward to account for the remarkable phenomena of the new star stands the persistence without any material alteration —though probably with small changes—of the great relative velocity of about 550 miles a second in the line of sight between the hydrogen which emitted the bright lines and the cooler hydrogen producing the dark lines of absorption.

If we assume two gaseous bodies, or bodies with gaseous atmospheres, moving away from each other after a near approach, in parabolic or hyperbolic orbits, with our Sun nearly in the axis of the orbits, the components of the motions of the two bodies in the line of sight, after they had swung round, might well be as rapid as those observed in the new star, and might continue for as long a time without any great change of relative velocity. Unfortunately information as to the motions of the bodies at the critical time is wanting, for the event through which the star became suddenly bright had been over for some forty days before any observations were made with the spectroscope.

Analogy from the variable stars of long period would suggest the view that the near approach of the two bodies may have been of the nature of a periodical disturbance, arising at long intervals in a complex system of bodies. Chandler has recently shown in the case of Algol that the minor irregularities in the variation of its light are probably caused by the presence of one or more bodies in the system, besides the bright star and the dusky one which partially eclipses it. To a similar cause are probably due the minor irregularities which form so prominent a feature in the waxing and waning of the variable stars as a class. We know that the stellar orbits are usually very eccentric. In the case of γ Virginis the eccentricity is as great as 0.9, and Auwers has recently found the very considerable eccentricity of 0.63 for Sirius.

The great relative velocity of the component stars of the Nova, however, seems to suggest rather the casual near approach of bodies possessing previously considerable motion; unless we are willing to concede to them a mass very great as compared with that of the Sun. Such a near approach of two bodies of great size is very greatly less improbable than would be their actual collision. The phenomena of the new star scarcely permit us to suppose even a partial collision; though if the bodies were very diffuse, or the approach close enough, there may have been possibly some mutual interpenetration and mingling of the rarer gases near their boundaries.

A more reasonable explanation of the phenomena, however, may be found in a view put forward many years ago by Klinkerfues, and recently developed by Wilsing, that under such circumstances of near approach eno[illegible]urbances of a tidal nature would be set up, amounting it may well be to partial deformation in the case of gaseous bodies, and producing sufficiently great changes of pressure in the interior of the bodies to give rise to enormous eruptions of the hotter matter from within, immensely greater, but similar in kind, to solar eruptions.

In such a state of things we should have conditions so favorable for the production of reversals undergoing continual change, similar to those exhibited by the bright and dark lines of the Nova, that we could not suppose them to be absent; while the integration of the light from all parts of the disturbed surfaces of the bodies would give breadth to the lines, and might account for the varying inequalities of brightness at the two sides of the lines.

The sources of the light of the continuous spectrum upon which were seen the dark lines of absorption shifted towards the blue, must have remained behind the cooler absorbing gas; indeed must have formed with it the body which was approaching us, unless we assume that both bodies were moving exactly in the line of sight, or that the absorbing gases were of enormous extent.

The circumstance that the receding body emitted bright lines, while the one approaching us gave a continuous spectrum with broad absorption lines similar to a white star, may, perhaps, be accounted for by the two bodies being in different evolutionary stages, and consequently differing in diffuseness and in temperature. Indeed in the variable star β Lyræ, we have probably such a binary system, of which one component gives bright lines, and the other dark lines of absorption. We must, however, assume a similar chemical nature for both bodies, and that they existed under conditions sufficiently similar for equivalent dark and bright lines to appear in their respective spectra.

We have no knowledge of the distance of the Nova, but the assumption is not an improbable one that its distance was of the same order of greatness as that of the Nova of 1876, for which Sir Robert Ball failed to detect any parallax. In this case, the light-emission suddenly set up, certainly within two days and possibly within a few hours, was probably much greater than that of our Sun; yet within some fifty days after it had been discovered, at the end of January, its light fell to about $\frac{1}{300}$ part, and in some three months to nearly the $\frac{1}{10000}$ part. As long as its spectrum could be observed the chief lines remained without material alteration of relative brightness. Under what conditions could we suppose the Sun to cool down sufficiently for its light to decrease to a similar extent in so short a time, and without the incoming of material changes in its spectrum. It is scarcely conceivable that we can have to do with the conversion of gravitational energy into light and heat. On the theory we have ventured to suggest, the rapid calming down, after some swaying to and fro of the tidal disturbances and the closing in again of the outer and cooler gases, together with the want of transparency which might come in under such circumstances, as the bodies separated, might account reasonably for the very rapid and at first curiously fluctuating waning of the Nova; and also for the observed absence of change in its spectrum.

I may, perhaps, be permitted to remark that the view suggested by Dr. William Allen Miller and myself, in the case of the Nova of 1866,* was essentially similar, in so far as we ascribed it to erupted gases .The great suddenness of the outburst of that star, within a few hours probably, and the rapid waning from the 3.6 magnitude to the 8.1 magnitude in nine days, induced us to throw out the additional suggestion that possibly chemical actions between the erupted gases and the outer atmosphere of the star may have contributed to its sudden and transient splendor; a view which, though not impossible, I should not now, with our present knowledge of the light-changes of stars, be disposed to suggest.

PRINGSHEIM† ON KIRCHHOFF'S LAW.‡

HENRY CREW.

It will be remembered that in the demonstration which Kirchhoff gave (*Pogg. Ann., Bd. 109, pp. 275-301, 1860*) for his law connecting the absorption and emission of radiant energy, he made the whole of his mathematical deduction rest upon the experimental basis that a body, placed within an enclosure whose walls are held at a constant temperature, will assume and maintain the temperature of the walls, whatever be their nature or the disposition of their parts. But, as Kirchhoff then pointed out, this demonstration does not hold when the radiation absorbed by any body is transformed into any kind of energy other than heat; nor is it valid for radiation produced by any means other than simple heating.

---

* Roy. Soc. Proc., vol. 15, p. 146.

† Pringsheim, *Wied. Ann.*, [illegible] 428-459. (1892.)

‡ Communicated by the [illegible]

If, for instance, the incident radiation were changed into any other form of energy than heat, it would not be registered on the thermometer. Likewise, if the radiation emitted by the body were at the expense, say of chemical energy, a decrease of temperature corresponding to the energy radiated would not be registered on the thermometer.

A glance at the text books, *e. g.* Wüllner's *Experimental Physik*, suffices to show that Kirchhoff's law has generally been illustrated by the solar spectrum and the spectra of the fixed stars, as well as by luminous flames. All assumptions, however, regarding the constitution of the stars are based upon evidence obtained from flames in the laboratory. In view of these facts, the paper which Mr. Pringsheim prints in the current number of *Wiedemann's Annalen* becomes one of more than ordinary interest, not that it will in any degree affect present views regarding the physical constitution of the stars, but rather because it throws new light on the manner in which stellar constituents are made known to us. It must not be forgotten that the solitary basis of *interpretation* of stellar spectra is laboratory work. Stars can be observed, but experiments* cannot be tried upon them.

After pointing out that our knowledge of highly heated gases is very meager, and that there is no *evidence* for thinking that gases become luminous when merely heated, Mr. Pringsheim proposes for solution these two questions.

(1.) Do gases possess the property of becoming luminous by a simple increase of temperature?

(2). Is there any gaseous source of light known which fulfills the conditions of Kirchhoff's Law?

The first of these problems was attacked by heating sodium vapor in a long porcelain tube which was placed in a specially designed gas furnace capable of producing temperatures considerably above one thousand degrees. At first the substances to be examined were introduced into the tube while cold. On the ends of this porcelain tube were then cemented plane parallel glasses and portions of the tube near the end were cooled by running water: so that the cemented ends served to make the tube airtight. A small side tube, containing a four-way stop-cock, branched off from the porcelain tube. By this means, the tube could be emptied of air and filled with a neutral gas, such as nitrogen or carbon dioxide. This, of course, was for the prevention of chemical action during the heating. For observing the absorp-

---

* See Maxwell's *Scientific Papers, Vol. II., p. 505.*

tion spectra an argand burner was placed before the far end of the porcelain tube. The continuous spectrum of this flame could be viewed, through the heated vapor, by means of a spectroscope placed at the near end of the tube. Careful precautions were taken to shut off all direct radiation from the walls of the porcelain tube to the slit of the collimator.

On thus heating sodium carbonate and sodium chloride it was found that *the highest available temperature of the furnace failed to give the slightest trace of the D lines in either the emission or absorption spectrum.*

Metallic sodium, on the contrary, showed the D lines in both spectra. Mr. Pringsheim thinks, however, that it is quite impossible to prepare, at present, any of the neutral gases so free from oxygen that the spectroscope will not detect some chemical reaction with metallic sodium. The results just given are equally true whether the substances are heated in nitrogen, carbon dioxide or air.

The next step was to heat these salts in one of the so-called "cold flames." A mixture of carbon bisulphide and air was chosen. This flame can be ignited by a glass rod heated to 149° C. The temperature of the flame was varied, (by changing the proportions of the mixture,) until the characteristic spectrum of sodium was just visible in a direct-vision spectroscope of small dispersion. The temperatures of the porcelain tube and of this flame were measured by a Platinum—Palladium couple.

The result was that sodium *salts* gave the two yellow lines in the flame at temperatures at which not the faintest trace of luminosity could be detected when the same salts were heated in neutral gases.

The natural conclusion is that the luminosity of sodium chloride in flames is due to some form of energy other than that of heat, probably chemical. The following variations were introduced to find if possible what this chemical action might be. The fact that sodium salts, when heated in a closed porcelain tube filled with air, do not become luminous would seem to indicate that the chemical process is, at least, *not* one of oxidation. Reducing agents were, therefore, tried. The four-way stop-cock mentioned above was connected by one outlet to a supply of hydrogen, by another to a supply of coal gas. It was then found that a large number of sodium salts—all, indeed, that were tried—when heated in an atmosphere of either of these gases gave the usual emission and absorption spectra.

On pumping out the hydrogen, or illuminating gas, these spectra diminished greatly in intensity. The introduction of air, in place of hydrogen, sufficed to entirely quench all luminous radiation.

A bit of charcoal introduced along with the neutral gases would bring out the sodium lines. A small piece of iron had the same effect.

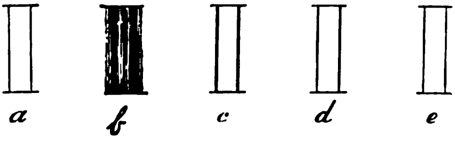
In every case, it will be observed, the presence of a reducing agent appears to produce luminous radiation. The fact that charcoal in the presence of air does not have this effect is evidently because the carbon is all used up on the oxygen in the air. In the ordinary Bunsen flame, therefore, it would appear that the molecules of the salt are not broken up by oxidation, nor yet by dissociation due to heat, but rather in consequence of reduction by illuminating gas and carbon monoxide.

If this view be correct,—and it is not an entirely new* one,—one would expect that the introduction of Na_2CO_3 into the heated tube filled with hydrogen would bring the sodium lines suddenly into view. The withdrawal of the sodium salt ought then to make these lines as suddenly disappear.

This test was accordingly made with several gases. For placing the substance in the heated part of the tube quickly, an iron spoon was used. The salt was placed in this spoon before the tube was sealed up.

An electro-magnet was used to draw the loaded spoon alternately into and out of the heated portion.

The results are indicated in the accompanying figure:



Hydrogen.

Since the porcelain tube, except when used for the first time, is always covered with a glaze of sodium silicate the mere introduction of hydrogen sets up a process of reduction which gives the D lines as pictured in *fig. a*.

The same thing happens when the iron spoon remains in the cold part of the tube. If now the salt be drawn into the hot portion of the tube, the spectrum suddenly assumes the appear-

---

* Vogel: *Spectralanalyse irdischer Stoffe, p. 104.*

ance of *fig. b*. On withdrawing the salt the spectrum *immediately* returns to *fig. a*.

Carbon dioxide.

In this gas, the D lines cannot be seen at all until the sodium carbonate is pushed into the hot part; they then show themselves as in *fig. c*: but, on withdrawing the salt, they do not disappear completely, but become sharp as in *fig. e*.

Air.

In air, there is no spectrum seen until the salt is drawn into the region of high temperature, when *fig. d* represents the appearance. As soon as the carbonate is drawn out the spectrum disappears completely.

The trend of these experiments is evident. They were intended to furnish an answer to this question: Does the vapor of a salt, having been broken up into its chemical constituent atoms by means of a reducing agent, become luminous by the heat alone or is the luminosity due to the chemical reaction? If it be due to heat alone, the spectrum of the vapor in the heated tube should disappear more or less *gradually* when the remaining solid salt is withdrawn. Such, however, is the case only with carbon dioxide in which the spectrum drops gradually from *c* to *e*. And this, the author thinks is only an apparent anomaly. But the chemical explanation which he offers does not appear perfectly satisfactory.

The outcome of the whole matter is that Mr. Pringsheim's experiments have made it highly probable that gases become luminous only at the moment of some chemical change. Indeed, as Siemens pointed out more than ten years ago, we have as yet no evidence that any gas will radiate light in consequence of high heating.

As to the case of the electric spark and the Geissler tube, these are confessedly complicated by electrical phenomena which are, at present, inseparably connected with the heating effect. The recent and numerous experimental verifications of the electromagnetic theory of light and the exceedingly low temperature of the Geissler tube both lead one to think that the luminosity of the spark may owe more to electrical than to purely thermal processes.

The author closes with the interesting remark that his experiments show in a *qualitative* way, at least, just the phenomena which one might predict from Kirchhoff's Law, *yet without satisfying the conditions of that law.* The classical mechanical explanation, resonance, is the one offered. Following is Mr. Pringsheim's own summary:

(*1.*) *There are no luminous gases known which satisfy the conditions of Kirchhoff's Law.*

(*2.*) *It is possible to produce luminous gases whose temperatures fall below 150° C.*

(*3.*) *Sodium salts, in flames, become luminous only in consequence of chemical processes.*

(*4.*) *Metallic sodium, heated in neutral gases, is luminous only in consequence of chemical processes.*

(*5.*) *The assumption that gases can become luminous by mere increase of temperature is an hypothesis, demanded neither by experiment nor by theory.*

This piece of work strikes one as having been very carefully and skillfully performed. But the author will probably find some of his deductions questioned. For instance, it will be remembered that Mr. Pringsheim measures his temperatures with a thermopile whose dimensions, compared with the size of the flame, are small be sure; but, when compared with molecular sizes and distances, they are practically infinite. So that he uses what one might style an "integrating thermometer." May not the temperature, developed in the immediate vicinity of those molecules in which chemical action (reduction) is going on, be very much higher than that registered on the thermopile? Is it not possible that local temperatures thus produced in cold flames may give rise to intramolecular* motions which are sufficient to produce radiation? Wüllner has shown that this is what actually happens in Geissler tubes when the pressure exceeds a certain fraction of one atmosphere. A rotating mirror shows that only slender filaments of the gas are heated at each passage of the spark. So that, in two tubes where the amount of heat generated per second is the same in each, the local temperature produced by the sharp linear discharge *appears* to be much higher than those produced in the low pressure tubes where the discharge is diffuse. May it not be the same with chemical reactions in the flame?

This is by no means the first time that doubt has been cast upon Kirchhoff's Law. See Schuster's article on *Spectroscopy* in the

---

* I take it for granted that light is due rather to the relative motions of the parts of the molecule, than the motion of the molecule as a whole. On any other supposition, one would find the utmost difficulty in explaining the large number of spectral lines produced by single substances.

Encyclopedia Britannica where he sets forth some experimental evidence for thinking that this law does not tell the whole story. See also E. Wiedemann's paper on the Mechanics of Light (Wied. Ann., Bd. 37, p. 185), where, after pointing out the limitations of the law, he distinctly avows his belief that it holds "for an ideal case only."

LICK OBSERVATORY, 18th of May, 1892.

NOTES ON THE SPECTRA OF SUN-SPOTS.*

A. L. CORTIE.

As we have now arrived at a period in the Sun-spot cycle, when large spots may be expected to be frequently seen on the Sun, it may be well to call the attention of solar observers to some lines in the red end of the spectrum which the experience of the Stonyhurst observers has so far shown to be much widened in the spectrum of large spots. Many of these lines are faint lines, not recorded by Angström in his map, and accordingly require a high dispersion for their detection. The wave-lengths of lines which are given in the present paper are taken from a magnificent set of prints from enlarged positives of the region D to λ 6677, which have recently been presented to the writer by Mr. George Higgs of Liverpool, as specimens of the photographic studies of the normal solar spectrum on which he is at present engaged. These prints are on about one-third the scale of Professor Rowland's well-known maps, and are founded upon his wave-lengths. A careful comparison of the two maps over the region indicated has shown a perfect agreement in the wave-length numbers, so that possessors of Rowland's maps will be easily able to identify the lines presently to be mentioned. Much use, also, has been made of Mr. McClean's excellent comparative photographic spectra of the high and low Sun lately presented by him to the Stonyhurst Observatory. In the observations of Sun-spot spectra made at Stonyhurst, the full battery of twelve prisms of 60° in a Browning automatic spectroscope is generally employed.

Our plan will be to follow the spectrum from D to C, and to call attention to some salient points as we advance. For these notes are by no means intended to be exhaustive, but rather typical of what may be seen by a diligent observer,

---

* Communicated by the author.

even in this small portion of the solar spectrum. We begin with a double at λ 5978.0 and λ 5978.8, the former of which lines both Thollon's and McClean's maps show to be an air line, while the latter is a faint titanium line. A peculiarity noted in this line in Sun-spot spectra is that it is one of those which are most affected in the penumbra of spots. At times it has been traced as a widened line to a considerable distance on the disc. At λ 6042.4, 6056.2, 6065.8 and 6078.8 are four well-marked iron lines. Each of these lines is preceded by some faint lines of which λ 6040.0, 6053.95, 6063.1, 6077.1 are the most conspicuous. All these lines are solar lines, as both the maps of Thollon and McClean give them of the same intensity in both high and low Sun. Of the four faint companion lines to the iron lines Ångström only draws one, a line in his map corresponding to λ 6077.1. Yet this line is the faintest of the four, and my own experience is corroborated by the photographs of Higgs and McClean, and, except perhaps for the line λ 6040.0, by Rowland's chart. These faint lines are remarkably and persistently widened in Sun-spots, irrespective of size or period in the cycle.

Between the line 6079.2 and the triplet at 6102.9, of which the outer components are due to iron and the middle line to calcium according to Thollon, thus furnishing one among many examples of the resolution of a "basic" line, occurs a group of faint solar lines, the number of lines in which has been variously estimated by different observers. Of these faint lines two are due to iron, and two to titanium, the line of this latter metal at 6088.05 being frequently very much widened. At λ 6160.95 and 6161.4 occurs a double of which either one or both components are due to sodium. It just precedes a dark calcium line at 6162.3. If a moderate dispersion be employed these three lines will form but one and will be found to be greatly widened in spots. But when the three lines are separated by higher dispersion the widening in general is seen to be principally due to the sodium lines, which present at times quite the appearance of a fuzzy band.

The next point of interest is to be found in the neighborhood of the fine double iron line at λ 6191.4 and 91.7, which is followed by another strong iron line at 6200.5. In the intervening space the map of Thollon gives two groups each of three faint lines, groups which in this instance are rather better seen in Rowland's than in Higgs' map. The first of these groups ends with a line at λ 6196.4, and the second has a mean position at about λ 6199.5. In the instrument I have employed each of these groups has appeared as a single faint line, and of these the line representing the group at mean position 6199.5 has been very much widened. A fairly strong line at λ 6204.9 is also conspicuous in Sun-spots.

The group of lines extending between λ 6230 and the head of the *a* band contains several strong iron lines and a titanium line. These iron lines, especially those on each side of the comparatively bright gap in the spectrum, whether due to contrast or really bright, at 6250 are much widened in Sun-spots. It is to be noticed, however, that the strong lines at 6252.8, 54.3, and 56.4 are preceded by faint companions. Although I can just separate these companions from the stronger lines, in spots the widening is as of single lines, and it is not at all unlikely, from analogy with other parts of the spectrum, that the greater share of the widening may be due to these faint lines. A greater dispersion should show this. The question often arises as to whether changes have occurred in the solar spectrum since it has been studied and mapped with care. Comparison with Angström's normal maps brings to light several discrepancies with what is now to be seen in this portion of the spectrum. As an example we will select a fairly strong line which Angström draws, and which Burton in the British Association Catalogue for 1878 places at 6262.68, but for which he gives no intensity or width. On Rowland's scale the position of the line would be about 6263.68, but at this position there is no trace of a line either on his or Higgs' maps. I have looked for the line several times and have failed to see it. The only possible lines which occur between 6261.3 and 6265.3, the places of two other strong lines, are three faint lines, partly solar and partly atmospheric, which occur on Thollon's maps, Plate VI, No. 12, at scale readings 307.77, 308.43, and 310.38. These faint lines do not seem to be in Rowland's map; there is a slight suspicion of something at 6262.5 in a photograph of Higgs', solar altitude 48°, and a line is to be seen somewhat in this position in McClean's low Sun photograph. Either Angström made a mistake, or it may be possible that his strong line is represented by these approximately near faint lines.

But of all the Sun-spot lines in this region the most remarkable for widening is a faint line given by Rowland and Higgs at 6243.2 preceded by a very faint line at 6243.0. Angström does not give either line. The appearance of 6244.0 in Sun-spots led me to suspect the presence of 6243.2 in the solar spectrum. For at times 6244.0 seemed just as if it had been pricked on the more refrangible side and a bead of black matter had exuded. Either then 6244.0 was very much displaced, or the bead was due to the widening of a fainter line which I had so far failed to trace in the solar spectrum. The latter turned out to be the correct explanation. This line is on Thollon's chart at Plate VII, No. 13, scale reading 63.44, while the still fainter line at 6243.0 is at scale-reading 64.70. The lines are solar, for Thollon draws them of the same intensity throughout the four horizons of his map, and 6243.2 is also of the same intensity in McClean's high and low Sun photographs. My dispersion does not show me whether the widening is wholly attributable to 6243.2 or to this line and 6243.0 conjointly. On flashing a Sun-spot across the slit of a grating spectrometer of 14,438 lines to the inch and using the second order, it was possible to see that both these lines were widened.

The *α* band is full of very interesting details in Sun-spots, although it is greatly complicated by the presence of atmospheric lines. And this leads to a remark with regard to the possible cause of the widened appearance of telluric lines in Sun-spots, for such lines are to be seen among the lines thus affected by spots. When a fuzzy set of telluric lines are seen across a spot, one optical effect is that of widening, although, except in the case of bands of lines, this is not very marked. But the case we are considering is that of isolated telluric lines which are seen widened even when the Sun is at a good altitude above the horizon. This is probably due to the presence of a solar line so close to the air line that none but the greatest dispersion will separate them. Of such a composite nature is probably the line between the D lines at 5891.9 often seen widened in Sun-spots. The nickel line too between the D lines has a telluric companion so close that in a photograph of Higgs of the E and W limbs of the Sun, they form one line on the W limb picture, and are well separated on that of the E limb. In fact this observer has suggested the observing of telluric lines in Sun-spots as a further means, in addition to that of observing the lines for intensity at various solar altitudes, for determining the presence of faint solar lines which are exceedingly close to air lines. But to return to the *α* band. The two lines at 6305.95 and 6306.8 would well repay attention. Higgs' photographs of this portion of the spectrum are superb, especially one taken with a low Sun. With regard to these two lines a comparison of the observer's high and low Sun pictures show that they are at least in part due to our atmosphere. They are much darker, too, in McClean's low than in his high Sun photograph.

Turning now to Thollon, the lines are at scale-readings 139.96 corresponding to λ 6305.95, and 137.05 corresponding to λ 6306.8, on Plate VI, No. 12. But while 6305.95 is continued to the fourth horizon, showing that it is partly solar in origin, 6306.8 is terminated in the third horizon, indicating a purely telluric line. In the *Bulletin Astronomique*, Vol. I, p. 74, will be found a study by M. Cornu of the rays of this band, in which these two lines are attributed to oxygen in the Earth's atmosphere. Mr. Higgs also independently was led by his studies to attribute them to the same source. Curiously enough I too, before I had consulted any of these maps or Cornu's memoir, found that while 6305.95 was very greatly widened in some Sun-spots, 6306.8 was not widened at all. In Cornu's paper his method is described of determining the solar or atmospheric character of a line by oscillating the solar image across the slit. His result is that both these lines are air lines, and due to oxygen, thus differing from Thollon, who draws one as partly due to the Sun, which one was independently seen widened in Sun-spots. Is it possible, then, that there is a line in the Sun so close to the position of an oxygen line in our air, that neither Cornu's oscillation method nor the great dispersions of Thollon, Rowland and Higgs will separate them? With regard to the widening, however, it is just possible that a very faint line which Thollon gives at scale-reading 142.03, and which is λ 6305.6 on Higgs' and Rowland's maps, may, with the dispersion I employ, have some part in the result.

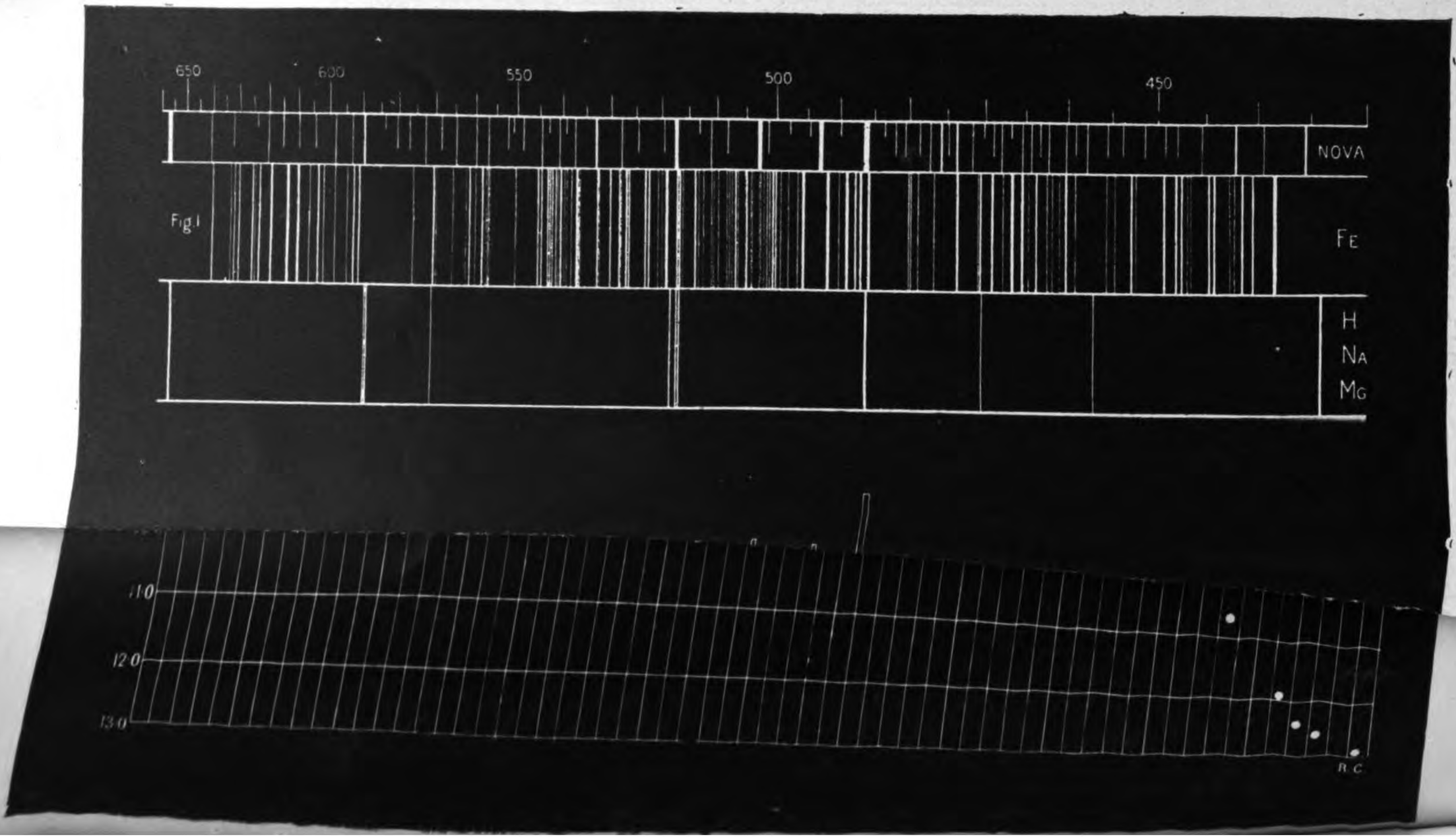
Telluric lines complicate the spectrum from this to C. For instance there is a group of five lines extending from 6361.05 to 6363.05, of which, as Mr. Higgs informs me, the first, fourth and fifth are solar, and the second and third are air lines. On Rowland's maps the three solar lines are well given, while McClean's map brings out the fact very well that the group is much darker in the low Sun. Yet Thollon, in Plate VI, No. 11, readings 254.47 to 246.92, draws them all of the same intensity throughout, so that according to this observer they are purely solar lines. In the large Sun-spot of September, 1891, I found the three solar lines affected, while the other two were not. Among the five lines is an example of a variable line at 5362.6, a zinc line which according to Mr. Lockyer had dropped out of the solar spectrum in 1873, although it was present in Kirchhoff's time. Angström has it at 6361.16, so has Burton, Rowland, Higgs, Thollon; so too probably has Fievez at 6361.2, and Piazzi Smyth. It was therefore in the Sun in 1861, 1868, 1878, 1882, 1884, 1888, and we may say ever since. In 1873 it had gone.

The region from this on to C is one that is very rich in spectroscopic details. There are several chromospheric lines of Young's catalogue to be found here, some strong iron and calcium lines at times much affected in spots, and also some faint lines which will well repay study. At λ 6415.2 and 6417.1 are two lines which I have observed on more than one occasion to be obliterated when they crossed a spot. This too is the region where the spot-bands were seen, similar to those previously discovered by Young and Maunder. The evidence so far collected would seem to indicate that their appearances in the spot-spectra are to be looked for at that period of the spot cycle when the curve has attained its maximum and has commenced its decline. Although my own observations since 1889 have been somewhat desultory, yet in such observations as I have been able to make I have not seen these bands since the well-marked drops in the Sun-spot curve in 1886.

In large Sun-spots the C line is always an object of interest, and no very great dispersion is needed to observe its changes. The Stonyhurst observations would seem to show that in spots, or in their neighborhood, it is generally when not reversed less dark, or if widened, only slightly so. Reversals too are to be expected both in the umbra and in the penumbra, and in the faculæ surrounding spots. In this connection we would offer in concluding these notes a remark with regard to the interesting observations of Professor Hale and Dr. Crew on the C line in the big spot of February, 1892. (ASTRONOMY AND ASTRO-PHYSICS, April, 1892.) Considering the difference in dispersion employed by the American observers and by myself I am induced to think that the appearance which I observed in the spot of September, 1891, and which was reported in the "*Observatory*" for November, 1891, as a thin hair-like line adhering to the C line, turned towards the red, and forming an angle of about 30° with the C line, was a very similar appearance to that observed by Dr. Crew and Professor Hale in the February, 1892, spot. With regard too to the lines, possibly three on Rowland's map, which occur between C and the iron line at λ 6569.3, and across some of which the appearance extended, both Higgs' photographs and Thollon's maps show altogether seven lines. Two of these are quite close up to C, and one of them is well shown on Rowland's map. Of the other five one is slightly in advance of the iron line. The four remaining lines are very faint lines given by Thollon, Plate V, No. 9, between the readings 181.98 and 190.98, and drawn of equal intensity in all four horizons, thus indicating their purely solar origin. But while on Higgs' maps three of these four lines are

PLATE 23.—SPECTRUM, INTENSITY-CURVE AND MAGNITUDES OF NOVA AURIGÆ, 1892.

ASTRONOMY AND ASTRO-PHYSICS, No. 107.



just traceable at solar altitude 45°, the same three are well marked and the fourth is visible at solar altitude 13°. Referring to McClean there are no lines between C and the iron line in the high Sun photograph, but the three well marked lines of Higg's low Sun photograph are also quite black and conspicuous in McClean's low Sun map. Photography would then indicate that these lines are partially, if not wholly, air lines.

STONYHURST OBSERVATORY, April 22, 1892.

ON THE NEW STAR IN THE CONSTELLATION AURIGA.*

PROFESSOR RALPH COPELAND, ASTRONOMER ROYAL FOR SCOTLAND.

Together with Observations of the Same by Dr. L. Becker.

(Read 15th February, 1892.)

The discoverer of Nova Aurigæ is the Rev. Thomas D. Anderson of Edinburgh, D. Sc. in Classical Philology. Dr. Anderson is "almost certain" that he saw the star at 2 A. M. on January 24 of this year; it was then slightly brighter than χ Aurigæ. Unfortunately he mistook it for 26 Aurigæ, which it precedes by about $6^m\ 39^s$, merely remarking to himself that the star was brighter than he had previously thought it to be. Twice in the following week he made the same observation at about the same hour of the night. At last on the morning of January 31, it flashed upon him that, after all, the star was not 26 Aurigæ, and that 26 Aurigæ had a much greater right ascension. He consulted a small star map, and the discovery was made. Regretting that he had not earlier compared the map with the heavens, and thinking that the star might be well known to astronomers, Dr. Anderson wrote an anonymous post card to me on the same morning bearing the words: "Nova in Auriga. In Milky Way, about two degrees south of χ Aurigæ, preceding 26 Aurigæ. Fifth magnitude, slightly brighter than χ." I may add that Dr. Anderson's plant consists of a small hand spyglass adapted to astronomical purposes by removing the front pair of lenses from the eyepiece. In this state it magnifies about ten times, and, of course, gives inverted images. Dr. Anderson hopes that amateurs, although provided with only the most modest appliances, may, by his unexpected success, be induced to persevere in their observations.

I have examined a large number of star maps and catalogues,

---

* Communicated by the author, by permission of the Royal Society of Edinburgh.

ancient and modern, without finding any previous record of the new star. Several stars are mentioned by Sufi as being visible in the tenth century which we cannot now identify, but they seem certainly to have no connection with the Nova. The two stars named "the Shaker," and "the excellent Milch Camel" may, however, possibly be identified by a study of certain Arabian authors referred to by Sufi.

As to our observations of the Nova at the Royal Observatory, its place has been found by differential methods by Mr. Heath, First Assistant Astronomer, using the transit instrument, and by Mr. J. A. Ramsey, student of astronomy, observing with the Mural Circle. The mean coördinates for 1892.0 derived by them are:—

R. A. = $5^h\ 25^m\ 3^s.25 \pm 0^s.02$ (9 obs.).
Decl. = $+\ 30^\circ\ 21'\ 48''.76 \pm 0''.09$. (7 obs.).

Already on the night of February 1, a small spectroscope revealed the presence of bright lines, of which some account was at once telegraphed to the Central Station for Astronomical Telegrams at Kiel, and also to the President of the British Association, Dr. W. Huggins. Already in the daytime, before the star was visible, a message had been forwarded to Greenwich Observatory.

The remarkable nature of the star's spectrum once established, Dr. Becker immediately set about packing the most suitable apparatus to take to Dunecht, where the 15-inch refractor is fortunately still in perfect adjustment. Meanwhile I arranged to keep a record of the stars magnitude, and try what could be done with the apparatus at Calton Hill. Owing to the great loss of light in the universal spectroscope of the 24-inch reflector, it soon became evident that only a few of the very brightest lines of the spectrum could be measured therewith, while it was impossible when using it to obtain a good general idea of the spectrum and its possible changes. Eventually I returned to a small instrument of Vogel's pattern, which had proved useful on former occasions.* With it were obtained on February 9, a set of measures which eventually yielded the following rough approximations to the positions of the principal bright lines in the spectrum of the Nova:—

---

* See *Copernicus*, vol. ii. p. 105,for a description of this instrument.

Wave-length. mmm.	Relative Brightness.	Remarks.
657.1	10	*C.*
645	...	Edge of black band extending from *C.*
594.2	2	Possibly an inaccurate place of D.
562.1	3	
534.5	6	
519.3	10	Possibly carbon band or magnesium.
503.2	5	Bright band near nebular line but not identical therewith.
495.25	3	Near nebular line, but also distinct therefrom.
487.1	4	*F.*
450.8	1	Extremely faint; place very uncertain.

Respecting the brightness or "magnitude" of the star there is a telegram from Professor Pickering of Harvard College, Cambridge, Mass., dated February 5:— "Nova bright on photograph December tenth, faint December first, maximum December twenty, spectrum unique." This is understood to mean that the star could be detected on a photograph taken on December 1, that it was brighter on December 10, and brighter still on December 20. At least this is the very probable reading offered by Professor Krueger of Kiel. So far as is known, there is no certain record of the star's having been seen or photographed previous to December 1, 1891. A faint star seen by Krueger near to the spot, 1858, March 23, in one of the revisional zones of Argelander's Atlas, has been identified in the heavens near to the Nova. Then we have Dr. Anderson's observations, Jan. 23 to January 30—Nova slightly brighter than χ Aurigæ, 4.8 magnitude.

From February 1 to 11, I have a complete set of estimations. These indicate a maximum about the 7th or 8th. [Compare the curve in fig. 3 and the table on page 2, which have been extended so as to include the subsequent observations.] Not one of the four Novæ of modern times has exhibited a curve of this character, at least as far as one can judge from the present available data for Nova Aurigæ.

From Dr. Becker I have received the most satisfactory results, derived from observations made on February 3, 4, and 5, and again on the 10th and 11th. [These results were exhibited to the Society in a graphic form, but it is here preferable to give Dr. Becker's written account of the observations as received from him on February 16.]

Observations of the Bright Lines in the Spectrum of Nova Aurigæ, made at Dunecht by Dr. L. BECKER.

The day after the discovery of the new star was announced, I left for Dunecht Observatory in order to observe its spectrum with the 15-inch refractor. The large spectroscope by Cooke, with a collimator 24 inches in length, having already been removed to Edinburgh, I employed in my observations the smaller spectroscope by Grubb, the same with which Professor Copeland had made the greater part of his former observations. The collimator of this instrument has 7 inches focal length, and an effective pencil of light 0.6 inch in diameter; the viewer is 10 inches in length, and turns by a worm-screw with a divided head working against a sector which can be clamped to the prism-box. The prism is kept in a fixed position. In these observations a compound prism was used at the minimum deviation for *b*. On the first night, February 3, a power of 14 diameters was used but on the following nights one of 7. For comparison I employed the sodium and lithium lines, and the lines of the zinc-lead spark spectrum, as produced by a five inch induction coil in connection with a Leyden-jar. The light from the spark passes through a lens, and is reflected to the upper and lower part of the slit by a small silver mirror, which is fixed in front of the slit and has an opening for allowing the light from the object-glass to pass. The same battery which works the coil serves to illuminate the field of view by reflection from the last surface of the prism, and also to produce bright wire illumination. By means of a small rheostat, which is clamped to the sector, the light may be moderated, while a switch enables the observer to put either the incandescent lamps or the coil into circuit. This arrangement, which I introduced in the last weeks of my stay at Dunecht in 1889, is very convenient if the observer has to observe without assistance. In reducing the observations to wave-lengths (Potsdam system) I first determined, once for all, 4 constants of Ketteler's formula of dispersion from measures of four solar lines equidistant between A and H, and computed a table giving the wave-length as a function of the readings of the screw. The deviations of this curve from the one given by the observations of solar lines are so small that they may be determined with great accuracy by the graphical method. The lines of the spark spectrum were measured along with the solar lines, the latter being at the center part of the slit, the former below and above. Although the values of their wave-lengths thus determined are erroneous by the amount of curvature of the lines, they have to be employed in the reductions of the star observations in order to reduce the lines of the stellar spectrum to wave-lengths.

In the night observations I measured at the beginning and end of each set the prominent spark-lines in the part of the spectrum under observation, always turning the screw in such a manner that the viewer moved opposite to the direction of gravity.

Their readings thus being known, I could then also pick them up while observing the stellar lines without being obliged to turn the screw in the opposite direction. The first observations serve to correct the reduction-table, the second to determine the changes of the zero point. Since the spectroscope is not rigid enough for taking several pointings of one line, without observing each time the spark spectrum, I measured through one region of the stellar spectrum without turning back. For this reason all the observations of any one line are quite independent. Almost all the measures were taken in bright field illumination. It is needless to say that the observations of most of the lines were very difficult, but I have not the least doubt that those repeatedly observed refer to real bright lines, and are not merely an effect of contrast produced by dark lines on the continuous spectrum. There are 302 observations, belonging to 71 lines, made on February 3, 4, 5, 10 and 11. Afterwards I made arrangements for photographing the spectrum, but the sky did not clear up before my return to Edinburgh.

The mean values of the wave-lengths λ and their intensity I (where 1 stands for faint, 6 for very bright) are:

1892.	No. of Obs.	λ	I	1892.	No. of Obs.	λ	I
Feb. 4. 5. 10	5	657.0	5	Feb. 4. 5	5	540.7	3
" 3. 4. 10	5	640.5	3	" 5	1	539 ±	1
" 4. 5. 10	4	632.5	2	" 4. 5	6	537.4*d*	3
" 5. 10	2	624 ±	1	" 3. 4. 5	6	533.0*	4
" 4. 10	3	620.3	2	" 3. 4. 5	5	528.0	3
" 3. 5. 10	6	615.1	2	" 3. 4. 5	6	524.6	2
" 3. 4. 5. 10	5	609.9	2	" 3. 5	3	519.6	2
" 3. 5. 10	7	604.7	2	" 3. 4. 5. 11	8	517.45 ± 0.12†	5
" 3. 4. 5. 10	7	598.5	3	" 3	1	513 ±	1
" 3. 4. 5. 10	8	593.4	3	" 3. 4. 11	4	511.1	2
" 3. 4. 5	13	589.7 ± 0.15	4	" 3. 4	2	508.2	2
" 3. 4. 5	4	583.8	1	" 3. 4. 5. 11	6	502.68 ± 0.11‡	5
" 3. 5	3	580.5	2	" 4	1	501 ±	2
" 4. 5	3	577.1	2	" 4. 11	2	497.9	1
" 4. 5	3	572.9	3	" 3. 4.	2	494.7	1
" 3. 4. 5	4	568.7	2	" 3. 4. 5. 10. 11	6	493.17 ± 0.17‡	5
" 3. 4. 5	4	564.9	3	" 3	1	490 ±	1
" 3. 4. 5	5	560.0	3	" 3. 4. 5. 10. 11	9	486.88 ± 0.08‡	6
" 3. 4. 5	6	557.0	3	" 10	1	483.6	1
" 3. 5	5	552.4	2	" 3. 4. 5. 10. 11	6	482.0	2
" 4	2	551.0	1	" 4. 5	2	480.7	2
" 3. 4	3	548.8	2	" 3. 4. 10	3	478.8	2
" 3. 4. 5	6	544.6	3	" 4. 5. 10. 11	6	477.4§	3
" 4	1	543 ±	1	" 4. 5. 10	4	475.7	4

* Many close lines in this part of the spectrum, of which this is the most prominent.

† On Feb. 10 it was recorded that the bright line 517.4 was very broad, and that the intensity fell off gradually towards the red, while it was cut off abruptly at the more refrangible edge.

‡ It was noted on Feb. 3 that the three lines, 502.7, 493.2, and 486.9, "look as if they are double." On Feb. 4 the line 493.2 is entered as the "middle of two lines."

"Dark spaces between the very bright lines" were seen on every night of observation from Feb. 3 to Feb. 11.

§ More lines in this place.

1892.	No. of Obs.	λ	I	1892.	No. of Obs.	λ	I
Feb. 10	2	474.8	2	Feb. 4, 5, 10	6	459.1	2
" 3, 4, 5, 10, 11	7	473.7	4	" 4, 5, 10	9	457.8	3
" 10, 11	5	471.7	3	" 4, 5	3	455.4	2
" 5, 11	2	470.2	1	" 4, 5	4	453.8	2
" 4, 10	3	469.0	2	" 4, 5	3	451.4	2
" 5, 11	3	468.0	2	" 5	1	449.2	1
" 5, 10	3	466.8	1	" 5	2	448.0	2
" 4, 5, 10, 11	6	465.4	3	" 4, 5	3	445.5*d*	3
" 5, 10, 11	5	464.3	3	" 4, 5	5	442.1	4
" 4, 10	4	463.3	2	" 5	3	439.4	3
" 5, 11	3	462.3	3	" 5	4	435.5	4
" 4, 5, 10, 11	5	460.2	3				

The lines marked *d* are double. All the measured lines are shown in fig. 1, where the fainter grades are indicated by shortening the lines. In fig. 2 an attempt has been made to represent the relative intensity of the various parts of the spectrum.

In the spectrum the sodium line (D), and the two hydrogen lines C and F, are present; Hγ is very probably 435.5, which was just at the limit of visibility. All these lines show a decided shift towards the red, from which I find the following velocity of the body per second relatively to the solar system:—

C, + 211 miles, D, + 135 (±47) miles, F, 290 (±31) miles.

The very bright line 517.45 lies within the magnesium lines b_1, b_2, b_4, and, considering the shift of the lines, lies close to the iron lines b_3, b_4. However, the great intensity of the line compared with that of the other lines of the spectrum, if iron be supposed to be present, also the gradual falling away of the light towards the red, are in favor of magnesium. The remaining two bright lines are not the nebulous lines.

As the great intensity of the spectrum in the green, due to numerous lines, many of which I was not able to measure, suggests the presence of iron in the Nova, I have entered in the second line of the diagram the most prominent lines of the iron arc-spectrum for the sake of comparison. Although a number of the lines fall together with those of the Nova, one cannot lay much stress upon those coincidences, owing to the great number of lines in iron and the Nova scattered over the whole visible spectrum.

It is noteworthy that some of the brightest lines given above were observed by me at Dunecht in the spectra of R Andromedæ and R Cygni on October 28, 1889, on an intimation by the Rev. T. E. Espin that the F line appeared bright in the spectra of these stars. Although the observations of these stars could not be completed on account of my removing to Edinburgh shortly afterwards, I give the wave-lengths of all the brighter lines in their spectra, all of which, it will be seen, agree closely with prominent lines in the spectrum of the Nova. R Andromedæ was observed the with slit rather open.

R Andromedæ.		R Cygni.		Nova Aurigæ.	
λ	Intensity.	λ	Intensity.	λ	Intensity.
......	......	532.3	4	533.0	4
528.6	3	528.9	3	528.0	3
517.1[*]	4	517.0	4	517.4	5
494.5	4	......[†]	......	493.2	5
486.7	6	486.0	6	486.9	6

Postscript added 14th March, 1892.

The new star still continuing bright enough to be observed with the spectroscope, I returned to Dunecht on February 24, but was very unfortunate with the weather. On March 4, I found that the intensity of the spectrum had much decreased, but that the bright lines were still easily seen. From C to 550 I again measured all the brighter lines, while between 550 and F I obtained almost every line that is given above. Thirty-eight lines in all were re-measured, but the results are not combined with those already given. Beyond F the light was too faint for measuring. The results agree with the earlier ones as closely as the size of the spectroscope entitles one to expect. The power 14 was employed. The intensity of some of the lines relatively to each other appeared to be changed. Certainly F was no longer the brightest line, the line 517.5 considerably surpassing any of the others. I was not able to detect any narrow dark lines which had been announced in the meantime, but I measured the middle of the dark spaces to the violet of some of the brightest lines, which formerly I had attributed to the effect of contrast. The wave-lengths of the brightest lines in the green-blue, and their relative intensities (the brightness in February is given in parentheses), were observed as follows:—

Number of Observations.	λ	Intensity.	Remarks.
2	533.4	4 (4)	
2	528.7	4 (3)	
2	524.6	4 (2)	
2	517.5	6 (5)	
2	502.7	5 (5)	Breadth, 0.5
......	501.2	......	Middle of dark space; breadth, 2.0.
3	493.0	4 (5)	Dark bands to the red and violet.
5	487.1	4 (6)	
......	484.8	......	Middle of dark space; breadth, 3.6.

---

[*] A companion on either side 1.5 mmm off. [†] One very bright line missed (according to note-book) near F towards the red.

Further Remarks on Nova Aurigæ. Professor RALPH COPELAND.

(Communicated 21st March, 1892.)

The most remarkable additional fact that I have to communicate is a sudden diminution in brightness that seems to have set in about the 7th of March. Throughout the month of February the Nova exhibited continual and irregular changes of brightness, which are shown by the dots in the diagram. The state of the sky was unusually favorable during the earlier part of February, and later on still offered occasional opportunities of comparing the star with its neighbors. Unfortunately, on March 8, I had the misfortune to lose the very fine binocular that had up to that time been used in these observations. Hoping that it might be recovered, and not apprehending that any very surprising change in the star's brightness was about to occur, I did not attempt to replace it until the 18th, when, on examining the heavens with a good opera-glass, I was unable to identify the star. It was, however, readily found with a 3¼-inch refractor, but had declined to the 8.6 magnitude. [See fig. 3, and the table on page 601.] On the 19th it had lost a further $0^{m}.3$, while last night it had so far faded as only to be of the 9.1 magnitude. We thus see that on February 7 the Nova was about 132 times as bright as it was last night. Its brightness on the 8th and 20th are in the ratio of 14 to 1.

Last night, March 20, Nova being about one magnitude brighter than the small star close to it, which was observed at Bonn 34 years ago, it was still practicable to analyse its light with the small spectroscope. The spectrum was strongly continuous in the yellow, green, and blue, with several intenser parts that probably represented bright lines. No trace of the bright C line, formerly so conspicuous, could be made out. It does not seem, at present, that the spectrum is likely to become reduced to a single bright line as was the case with the Nova of 1876, but it seems rather to resemble the continuous spectrum of Nova Coronæ, as it appeared in 1866, when the bright lines were superposed on the continuous spectrum.

Note added April 17.

The further history of this star, as seen in the Edinburgh reflector, is one of steady and continued decline. The magnitudes on the days of observation are given below until April 1, when it was seen for the last time. The place was examined in a hazy sky on April 14, and again on the 18th, when the night was clear, with the exception of a little inevitable smoke; on neither of these occasions was a trace of the star discernible. Its spectrum was "continuous with traces of dots" on March 25, the star being estimated of the 10.7 magnitude. The brighter magnitudes have been apportioned in accordance with the *Durchmusterung* and some Harvard measures. The fainter part of the scale has been formed on the assumption that the "Bonn star" is 9^{m}.9, while the small star, which forms an equilateral triangle with it and the place of the Nova, is set down as 12^{m}.7.

On March 28, when it had fallen to 11^{m}.9, it could no longer be seen through a prism which gave a distinct spectrum of the neighboring 9^{m}.9 Bonn star. Hence we may certainly conclude that on this day the light of Nova Aurigæ was far from monochromatic, or it would have been visible through a prism.

Observed Magnitudes of Nova Aurigæ.

Day.	Hour.	Mag.	Comparison Stars and Remarks.	Inst.
1892	h			
Feb. 1	6.1	5.56	26 Aurigæ; Nova strong yellow. Image strictly stellar afterwards in the 24-in. telescope.	F.G.
" 2	8.1	5.56	26. Nova seen with naked eye.	"
" 3	9.4	5.13	26 and χ Aurigæ.	"
" 4	8.1	5.0	χ.	"
" 5	7.3 to 9.8	4.65	26 and χ.	"
" 6	6.5 and 7.8	4.55	χ.	"
" 7	12.0	3.80	χ, moon very near; Nova seen with unaided eye.	"
" 8	6.0 and 11.1	4.09	26 and χ.	"
" 9	7.8	5.03	26 and χ.	"
" 10	8.8 and 11.1	5.0	26 and χ.	"
" 11	10.0	5.0	χ.	"
" 16	8.3 and 8.8	5.87	26 and D.M. + 30° 898.	O.G.
" 17	6.9 to 12.2	5.43	26, 898, and χ; Nova certainly brighter than last night.	F.G.
" 18	7.8 to 12.4	5.38	26 and χ.	"
" 19	8.3 and 9.2	5.10	χ.	"
" 22	11.1	5.76	χ.	"
" 29	7.9	5.76	26.	"
Mar. 5	9.6	5.58	χ.	"
" 8	9.7	6.26	26.	O.G.
" 18	8.9 and 9.3	8.58	D.M. + 30° 912 and 913.	3¼ in.
" 19	9.8	8.9	913 and + 30° 932.	"
" 20	9.0 and 9.5	9.1	913, 932, and Bonn star of 1858.	3¼ and 24 in.
" 23	9.4	9.7	Bonn star.	24 in.
" 24	11.6	10.0	Bonn star.	"
" 25	10.8	10.7	Bonn star and *p** of a pair *sf* = f.	"
" 28	8.7	11.9	f and faint star of triangle = g.	"
" 29	9.0	12.4	g.	"
" 30	9.0	12.6	g.	"
Apr. 1	9.1	12.9	g and next * to *s*.	"

The instruments used were F.G., a large field-glass; O.G., two different opera-glasses; a 3¼-inch refractor by Cooke, with a power of 27; and, lastly, the 24-inch Grubb reflector and a power of 138. The silvering of the last-named instrument is at present somewhat thin and imperfect.

THE ULTRA-VIOLET SPECTRUM OF THE SOLAR PROMINENCES.

II.

GEORGE E. HALE.

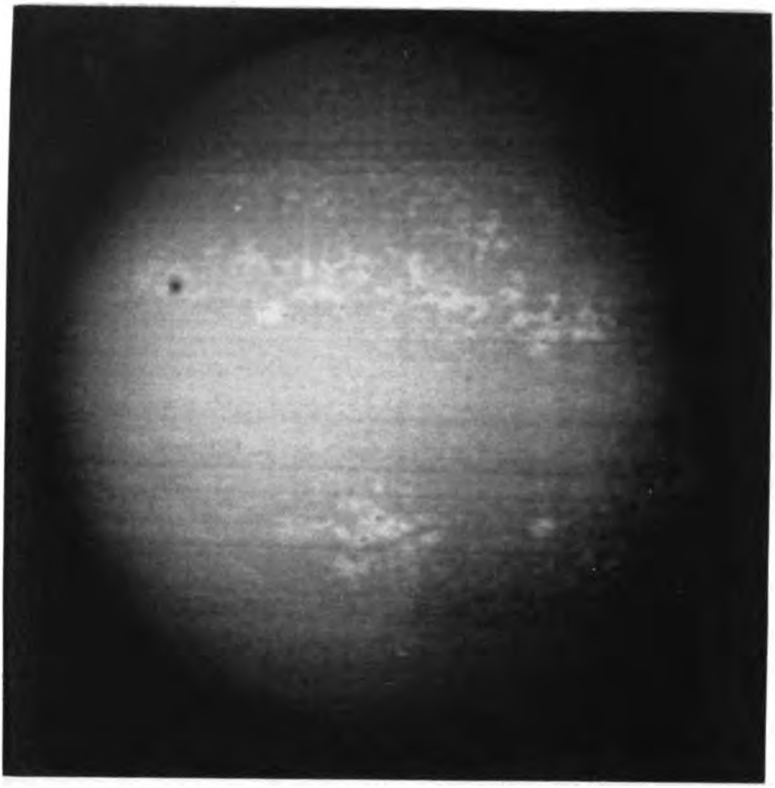
In a paper presented at a meeting of the Paris Academy of Sciences on June 13, 1892, I gave a list of the bright lines obtained in a photograph of the spectrum of a metallic prominence taken at the Kenwood Observatory on May 25, 1892. The photograph shows all lines hitherto discovered in the ultra-violet prominence spectrum (with the exception of a few of the most refrangible, which could not be obtained with the visual objective of the equatorial), and, in addition, four lines not before known. These new lines are marked with an asterisk in the following table:

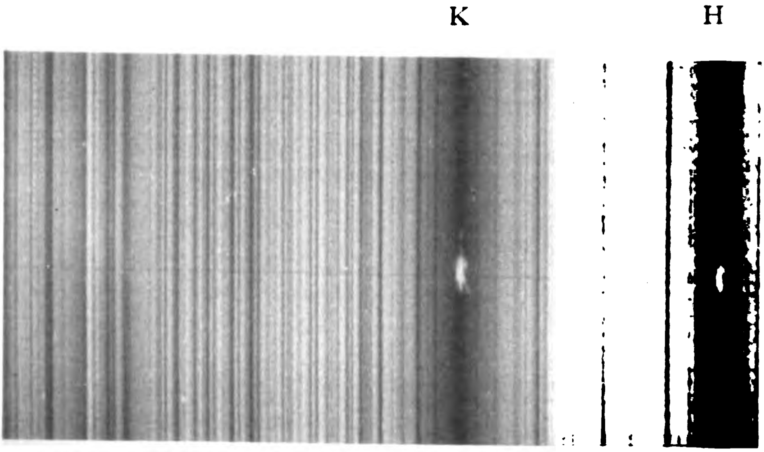
λ *Lines.*	*Elements.*	λ *Lines.*	*Elements.*
3970.2	Hydrogen (ε)	3835.54	Hydrogen (β_1)
3968.56	Calcium (H)	3832.5	Magnesium
*3961.7	Manganese?	3829.5	"
3933.86	Calcium (K)	3798.1	Hydrogen (γ_1)
*3900.7		3770.8	" (δ_1)
3889.14	Hydrogen (α_1)	3761.4	
3888.73		3759.3	
*3886.4		3750.2	Hydrogen (ε_1)
*3860.0	Iron?	3734.2	" (ζ_1)
3838.4	Magnesium		

A new photographic objective (12 inches aperture) has just been completed by Brashear, and mounted on our equatorial, and by its means I hope to add many new lines to the number now known to be present in the ultra-violet spectrum of metallic prominences.

KENWOOD ASTRO-PHYSICAL OBSERVATORY,
Chicago, July 11, 1892.

PLATE XXIV.

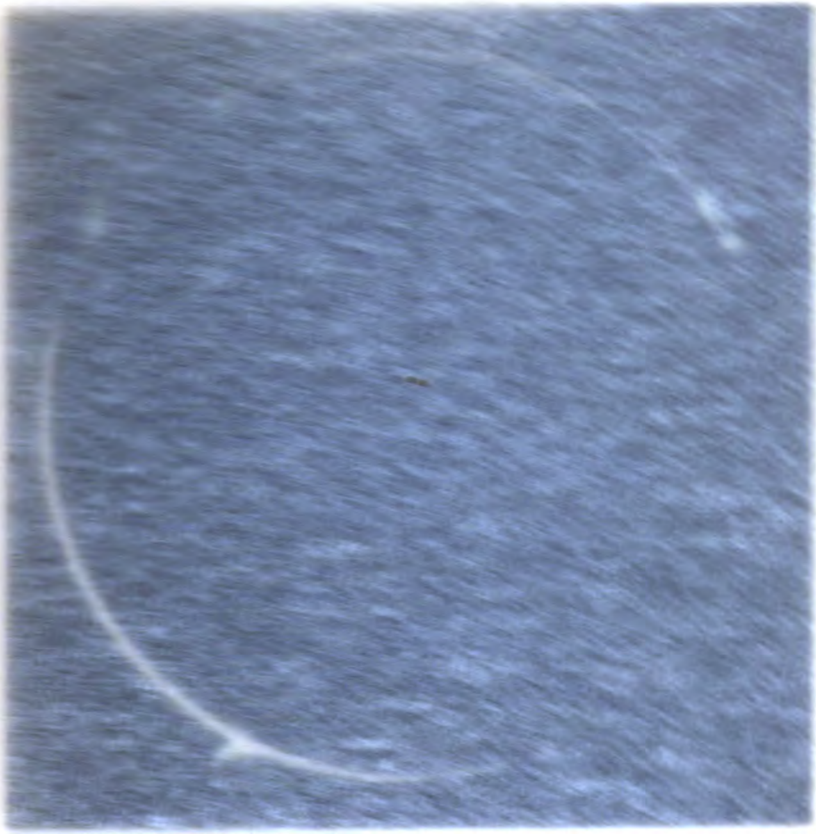


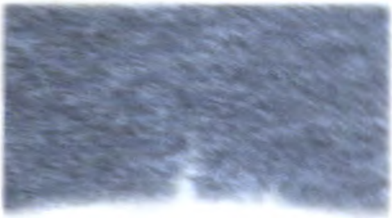


Photographs made with the Spectroheliograph of the Kenwood Astro-Physical Observatory, Chicago, by George E. Hale.

1. *Fac Sun-spots.* (*May 21, 1892.*)

the Spectrum of a Prominence. (*May 6, 1892.*)



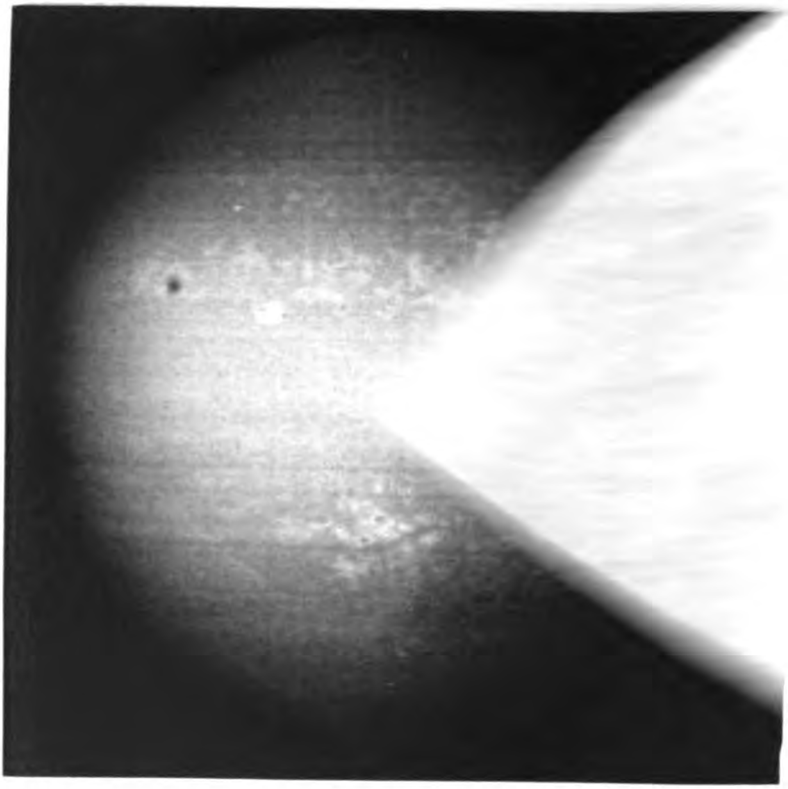


[illegible]

Observatory, Chicago, by [illegible] Hale.

1 Chromosphere an [illegible] (M. [illegible]

2 Solar Prominenc [illegible] 92 [illegible]

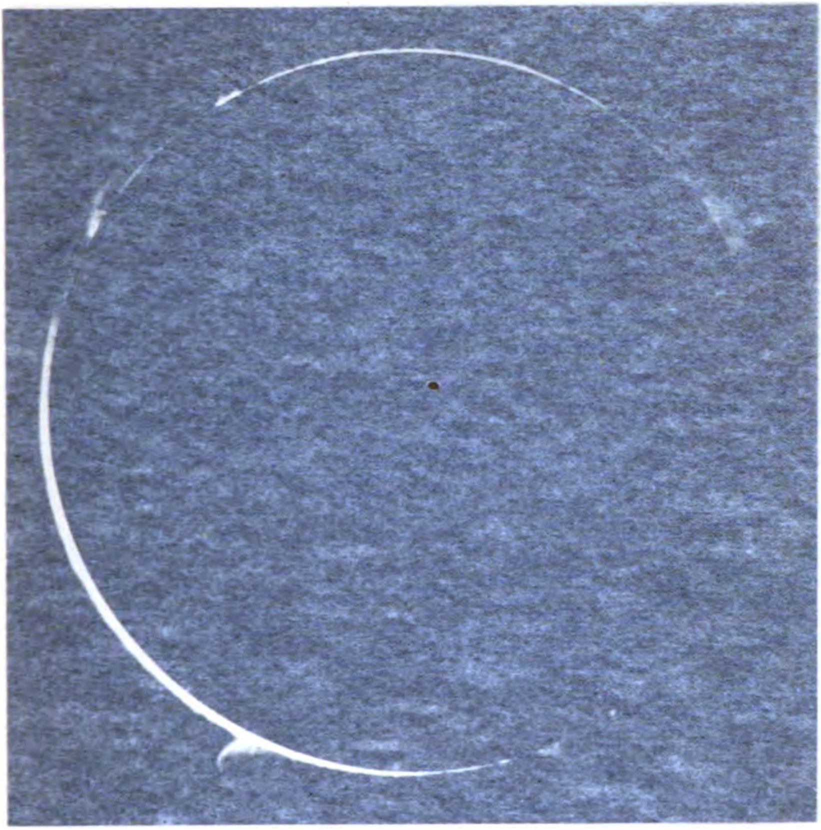


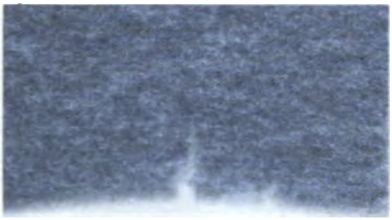
Photographs made with the Spectroheliograph of the Kenwood Astro-Physical Observatory, Chicago. by George E. Hale.

1. *Faculæ and Sun-spots.* (*May 21, 1892.*)

2. *H and K Lines in the Spectrum of a Prominence.* (*May 6, 1892.*)

PLATE XXV



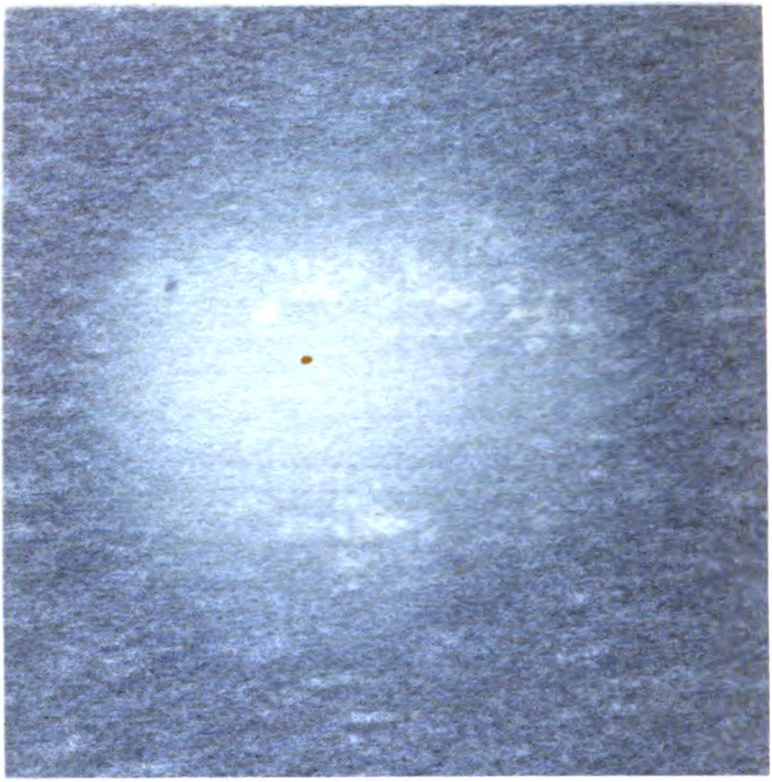


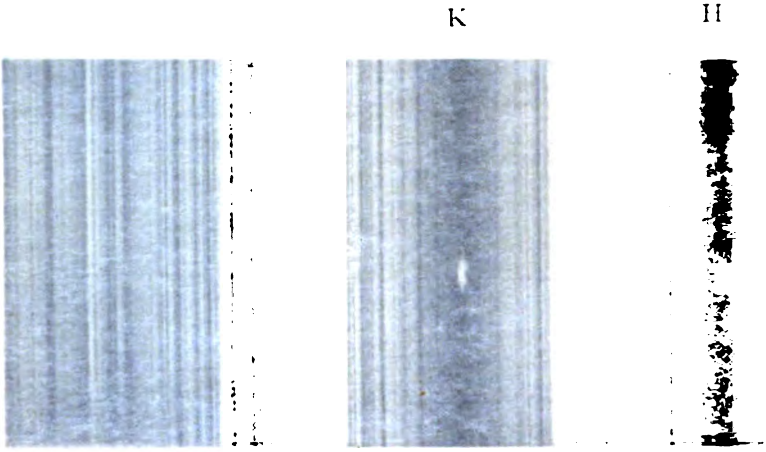
Photographs made with the Spectroheliograph of the K
Observatory, Chicago, by George E. H

1 *Chromosphere and Prominences.* (*May 21, 189*

2 *Solar Prominence.* (*March 24, 1892.*)

PLATE XXIV



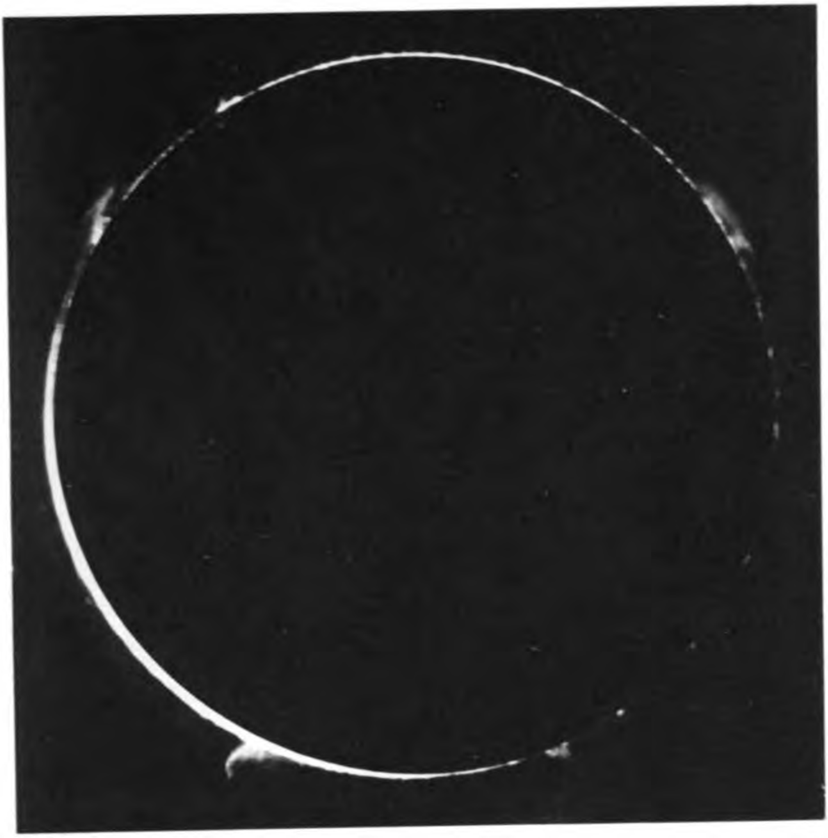


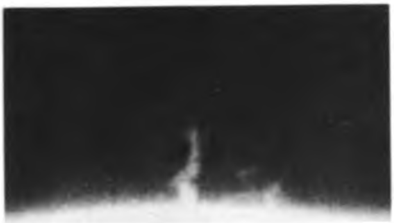
Photographs made with the Spectroheliograph of the Kenwood Astro-Physical Observatory, Chicago, by George E. Hale.

Faculæ and Sun-spots. (*May 21, 1892.*)

and K Lines in the Spectrum of a Prominence. (*May 6, 1892.*)

PLATE XXV.



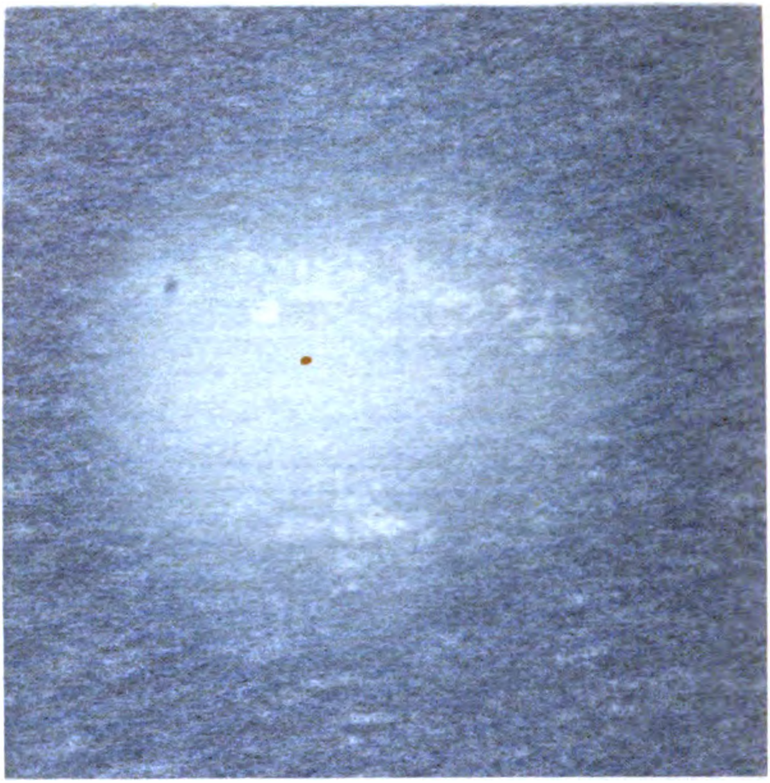


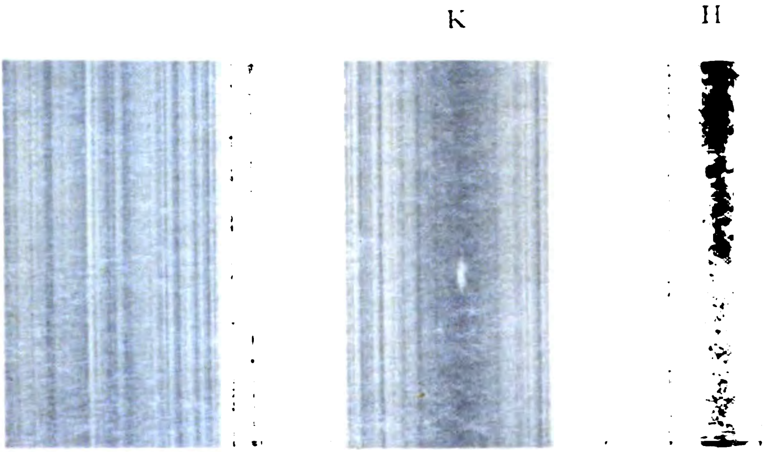
Photographs made with the Spectroheliograph of the Kenwood Astro-Physical Observatory, Chicago, by George E. Hale.

1. *Chromosphere and Prom* (*May 21, 1892.*)

2. *Solar Prominence.* (

PLATE XXIV





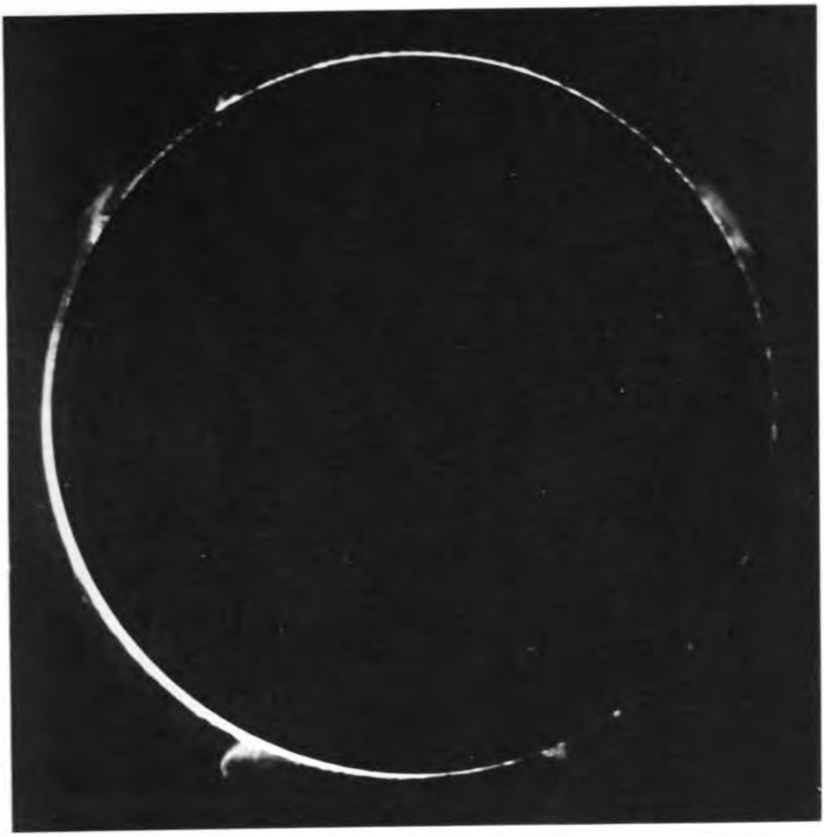
Photographs made with the Spectroheliograph of the Kenwood Astro-Physical Observatory, Chicago, by George E. Hale.

1. *Faculæ and Sun-spots.* (*May 21, 1892.*)

2. *H and K Lines in the Spectrum of a Prominence.* (*May 6, 1892.*)

[illegible] ASTRO-PHYSICS, No. 107

PLATE XXV.



Photographs made with the Spectroheliograph of the Kenwood Astro-Physical Observatory, Chicago. by George E. Hale.

1. *Chromosphere and Prominences.* (*May 21, 1892.*)
2. *Solar Prominence.* (*March 24,* [illegible])

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

single exposure, as the time required to bring out the prominences is much too long for the faculæ. The diaphragm covering the Sun's image at the focus of the equatorial is therefore employed as usual, and the slits are made to move across at the speed required for the prominences. At the end of the stroke the diaphragm is removed, and the slits made to move back over the image at a much higher speed by adjusting the valves of the clepsydra. An image of the Sun's surface, with the faculæ and spots, is thus formed on the plate exactly within the image of the chromosphere formed during the first exposure. The whole operation is completed in less than a minute, and the resulting photographs give the first true pictures of the Sun showing all of the various phenomena at its surface.

KENWOOD ASTRO-PHYSICAL OBSERVATORY,
Chicago, July 11, 1892.

NOVA AURIGÆ.*

WALTER SIDGREAVES.

A short account of the Stonyhurst College Observatory in connection with the subject of this paper will help to explain the long delay in publishing the map of the spectrum of the temporary star in Auriga, and may be of interest to the readers of ASTRONOMY AND ASTRO-PHYSICS, many of whom were well acquainted with its late director, Father Perry.

In pursuance of his desire that stellar spectroscopy should be added to the work of the Observatory, a long series of experiments with three spectroscopes has been carried on during the last two years, with the view of deciding which of them would be the most serviceable, and whether the work could be undertaken with any reasonable hope of contributing to the subject from the small optical power of an eight-inch refractor.

The experiments were commenced with eye observations, using a very superior stellar spectroscope constructed by Mr. Hilger, and fitted with every mechanical aid that could be desired by a spectroscopist struggling to see and to locate barely visible lines in a feeble spectrum. But it was found that only with the best atmospheric conditions for optical calmness any reliable measures could be made, and the eye experiments soon gave place to those of the photographic plate. The plate showed itself com-

---

* Communicated by the author.

paratively indifferent to the scintillations that troubled the eye, and gave better promise of continuous work.

These experiments included the two methods of giving breadth to the spectrum:—by a cylindrical lens at various positions, and by trailing the star's image over the plate both along the slit and without a slit. They proceeded slowly as each exposure was necessarily long, many repetitions were needed for each adjustment, and the unusual cloudy condition of the sky during the past two years afforded few opportunities for advancing the work.

Eventually the method of trailing without a slit became the one always followed, and the spectroscope selected was a direct vision spectroscope of two compound prisms made by Hilger for service on one of the recent expeditions for observing a solar eclipse. One of the prisms was removed and the reduced dispersion made it possible to obtain an impression of the spectrum of β Lyræ that was quite readable under the microscope.

It was then necessary to find the proper inclination of the plate to suit the focal positions of the series of rays between D and H, the extreme limits of the spectrum obtainable. And this operation occupied all the available nights between the beginning of June and the end of September, 1891. There was not space enough between the extremity of the ocular tube and the position of the focus for a camera provided with an angular adjustment of the plate-holder, and it was necessary to separate the holder from its adapter by a slotted wedge of hard wood. The angle of the wedge was estimated from the measured difference of the focus of *b* and G; but it was found to be much too small, probably on account of the ease with which the eye adapted itself to the different conditions of seeing by green and by blue light. Four wedges had to be tried before the exact angle was obtained. The final result was very satisfactory, the focus appearing uniformly good all along the spectrum from near D to near H.

The angular adjustment of the plate became, by means of the wedge, an unchangeable fixture. And the carrying tube was secured at the position to show G in the middle of the visual field. So that no alteration of the adjustments could be accidentally introduced.

The instrument was thus ready for work four months before the new appearance in Auriga. A number of impressions had been obtained of the spectra of some of the brighter stars, and a series of plates of the variable spectrum of γ Cassiopeiæ. β Lyræ had also been tried, and the results seemed to show that it would be useless to attempt any smaller star. But no steps had been taken for tabulating the spectral lines to wave-length scale. The observers were waiting for the greater optical power promised by the efforts of a number of gentlemen to benefit the Observatory, to the memory of the late Father Perry, who had lost his life to himself and to it in the cause of its science.*

We are indebted to the kindness of Dr. Huggins for the photograph of the spectrum of the Nova. An early telegram from him, arriving before the Edinburgh circular, gave us the opportunity of the 3rd of February when the star was at its brightest and the sky was exceptionally clear. Two impressions were obtained, and it became necessary to construct a complete map of the details of the spectrum. This required time. No wavelength curve had yet been drawn, and for its construction a sufficient number of solar lines had to be sought and verified on the same small-sized photograph of the spectrum of Capella, or of Arcturus. The solar spectrum itself could not be used, for the same reason that solar light could not be employed in any of the experiments for the accurate adjustment of the slitless stellar spectrograph:—viz., that the spectrograph as used upon the stars without the slit and cylindrical lens is not the same instrument as when provided with the slit for the Sun or planets.†

But eventually an excellent interpolation curve was drawn through forty-two fiducial points obtained from the spectra of Capella and Arcturus, and the two plates of the 3rd February became the subjects of a prolonged and careful study before the map was complete. A catalogue of lines together with the map will appear in the memoirs R. A. S,, and in the accompanying paper some experiments are described, which were instituted to test the reality of the breadth of the lines as shown on the plates and the applicability of the interpolation curve to the spectrum of the Nova. The latter consideration was all important on account of the absence of a slit to direct the incident

---

* The memorial probably failed to get generally known, and the fund barely reached the figure needed for a 15-inch objective, which had been the desire of the late Father Perry. And we owe much to the generosity of Sir Howard Grubb, who has undertaken to work the glasses and the necessary fittings for the available fund.

† In the latter case the illuminated slit is the object to be focussed on the plate by the lenses of the spectrograph, and is the one position of the object for every color-image on the plate. In the former case the image of the star, as given by the telescope objective, takes the place of the slit. And this is a multiple image forming so many color-objects at different distances from the focussing lenses. The inclination, therefore, of the plate is not the same in the star camera and Sun camera and the two spectra differ in length.

rays to the plate. If the incident angles from the Nova and from the star that furnished the wave-lengths of the curve, were not the same, the two spectra would not be of identical dispersion, and the curve would not suit the Nova. The result was satisfactory, showing that the possibility of the angles being materially different was very small.

The map is a double one: the lower one showing the lines or bands as they are easily seen on the plates, the upper one giving further subdivisions or superpositions, as discovered by a more careful study of the details. Each line in this map has the authority of two examiners, experienced assistants of the late Father Perry, viz., Fr. Cortie and Mr. W. McKeon,—the conditions of acceptance being the evidence of both plates to each examiner.

The object of the paper in the memoirs is to offer the fullest account of the map and catalogue, in order that their value may not be either over-estimated or under-rated. They were completed only a few days before the meeting of the R. A. S. in May; and it was premature to advance any hypothesis to account for the new appearance in Auriga. But it was impossible to omit allusion to an impression which had grown upon us during the construction of the map: that the spectrum was, on the whole, what the solar chromospheric spectrum might be expected to show on a grander scale of disturbance. The general distribution of lines in the two spectra agreed; the richer and the poorer regions being the same in both, and many coincidences appearing amongst them. The breadth of the lines, and the central divisions of F and G′ have also their likenesses in the spectra of our own solar disturbances. Father Fényi, detailing the phenomena observed by him in the region of the great solar spot group of February, says that C "was remarkably widened and had a dark line running through the center." The occasional great displacements of the hydrogen lines over spots are well-known to all students of solar physics, and even the opposite displacements of the bright and dark companions on the Nova's spectrum have had their imitations on solar spot spectra. We may then have to wait till our studies of the solar disturbances are further advanced, to be in a position to interpret correctly the perplexing spectrum of Anderson's new star.

STONYHURST OBSERVATORY,
Lancashire, England.

DISTRIBUTION IN LATITUDE OF SOLAR PHENOMENA OBSERVED AT THE ROYAL OBSERVATORY OF THE ROMAN COLLEGE DURING THE FIRST QUARTER OF 1892.*

P. TACCHINI.

The following results were determined for each zone of 10°, in both hemispheres of the Sun.

1892.	Prominences.		Faculæ.		Spots.		Eruptions.	
90° + 80°	0.000							
80 + 70	0.000							
70 + 60	0.033							
60 + 50	0.080							
50 + 40	0.097	0.536	0.007					
40 + 30	0.116		0.054		0.000			
30 + 20	0.097		0.200	0.480	0.213	0.476		
20 + 10	0.086		0.057		0.213			
10 . 0	0.027		0.062		0.050			
0 − 10	0.043		0.068		0.012		0.000	
10 − 20	0.050		0.212		0.287		0.000	
20 − 30	0.150		0.178	0.520	0.200	0.524	0.714	1.000
30 − 40	0.070		0.055		0.025		0.286	
40 − 50	0.057	0.464	0.007					
50 − 60	0.087							
60 − 70	0.007							
70 − 80	0.000							
80 − 90	0.000							

The few metallic eruptions observed are confined to the southern hemisphere; the distribution of the faculæ is in accord with that of the spots, and the frequency is greater south of the equator for the faculæ, spots and eruptions.

The prominences, on the contrary, have been a little more frequent in the northern hemisphere, and they have also occurred in much higher latitudes, as compared with the other phenomena. The law which regulates the distribution of the prominences at the surface of the Sun is thus quite different in relation to the faculæ and spots, and it is consequently difficult to attribute the production of all of these phenomena to the same cause; it may even be called impossible.

The prominences are few near the equator and absent in the regions (± 70° ± 90°); we are thus still far from the *maximum* of chromospheric phenomena, although there are so many spots at the present time. Probably the maximum of aurorae will also be retarded if they are, as I have always thought, more closely related to the prominences than to the spots.

R. OSSERVATORIO DEL COLLEGIO ROMANO, ROME, 3 June, 1892.

---

* Communicated by the author.

ON A PROMINENCE OF EXTRAORDINARY HEIGHT OBSERVED MAY 5, 1892.*

JULIUS FENYI.

On May 5, a short time before 12^h (Kalocsa mean time), I observed a singularly bright and very high prominence at position angle 97° 24′ — 101° 30′, which at 10^h 25^m was not seen at that place; only a few faint and insignificant elevations were there at that time. The prominence which had risen during the interval consisted of very bright streamers, the lower part inclined about 70° with the equator; the upper part was more inclined, and was cloud-like in appearance, while the lower part was banded. About 11^h 55^m four transits over the slit gave a height of about 139″, without evidence of a rapid uprush. Unfortunately passing clouds prevented complete and uninterrupted observation of details. Beginning at 12^h 11^m rapid rising was observed; transits immediately following each other giving considerably increased heights. At 12^h 17^m 34^s it had reached 287″, and at 12^h 18^m 45^s it had risen to 317″; *i. e.*, with a velocity of 306 kilometers per second. The lower parts vanished during these few minutes, so that at 12^h 21^m 9^s nothing could be seen up to a height of 360″. The parts floating at this height rose with the enormous velocity of 368 kilometers to a height of 531″, which was measured at 12^h 29^m 25^s. The highest fragment stood exactly over the position 90°; the time of transit was 37^s. The absolute height was 0.557 of the Sun's semi-diameter, corresponding to 381,800 kilometers, or 51,400 geographical miles.

Kalocsa mean time.			Height.	Velocity in kilometers per second.
h	m	s		
11	55	0	140	
12	17	34	287	306
12	18	45	317	
12	21	9	368	257
—	—	—	377	142
12	25	0	404	
—	—	—	410	368
—	—	—	480	
12	29	25	531	

It remains to be said that also in this case the highest parts showed the greatest proper motion in the line of sight. The highest streamers, in about the last quarter of the height, were

---

* Communicated by the author.

all displaced toward the blue. The amount of the displacement was measured by a single setting of the filar micrometer, and gave a velocity of 368 kilometers per second, exactly the same as that of the uprush mentioned above. Somewhat later a place at the limb, at about 101°, showed a marked motion toward the red. The heliographic latitude of the place of eruption was — 30° 43′ to — 34° 49′; longitude 142°.

If we combine the simultaneously observed motion of the uprush and the velocity in the line of sight to form a resultant, we obtain the enormous velocity of 520.4 kilometers per second. Since at the height of 531″ above the surface a body falling from an infinite distance can have attained a velocity of only 451 kilometers per second, it follows that the velocity of 520 kilometers per second in this prominence carried the matter entirely away from the Sun into space.

The eruption did not necessarily take place exactly on the limb, but possibly at a place on the visible disc or behind the limb. For the prominences observed at 9^h at the positions 127°, 106°, and 79° remained of the same form after the eruption; even a small bright flame at 90° remained entirely unchanged.

Observation of the solar surface revealed neither faculæ nor spots to which this enormous eruption could have been referred.

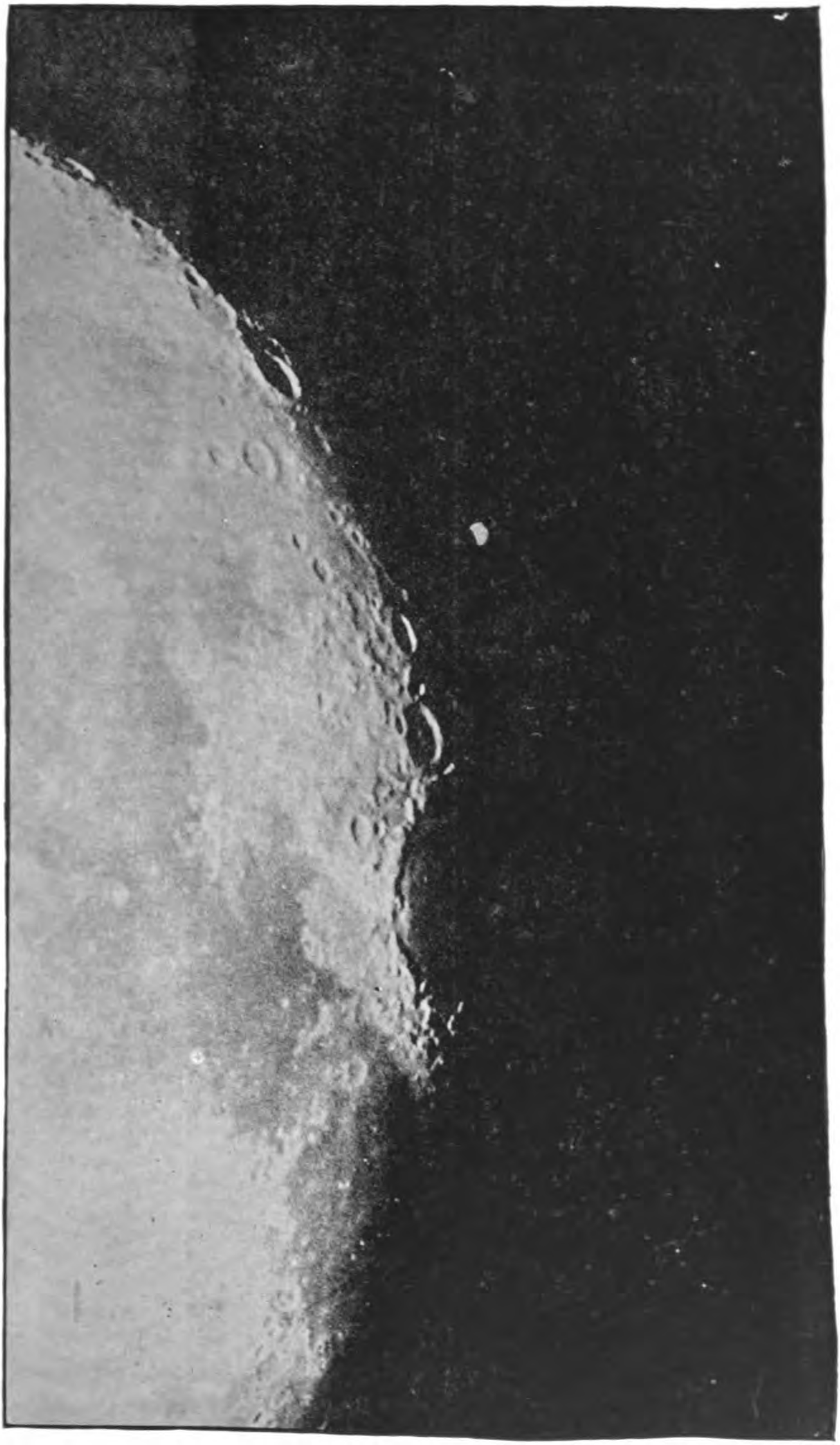
KALOCSA, Hungary, 22 May, 1892.

PHOTOGRAPHS OF THE OCCULTATION OF MARS BY THE MOON (JULY 11, 1892), MADE AT THE KENWOOD ASTRO-PHYSICAL OBSERVATORY.

GEORGE E. HALE.

Our new photographic objective by Brashear has now been in place on the equatorial for about a week, and among other objects we have been making a number of photographs of the Moon by its means. This objective, which is corrected for the $H\gamma$ line, has an aperture of 12 inches and a focal length of 18 feet. It is mounted in a double cell with a visual objective of the same aperture and focal length on the single tube of the equatorial. The projecting half of the cell support is braced to the tube by iron rods. At the eye-end of the tube a tail-piece is supported on the side by similar braces; so that we have the two objectives side by side, one with and the other without a tube. The double cell is similar to the double nose-piece of a microscope, and by loosen-

PLATE XXVI.



Mars emerging from occultation, July 11, 1892. Photographed at the Kenwood Astro-Physical Observatory, Chicago.

ing two clamping screws the cell may easily be rotated about an axis parallel to the tube, thus making the objectives readily interchangeable. This arrangement is a very convenient one, as the large spectroheliograph is permanently attached to the tube, and for different classes of work it is necessary to use both the visual and the photographic objective with it. No difficulty has been experienced in regard to the centering.

The accompanying photograph of Mars emerging from occultation was taken by Mr. G. W. Ritchey on July 11, 1892. The photographic objective was used without the tube, as the definition seems to be better than when the tube is employed. The exposure of ¼ second proved to be very satisfactory for both Mars and the Moon. In spite of the fact that the air was not very steady at the time the original negative is quite sharp, and although the image of Mars is only about $\frac{1}{32}$ inch in diameter, not only are the polar-caps very clearly shown, but also some other markngs on the surface. In the present photograph about one-third of the planet is hidden behind the dark limb of the Moon. Three other photographs were secured by Mr. Ritchey, showing the planet after egress. The half-tone cut is made directly from a six-fold enlargement of the original negative.

KENWOOD ASTRO-PHYSICAL OBSERVATORY,
Chicago, July 12, 1892.

A REMARKABLE SOLAR DISTURBANCE.

GEORGE E. HALE.

On July 15, 1892, there occurred on the Sun a phenomenon which in suddenness of appearance, exceptional brilliancy, and rapidity of change in form and brightness might almost be ranked with the classic observation of Carrington and Hodgson in 1859. The scene of the disturbance was the active spot in the southern hemisphere, whose high heliographic latitude and rapid changes in form have directed to it more than usual attention.

A photograph of the Sun, showing the faculæ, spots and prominences, was taken with the spectroheliograph of the Kenwood Observatory on July 15 at about $11^h\,8^m$ A. M. (Chicago Mean Time) and showed nothing unusual in the spot in question, except that the facula running between the northern and southern umbræ of the spot was brighter than usual. The next photograph, taken at about $11^h\,20^m$, showed a very different state of affairs. Extending between the umbræ, in a direction slightly inclined to the Sun's equator, was a perfectly straight and exceedingly brilliant object, which expanded slightly at its eastern extremity, and turned sharply toward the north, terminating abruptly in a brilliant ball just east of the center of the northern umbra. The sudden formation of this remarkable object did not seem to affect the general group of faculæ surrounding the spot, for they remained in practically the same form as at first. As the plates were not developed immediately we knew nothing of the disturbance, and the next photograph was not taken until about $11^{h}\ 47^{m}$. Meanwhile an entire transformation had taken place in the luminous phenomenon, and so completely were the umbræ covered by the brilliant outbursts that they were no longer visible in the photograph. The straight tongue running between the umbræ in the first photograph had developed into an S-shaped form, similar in appearance to a facula shown in our photographs of the great February Sun-spot when on the eastern limb. Brilliant forms had also appeared to the northwest of the northern umbra, and the disturbance extended over an area of about four billion square miles.

Unfortunately no more exposures were made until $1^{h}\ 21^{m}$, when eleven photographs of the spectrum of various parts of the spot region showed nothing out of the ordinary. A photograph of the Sun exposed at $1^{h}\ 41^{m}$, and another at $1^{h}\ 50^{m}$ show the forms of the great region of faculæ surrounding the spot to be the same as they were before the disturbance, which had now completely disappeared.

My visual observations were few, for until toward the end of the disturbance I did not know of its existence. About $0^{h}\ 45^{m}$, however, I observed the C line in the spectrum of the spot and found, at some distance to the west of the group, that the reversals were so brilliant that the forms could be very well seen with the slit quite widely opened. A sketch of these forms was made at this time by my assistant, Mr. G. Duwalt, who informs me that he happened to glance at the projected image of the spot during the time of disturbance, but noticed no unusual appearance.

The fact that the faculæ surrounding the spot were not materially changed in form by the disturbance seems to me to indicate that the phenomenon occurred in a region higher above the photosphere than that occupied by the faculæ: in other words, we seem to be dealing with an extremely brilliant eruptive prominence. Mr. Carrington came to a somewhat similar conclusion in regard to the two brilliant objects seen by him which were much inferior in size to the phenomena we are now considering but probably much brighter. In the *Monthly Notices* for November, 1859, he says: "It was impossible on first witnessing an appearance so similar to a sudden conflagration, not to expect a considerable result in the way of alteration of the details of the group in which it occurred; and I was certainly surprised on referring to the sketch which I had carefully and satisfactorily (and I may add fortunately) finished before the occurrence, at finding myself unable to recognize any change whatever as having taken place. The impression left upon me is that the phenomenon took place at an elevation considerably above the general surface of the Sun, and, accordingly, altogether above and over the great group in which it was seen projected." Mr Carrington goes on to add: "Both in figure and position the patches of light seemed entirely independent of the configuration of the great spot, and of its parts, whether nucleus or umbra." With this point my own observation does not fully agree, for the first outbreak occurred exactly on the line of separation of the two umbræ, where it would not be likely to be projected by chance alone. I am inclined to think that the luminous phenomenon had its origin in the spot region, and was eruptive in character.

I have as yet received no information in regard to the magnetic record at the time of disturbance.

KENWOOD ASTRO-PHYSICAL OBSERVATORY,
Chicago, July 16, 1892.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in ASTRO-PHYSICS, should be addressed to George E. Hale, Kenwood Astro-Physical Observatory, Chicago, U. S. A. Authors of papers are requested to refer to page 640 for information in regard to illustrations, reprint copies, etc.

The Spectra of Sun-Spots and the Chromosphere.—Everyone interested in solar work will be glad to learn that Professor C. A. Young has resumed his spectroscopic investigations on the Sun, with the large spectroscope described in the April number of this journal. The grating used with this instrument has 20,000 lines to the inch, and is characterized by Professor Young as "on the whole the best grating I have ever seen, and very near to ideal perfection." In a recent letter he adds: "I am going over my old observations of prominence and spot spectra, to fix the positions of the lines with accuracy, and review the identifications of elements present. The recent work of Rowland throws a flood of light on these spectra. One interesting result is the conspicuousness of *Vanadium* in the spectrum of Sun-spots. Between C and D every one of the 28 lines of that metal found in that region of the spectrum is made conspicuous in the spot-spectrum, although almost evanescently faint in the photosphere. I have not yet had time to carry the comparison clear through the other regions of the spectrum. While I am about it I might note also that I have been able to fix accurately the wave-length of the first line in the Chromosphere Catalogue, by comparing it in the second and third order spectrum with the underlying spectra of the third and fourth order: it comes out 7065.5 ± 0.05, instead of 7055 ? as given in the old catalogue. It falls in a place where direct comparison was not possible with any wave-length map, and the identification on the prismatic maps was extremely difficult and uncertain because of the continually varying appearance of the atmospheric lines among which it is situated."

Professor Young has also secured a number of photographs of Sun-spot and chromosphere spectra, and two positives on glass of the chromosphere spectrum which we have recently received from him are beautifully sharp. One of these shows the hydrogen α_1 line (λ 3889) clearly double, and thus confirms the results on this point obtained at the Kenwood Observatory. The line is certainly not always double, but very frequently so. The double reversal of the H and K lines in spots, which was pointed out in a paper on "Spectroscopic Observations of the Great Sun-Spot of February, 1892," in the April number of ASTRONOMY AND ASTRO-PHYSICS, has also been confirmed by Professor Young's photographs.

Observation of a Solar Prominence.

TORONTO, Canada, June 13, 1892.

Professor George E. Hale.
Kenwood Astro-Physical Observatory, Chicago.

DEAR SIR:—I beg to direct your attention to a phenomenon observed by me, 1892, June 12, between 7^h 45^m and 8^h 20^m morning, standard time. I had just commenced examination of the solar limb in search of prominences, the instruments employed being a 4-in. equatorial refractor (Wray) and a diffraction spectroscope with Rowland grating. The slit was placed tangential to the limb at position angle 300 approximately, and the focus adjusted for the C line. When the slit was opened I at once noticed a glowing hydrogen cloud hanging suspended above the chromosphere and entirely detached from it. It was much brighter than such clouds usually appear and seemed to roll or move in a manner which made its outline indistinct notwithstanding its vividness. At the moment I attributed this to terrestrial atmospheric tremors (though I subsequently came to believe the motion real)—and made several alterations of focus to improve the seeing. In about five minutes the outlines became sharper and I was that a short conical body like the upper portion of an eruptive prominence was now visible below the cloud, but still detached from the limb. Concluding that the change of aspect was due to better seeing, I proceeded to sweep all round the Sun's limb in search of other forms, and after 10^m thus occupied, returned to the first position to re-observe the object I had before noticed; but could no longer recognize it in theform which I then discovered,—*i. e.* a tall shining pillar-like column very bright and sharply defined. About 5^m were occupied in carefully examining the limb all round the position where the floating cloud-mass had been seen, to assure myself that I had not missed it by an erroneous setting of the circle, but I was soon convinced that the bright pillar occupied the exact site of the other form. Continuing to observe this column, I found it rather rapidly becoming faint while at the same time it was declining or bending over. While its P. A.

was being ascertained with more exactness, it rapidly diminished in brightness and 5^m later had vanished entirely. I however noted that the chromosphere at that point and for some degrees on each side of it, was more brilliant and more sharply defined than elsewhere round the limb.

I now feel convinced that the fluctuations noted in the original cloud when first seen were due to actual motions of the mass in the line of sight, and not to atmospheric tremor; and that the change in appearance also really took place and was not, as I at the moment supposed, an improved view of the original form. I greatly regret that I did not continue to study the changes it was undergoing, as this would have revealed whether the cloud became actually metamorphosed into the pillar-like form. Of course it may be said that the former simply faded away while an eruptive prominence shot up from just below its site; but bearing in mind the size and density of the cloud, I cannot believe that this was what occurred. It seemed to be taking on a pillar-like form while I viewed it, an idea which passed through my mind at the moment, but unfortunately did not deter me from prosecuting the preliminary sweep for other forms so that no measurements or spectroscopic study with a narrow slit were made.

I should much like to know whether any of these phenomena were seen or photographed at your Observatory on the occasion in question. During the ten years in which I have made spectroscopic examination of the chromosphere forms a special study (so far as my rather limited leisure will allow) I have seen many gaseous or metallic uprushes gradually spread out into cloudy forms, but never the converse. However, in this instance, I almost believe that by a whirling action the cloud was gathered together and drawn down to the solar surface.

I trust you will pardon this lengthy communication which I am encouraged to send in view of your having expressed to the Astronomical and Physical Society of Toronto a desire to hear of spectroscopic observations made by the members. Respectfully yours, A. F. MILLER.

Sun-Spots and Magnetic Storms.

SALT LAKE CITY, Utah, July 13th, 1892.

Professor George E. Hale, Chicago, Ill.

DEAR SIR:—The two tables of dates of large Sun-spots and magnetic storms as published in June ASTRONOMY AND ASTRO-PHYSICS confirms, it seems to me, the theory advanced by the late Professor Tice, of St. Louis, in support of his Electro-magnetic Planetary Theory of Meteorology, namely, that the Sun and planets are electrically and magnetically disturbed when the one passes through the equatorial plane of the other and also when the one makes its nearest approach to the poles of the other, which of course would be 90° from the nodes on the plane.

Some months ago, Professor C. A. Young had the kindness to furnish me with a table of the heliocentric position of the nodes of the various planets on the solar equator. These values he says are based on Carrington's estimate of the Sun's inclination to the ecliptic and are as follows: Mercury, 145° 13′; Venus, 71° 52′; Earth, 73° 28′; Mars, 79° 18′; Jupiter, 68° 12′; Saturn, 53° 03′; Uranus, 73° 30′; Neptune, 60° 11′.

By comparing the dates as given in the above mentioned tables with the heliocentric position of the planets (especially of Mercury and Venus) on those dates, I find that in a majority of cases the planets were either directly at, or, at least, very near their solar nodes, or at their greatest declination from the plane of its equator. I herewith enclose a table of dates combined from the two tables above mentioned with the approximate position of the planets on or about those dates, and you can see for yourself whether there is a relation between the two events or not. There is no doubt in my mind, but that there is a relation, and that the passage of a planet through its solar nodes is the direct cause of many solar disturbances and all its accompanying phenomena.

I would like to investigate the matter further but I have not the necessary data, and would suggest that Mr. Maunder or others that may have access to the magnetic records and other data would investigate further by comparing the position of the planets in respect to the solar equator and poles and solar disturbances, and I firmly believe that the mooted relation would be shown to exist.

Yours truly, F. H. HESSE.

1880	Aug.	12.	♀ 162° on 13th. ☿ 325° on 16th.
1881.	Jan.	31.	♀ 72° on 29th. ☿ 325° on 31st.
“	Sept.	12.	♀ 72° on 12th.
1882.	Apr.	16.	☿ 325°.
“	“	20.	☿ 325° on 16th. ♀ 72° on 24th.
“	Oct.	2.	
“	“	5.	♀ 342° on 9th.
“	Nov.	17.	Saturn 53° 03 on 25th.
“	“	21.	
1883.	Apr.	3.	☿ 325°.
“	“	19.	☿ 55° on 21st.
“	June	30.	☿ 325°
“	July	11.	♀ 72° on 17th.
“	“	29.	☿ 145° on Aug. 2d.
“	Sept.	17.	
“	Oct.	16.	☿ 55° on 14th. ♂ 79° on 11th.
“	“	20.	
“	Nov.	1.	☿ 145° Oct. 29th. ♀ 252° on 6th.
“	“	19.	☿ 235° on 23d.
1884.	Mar.	2.	⊕ 343° on 3d. ♀ 72° on Feb 27th.
“	Apr.	24.	☿ 145° on 22d. ♀ 162° on 22d. ♂ 169° on 25th.
“	“	30.	♂ 169° on 25th.
“	July	2.	☿ 55° on 4th.
“	Oct.	1.	☿ 55° on Sept. 29th.
“	Nov.	2.	♂ 259° on Oct. 28th.
1885.	Jan.	23.	♀ 252° on 28th.
“	Feb.	5.	☿ 235°.
“	“	13.	
“	Mar.	15.	
“	May	26.	♀ 72° on 21st. ♃ 158°.12 on 25th.
“	June	24.	☿ 55° on 20th.
“	July	18.	♀ 162° on 16th.
1886.	Mar.	30.	☿ 145° on 27th.
1891.	Nov.	22.	
1892.	Feb.	13.	

As the true inclination of the Sun is not exactly known, the given value of the nodes may be several degrees in error. F. H. H.

Mr. S. W. Burnham returns to Chicago.—Chicago astronomers are delighted to welcome Mr. Burnham back to his old home after his absence of some years at the Lick Observatory. Though in becoming clerk of the U. S. Circuit court in this city, Mr. Burnham retires from professional work in astronomy, we trust that his observing days are by no means over, and that he will add many another difficult pair to his long list of double-star discoveries.

Dr. Henry Crew's Election as Professor of Physics in Northwestern University.—It is with no less pleasure that we learn from Dr. Henry Crew, recently Mr. Burnham's colleague at the Lick Observatory, that he has accepted the position of Professor of Physics in Northwestern University. Astronomical and spectroscopic work in Chicago will receive fresh impetus from the accession of two such well-known investigators as Mr. Burnham and Professor Crew.

Magnetic Disturbances and Auroras.—We have received from the U. S. Naval Observatory copies of the records of the more important magnetic perturbations during the first half of 1892. These occurred on Jan. 5, 29; Feb. 2, 5, 13; March 1, 2, 3, 4, 5, 6, 12; April 26; May 1, 18. A comparison with the solar photographs obtained at the Kenwood Observatory brings out several points of interest, which will be published in the near future.

On July 13 and 16 auroras were observed at the Kenwood Observatory, in connection with the magnetic storm which the telegraph companies report as more or less troublesome during nearly the whole of the preceding week. The aurora of July 16 was in every respect a remarkable one. About 9h 35m P. M. (Chicago Mean Time) a broad arc, pale green in color, was seen extending from N. E. to N. W. about 15° above the horizon at its highest point. Soon long shafts of light shot upward from the arch, and these coalescing, filled the entire northern sky with a brilliant dome of light which terminated abruptly about 15° south of the zenith. The arch had now disappeared, and about 9h 55m the whole northern sky was aflame with brilliant streamers, which flashed and pulsated continually. The flashes were such that small luminous masses seemed to be thrown through the air, from north to south. This was at first most brilliant in the N. E., but soon grew fainter there, and became more noticeable in the N. W. At about 10h 13m the long greenish arch appeared again, with straight streamers rising from it, which moved slowly toward the west. A pink tinge now spread over the whole northern sky. At 10h 17m the arch and pink color were much fainter, and at 10h 22m the aurora had almost completely disappeared.

There seems to be every reason to attribute these magnetic perturbations and auroral displays to the Sun-spot in remarkably high southern latitude which is now nearing the western limb. But though the spot has shown exceptional activity during the entire time of its transit across the disc, it is strange that the remarkable phenomenon in the spot photographed at the Kenwood Observatory on July 15, and described on another page, should not have been accompanied by some violent magnetic disturbance. In answer to a telegraphic inquiry addressed to the U. S. Naval Observatory on July 15, I have received the following answer, dated July 16: "Disturbance on twelfth and thirteenth; one in progress now; none on fifteenth *at eleven*; will send prints of record by mail. S. J. Brown, in charge Magnetic Observatory." The prints have not been received as we go to press.

Lewis Morris Rutherfurd.—The death of Mr. Rutherfurd, which occurred on May 30, 1892, will be deeply regretted by all who know of his important part in the advancement of science. A pioneer in astro-physical investigation, Mr. Rutherfurd's success in the study of stellar and solar spectra, in solar, lunar and stellar photography, and in the manufacture and use of the beautiful diffraction gratings which he distributed with so liberal a hand, has given him an honorable and a lasting place in the history of astronomy. When it is remembered that his photographs of spectra and of celestial objects are hardly surpassed to-day, after the remarkable improvements in photographic processes which have been brought about during the intervening years, we may in some degree appreciate what it meant to obtain such results in the days when the spectroscope was a new instrument and photography an almost unknown art. In the next number of ASTRONOMY AND ASTRO-PHYSICS we hope to give an article on Mr. Rutherfurd's life and work.

Since the note on the Ultra-Violet Spectrum of Solar Prominences (page 602) was written I have succeeded in photographing the following bright lines in metalic prominences and in the chromosphere, the color correction of the new objective assisting very materially in the more refrangible part of the spectrum. As in the preceding table, lines not previously known are marked with an asterisk:

Lines.	*Elements.*
*3737.2	
3721.9	Hydrogen (η_1)
*3720.0	
3711.8	Hydrogen (θ_1)
*3704.0	" (ι_1)
*3697.4	" (κ_1)
*3691.5	" (λ_1)
*3686.7	" (μ_1)
3685.3	

The lines 3704.0, 3697.4, 3691.5 and 3686.7 are considered to belong to the hydrogen series, as they agree closely with the values calculated from Balmer's law. New lines are suspected at 3820.6 and 3745.6 Most of the above wavelengths are to be regarded as approximate only.

The two tables taken together constitute a complete catalogue of the ultra-violet prominence spectrum so far as known. The hydrogen series may be further extended, and many more metallic lines added, as the maximum period of solar activity is approached.

July 26, 1892.

Errata.—p. 64, column 5 in table; for "Ascent per sec. of time," read "Ascent per 30 sec. of time."

p. 433, last part of table should read:

	5197	Line itself not seen. Prominence only.
	5188.2	
	b_1, b_2, b_3, b_4	Exceedingly bright.
	5019.3	Ti; in this line the prominence is about 3 times as bright as in the next.
	5016.6	Ni.
	4945.5	Fe?
10^h 38^m	4923.1	Fe: 40″: D; about 3 times as bright in this line as in the next.
	4921.	

Visibility of Venus.—Mr. A. Cameron, of Yarmouth, Nova Scotia, writes that he was able to see Venus with the naked eye *easy* at 12^h 30^m P. M., July 6, three days before conjunction. The planet was only 6.5° distant from the Sun. In a pamphlet recently published Mr. Cameron discusses the question of the visibility of Venus and finds that it is possible to get glimpses of the planet without instrumental aid on at least 552 out of the 584 days of her synodical period.

Mr. F. P. Leavenworth has resigned his position as director of Haverford College Observatory to accept that of Professor of Astronomy in the University of Minnesota.

CURRENT CELESTIAL PHENOMENA.

PLANET NOTES FOR AUGUST AND SEPTEMBER.

H. C. WILSON.

Mercury will be "morning star" during September, reaching greatest western elongation Sept. 11. It will be visible to the naked eye for a few mornings about that time. To see it one should look toward the east, a little above the horizon, about an hour before sunrise. In October the planet will be invisible with small telescopes, passing superior conjunction Oct. 7.

Venus will also be "morning star" during these months, blazing with a brilliancy equal to that which she had in the evening sky during April and May. She passes greatest elongation west of the Sun Sept. 18. After that time she will move slowly toward the Sun but will be visible in the morning for several months. Venus will be in conjunction with the Moon, 7° 36′ south, Sept. 16, at 3^h 56^m P. M., Central time, and again, 4° 27′ south of the Moon Oct. 16 at 9 A. M.

Mars will begin to rise rapidly in declination in September and so come into better position for observation in northern latitudes, although receding from the earth so that his apparent diameter will be less. He will be stationary in right ascension, at the west end of the loop in his path in Capricornus (see May number, p. 439). Mars is a brilliant object in the heavens nowadays, rivalling Jupiter and Venus in splendor. We had an excellent view of this planet, through Professor Hale's 12-inch refractor at Kenwood Physical Observatory, on the morning of July 6. The southern polar cap was very large and sharply defined, the outline of the nearer side appearing as a perfect ellipse. There was another white area just south of it, near the east limb of the planet. One of the great continents was on the meridian and the seas bounding it on the south and west were very distinct, their dark greenish blue color contrasting strongly with the brick red of the land. Although dark shadings were seen on the red areas no fine lines corresponding to the "canals" were seen. We had, however, only a few minutes to spend in this examination, and longer looking might have brought out much more of detail.

There will be an occultation of Mars by the Moon on Sept 4, visible throughout the United States beginning, as seen from Washington, at 1^h 30^m A. M eastern time, 12^h 30^m central time, and ending at 2^h 14^m A. M., eastern time, 1^h 14^m central time.

On the morning of October 25, at 4^h 41^m central time, Mars will approach very near to the third magnitude star δ Capricorni. In some localities an occultation of the star by the planet may be seen.

Jupiter comes to opposition Oct. 12, and so during these months will be in excellent position for observation. For chart of his path through the constellations see June number, p. 530. As Jupiter this year is from 5° to 8° north of the equator he is much better situated for observation than during last year.

Jupiter will be in conjunction with the Moon Sept. 9 at 7 A. M. There will be an occultation of the planet seen from the equatorial regions of the Pacific Ocean and the southwestern part of the United States. There will be another occultation of Jupiter, Oct. 6, visible in Asia.

Saturn is too nearly in line with the Sun for observation during the months of September and October. He will be at conjunction on Sept. 25.

Uranus will also be too near the Sun. He comes to conjunction Oct. 29.

Neptune will be at quadrature, 90° east from the Sun, Sept. 3, and may be observed after midnight. He is in Taurus about 5° northeast of Aldebaran.

Date. 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
MERCURY.					
Sept. 5	9 58.9	+11 04	4 10 A. M.	10 58.0 A. M.	5 46 P. M.
15	10 34.0	+10 20	4 07 "	10 53.7 "	5 38 "
25	11 37.5	+ 4 28	5 57 "	11 17.6 "	5 39 "
Oct. 5	12 42.8	− 3 08	5 52 "	11 43.3 "	5 34 "
15	13 44.7	−10 32	6 44 "	12 05.7 P. M.	5 27 "
25	14 45.0	−16 51	7 32 "	12 26.5 "	5 21 "
VENUS.					
Sept. 5	7 58.2	+17 13	1 43 A. M.	8 57.4 A. M.	4 12 P. M.
15	8 35.9	+16 14	1 46 "	8 55.8 "	4 06 "
25	9 16.4	+14 28	1 55 "	8 56.8 "	3 59 "
Oct. 5	9 58.5	+11 56	2 08 "	8 59.5 "	3 51 "
15	10 41.3	+ 8 43	2 25 "	9 02.9 "	3 41 "
25	11 24.5	+ 4 57	2 44 "	9 06.7 "	3 30 "
MARS.					
Sept. 5	20 44.4	− 23 58	5 21 P. M.	9 41.5 P. M.	2 02 A. M.
15	20 47.8	− 23 05	4 40 "	9 05.6 "	1 31 "
25	20 56.0	− 21 50	4 03 "	8 34.6 "	1 06 "
Oct. 5	21 08.6	− 20 17	3 29 "	8 07.7 "	12 46 "
15	21 24.2	− 18 30	2 57 "	7 44.0 "	12 31 "
25	21 42.3	− 16 29	2 27 "	7 22.7 "	12 19 "
JUPITER.					
Sept. 5	1 31.4	+ 7 53	7 53 P. M.	2 27.7 A. M.	9 02 A. M.
15	1 28.1	+ 7 32	7 12 "	1 45.2 "	8 18 "
25	1 23.9	+ 7 06	6 30 "	1 01.7 "	7 33 "
Oct. 5	1 19.2	+ 6 37	5 48 "	12 17.6 "	6 47 "
15	1 14.1	+ 6 07	5 06 "	11 33.3 P. M.	6 01 "
25	1 09.3	+ 5 38	4 24 "	10 49.1 "	5 15 "
SATURN.					
Sept. 5	12 06.4	+ 1 38	6 55 A. M.	1 05.0 P. M.	7 15 P. M.
15	12 10.8	+ 1 09	6 22 "	12 30.0 "	6 38 "
25	12 15.3	+ 0 42	5 50 "	11 56.1 A. M.	6 02 "
Oct. 5	12 19.9	+ 0 10	5 17 "	11 21.2 "	5 25 "
15	12 24.3	− 0 18	4 44 "	10 46.4 "	4 49 "
25	12 28.7	− 0 45	4 11 "	10 11.4 "	4 12 "
URANUS.					
Sept. 5	14 05.2	− 12 13	9 49 A. M.	3 03.8 P. M.	8 18 P. M.
15	14 07.0	− 12 23	9 12 "	2 25.9 "	7 40 "
25	14 09.1	− 12 34	8 36 "	1 49.1 "	7 02 "
Oct. 5	14 11.3	− 12 46	8 00 "	1 11.6 "	6 24 "
15	14 13.7	− 12 58	7 24 "	12 35.0 "	5 46 "
25	14 16.2	− 13 11	6 44 "	11 54.1 A. M.	5 04 "
NEPTUNE.					
Sept. 5	4 39.9	+20 36	10 05 P. M.	5 35.7 A. M.	1 06 P. M.
15	4 40.0	+20 36	9 26 "	4 56.5 "	12 27 "
25	4 39.8	+20 35	8 47 "	4 17.0 "	11 47 A. M.
Oct. 5	4 39.4	+20 34	8 07 "	3 37.3 "	11 08 "
15	4 38.8	+20 32	7 27 "	2 57.3 "	10 27 "
25	4 37.9	+20 30	6 47 "	2 17.2 "	9 47 "
THE SUN.					
Sept. 5	10 59.4	+ 6 28	5 28 A. M.	11 58.3 A. M.	6 28 P. M.
15	11 35.3	+ 2 40	5 40 "	11 54.8 "	6 10 "
25	12 11.2	− 1 13	5 52 "	11 51.4 "	5 51 "
Oct. 5	12 47.4	− 5 06	6 04 "	11 48.2 "	5 32 "
15	13 24.3	− 8 53	6 16 "	11 45.6 "	5 15 "
25	14 02.2	− 12 26	6 30 "	11 44.1 "	4 59 "

Jupiter's Satellites.

Sept. 1	12	47	A. M.	I	Oc. Re.
	6	53	P. M.	I	Sh. In.
	7	52	"	I	Tr. In.
	9	07	"	I	Sh. Eg.
	10	04	"	I	Tr. Eg.
2	7	14	"	I	Oc. Re.
	11	40	"	III	Sh. In.
3	2	07	A. M.	III	Sh. Eg.
	3	49	"	III	Tr. In.
5	3	08	"	II	Sh. In
6	7	07	P. M.	III	Oc. Re.
	10	07	"	II	Ec. Dis.
7	2	16	A. M.	II	Oc. Re.
	2	18	"	I	Sh. In.
	3	11	"	I	Tr. In.
	4	32	"	I	Sh. Eg.
	11	31	P. M.	I	Ec. Dis.
8	2	33	A. M.	I	Oc. Re.
	7	01	P. M.	II	Sh. Eg.
	8	36	"	II	Tr. Eg.
	8	47	"	I	Sh. In.
	9	38	"	I	Tr. In.
	11	01	"	I	Sh. Eg.
	11	50	"	I	Tr. Eg.
9	8	59	"	I	Oc. Re.
10	3	42	A. M.	III	Sh. In.
13	7	50	P. M.	III	Ec. Re.
	8	47	"	III	Oc. Dis.
	10	31	"	III	Oc. Re.
14	12	42	A. M.	II	Ec. Dis.
	4	12	"	I	Sh. In
	4	33	"	II	Oc. Re.
15	1	26	"	I	Ec. Dis.
	4	18	"	I	Oc. Re.
	7	05	P. M.	II	Sh. In.
	8	30	"	II	Tr. In.
	9	38	"	II	Sh. Eg.
	10	41	"	I	Sh. In.
	10	55	"	II	Tr. Eg.
	11	23	"	I	Tr. In.
16	12	55	A. M.	I	Sh. Eg.
	2	35	"	I	Tr. Eg.
	7	55	P. M.	I	Ec. Dis.
	10	44	"	I	Oc. Re.
17	7	24	"	I	Sh. Eg.
	8	01	"	I	Tr. Eg.
20	9	40	"	III	Ec. Dis.
	11	50	"	III	Ec. Re.
21	12	08	A. M.	III	Oc. Dis.
	1	52	"	III	Oc. Re.
	3	17	"	II	Ec. Dis.
22	3	21	"	I	Ec. Dis.
	9	43	P. M.	II	Sh. In.
	10	47	"	II	Tr. In.
23	12	17	A. M.	II	Sh. Eg.
	12	35	"	I	Sh. In.
	1	07	"	I	Tr. In.
	1	12	"	II	Tr. Eg.
	2	48	"	I	Sh. Eg.
	3	18	"	I	Tr. Eg.
	9	49	P. M.	I	Ec. Dis.
24	12	29	A. M.	I	Oc. Re.
	7	04	P. M.	I	Sh. In.
Sep. 24	7	33	P. M.	I	Tr. In.
	7	55	"	II	Oc. Re.
	9	17	"	I	Sh. Eg.
	8	45	"	I	Tr. Eg.
25	6	55	"	I	Oc. Re.
28	1	42	A. M.	III	Ec. Dis.
30	12	21	"	II	Sh. In.
	1	03	"	II	Tr. In.
	2	30	"	I	Sh. In.
	2	51	"	I	Tr. In.
	2	54	"	II	Sh. Eg.
	3	28	"	II	Tr. Eg.
	11	44	P. M.	I	Ec. Dis.
Oct. 1	2	13	A. M.	I	Oc. Re.
	6	07	P. M.	III	Sh. Eg.
	6	59	"	III	Tr. Eg.
	7	10	"	II	Ec. Dis.
	8	58	"	I	Sh. In.
	9	17	"	I	Tr. In.
	10	09	"	II	Oc. Re.
	11	11	"	I	Sh. Eg.
	11	29	"	I	Tr. Eg.
2	6	13	"	I	Ec. Dis.
	8	39	"	I	Oc. Re.
3	5	40	"	I	Sh Eg.
	5	55	"	I	Tr. Eg.
7	2	59	A. M.	II	Sh. In.
	3	19	"	II	Tr. In.
	4	24	"	I	Sh. In.
	4	34	"	I	Tr. In.
8	1	39	"	I	Ec. Dis.
	3	57	"	I	Oc. Re.
	7	47	P. M.	III	Sh. In.
	8	27	"	III	Tr. In.
	9	45	"	II	Ec. Dis.
	10	07	"	III	Sh Eg.
	10	15	"	III	Tr. Eg.
	10	53	"	I	Sh. In.
	10	59	"	I	Tr. In.
9	12	22	A. M.	II	Oc. Re.
	1	06	"	I	Sh. Eg.
	1	11	"	I	Tr. Eg.
	8	08	P. M.	I	Ec. Dis.
	10	23	"	I	Oc. Re.
10	5	21	"	I	Sh. In.
	5	25	"	I	Tr. In.
	6	51	"	II	Sh. Eg.
	6	53	"	II	Tr. Eg.
	7	34	"	I	Sh. Eg.
	7	37	"	I	Tr. Eg.
15	3	29	A. M.	I	Oc. Dis.
	11	41	P. M.	III	Tr. In.
	11	50	"	III	Sh. In.
16	12	09	A. M.	II	Oc. Dis.
	12	42	"	I	Tr. In.
	12	47	"	I	Sh. In.
	1	33	"	III	Tr. Eg.
	2	08	"	III	Sh. Eg.
	2	46	"	II	Ec. Re.
	2	54	"	I	Tr. Eg.
	3	00	"	I	Sh. Eg.
	9	55	P. M.	I	Oc. Dis.
17	12	13	A. M.	I	Ec. Re.

Oct. 17	6	42 P. M.	II	Tr. In.	Oct. 24	9	10 P. M.	I	Sh. In.
	6	56 "	II	Sh. In.		9	35 "	II	Sh. In.
	7	08 "	I	Tr. In.		11	02 "	I	Tr. Eg.
	7	16 "	I	Sh. In.		11	23 "	I	Sh. Eg.
	9	09 "	II	Tr. Eg.		11	26 "	II	Tr. Eg.
	9	20 "	I	Tr. Eg.	25	12	07 A. M.	II	Sh. Eg.
	9	28 "	II	Sh. Eg.		6	07 P. M.	I	Oc. Dis.
	9	29 "	I	Sh. Eg.		8	37 "	I	Ec. Re.
18	6	41 "	I	Ec. Re.	26	5	29 "	I	Tr. Eg.
23	2	21 A. M.	II	Oc. Dis.		5	52 "	I	Sh. Eg.
	2	25 "	I	Tr. In.		6	38 "	II	Ec. Re.
	2	42 "	I	Sh. In.		7	55 "	III	Ec. Re.
	2	54 "	III	Tr. In.	31	1	23 A. M.	I	Oc. Dis.
	3	52 "	III	Sh. In.		4	03 "	I	Ec. Re.
	11	39 P. M.	I	Oc. Dis.		10	35 P. M.	I	Tr. In.
24	2	08 A. M.	I	Ec. Re.		11	05 "	I	Sh. In.
	8	51 P. M.	I	Tr. In.		11	16 "	II	Tr. In.
24	8	58 "	II	Tr. In.					

Approximate Central Times when the Great Red Spot will pass the Center of Jupiter's Disk.

Aug.	5	7	29 P. M.	Aug.	29	7	15 P. M.	Sept.	24	12	46 A. M.
	6	5	24 A. M.		31	1	02 A. M.		24	8	38 P. M.
	7	1	16 A. M.		31	8	53 P. M.		26	2	24 A. M.
	7	9	07 P. M.	Sept.	2	2	40 A. M.		26	10	16 P. M.
	9	2	54 A. M.		2	10	31 P. M.		28	4	02 A. M.
	9	10	45 P. M.		4	4	18 A. M.		28	11	53 P. M.
	11	4	32 A. M.		5	12	09 A. M.		29	7	44 P. M.
	12	12	23 A. M.		5	8	00 P. M.	Oct.	1	1	31 A. M.
	12	8	14 P. M.		7	1	47 A. M.		1	9	22 P. M.
	14	2	02 A. M.		7	9	38 P. M.		3	3	09 A. M.
	14	9	53 P. M.		9	3	25 A. M.		3	11	00 P. M.
	16	3	39 A. M.		6	11	16 P. M.		4	6	52 P. M.
	16	11	31 P. M.		10	7	08 P. M.		6	12	38 A. M.
	17	7	22 P. M.		12	12	54 A. M.		6	8	29 P. M.
	19	1	09 A. M.		12	8	46 P. M.		8	2	16 A. M.
	19	9	00 P. M.		14	2	32 A. M.		8	10	07 P. M.
	21	2	47 A. M.		14	10	24 P. M.		9	5	58 P. M.
	21	10	38 P. M.		16	4	10 A. M.		10	3	54 A. M.
	23	4	25 A. M.		17	12	01 A. M.		10	11	45 P. M.
	24	12	16 A. M.		17	7	53 P. M.		12	7	36 P. M.
	24	8	08 P. M.		19	1	39 A. M.		13	1	23 A. M.
	26	1	55 A. M.		19	9	31 P. M.		13	9	14 P. M.
	26	9	46 P. M.		21	3	17 A. M.		15	3	01 A. M.
	28	3	33 A. M.		21	11	08 P. M.		15	10	52 P. M.
	28	11	24 P. M.		22	7	00 P. M.				

Occultations Visible at Washington.

Date 1892.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h	m	Angle f'm N pt. °	EMERSION Washington M. T. h	m	Angle f'm N pt °	Duration. h	m
Sept. 3	Mars................		13	22	110	14	06	200	0	44
4	B.A.C. 7550.......	6	11	03	23	12	06	275	1	03
8	96 Piscium........	7	17	14	91	18	10	208	0	56
11	A^1 Tauri............	4	9	24	55	10	12	262	0	48
11	A^2 Tauri............	6	9	33	79	10	23	237	0	50
26	22 Scorpii..........	5½	5	09	48	5	58	344	0	49
Oct. 6	*o* Piscium..........	4	8	36	352	9	02	301	0	26
7	*o* Arietis............	6	9	06	105	9	48	191	0	42
8	32 Tauri............	6	16	14	26	17	09	294	0	55
12	ω^1 Cancri..........	6	12	37	104	13	37	259	1	00

Configuration of Jupiter's Satellites at 10:30 p. m. Central Time

Sept.	
1	2 1 ○ 3 4
2	2 ○ 3 1 4
3	3 1 ○ 2 4
4	3 ○ 2 1 4
5	3 2 1 ○ 4
6	4 2 ○ 3 1
7	4 1 ○ 2 3
8	♃ 4 2 ○ 3
9	4 2 ○ 1 3
10	4 3 1 ○ 2
11	4 3 ○ 2 1
12	4 3 2 1 ○
13	4 2 1 ○ ●
14	1 ○ 2 3 ●
15	♃ ○ 1 4 3
16	2 ○ 1 3 4
17	3 1 ○ 2 4
18	3 ○ 1 2 4
19	3 2 1 ○ 4
20	2 3 ○ 1 4
21	1 ○ 2 3 4

Sept.	
22	♃ ○ 4 1 3
23	2 4 ○ 3 ●
24	4 3 1 ○ 2
25	4 3 ○ 1 2
26	4 3 2 1 ○
27	4 2 3 ○ 1
28	4 1 ○ 2 3
29	4 ○ 2 1 3
30	2 4 1 ○ 3
Oct.	
1	♃ 3 ○ 4 ●
2	3 ○ 1 2 4
3	3 2 1 ○ 4
4	2 3 ○ 1 4
5	1 ○ 2 3 4
6	○ 2 1 3 4
7	2 1 ○ 3 4
8	♃ ○ 1 4 ●
9	3 4 ○ 2 ●
10	3 4 2 1 ○
11	4 2 3 ○ 1

Oct.	
12	4 1 ○ 3 2
13	4 ○ 2 1 3
14	4 2 1 ○ 3
15	4 2 ○ 3 1
16	3 4 ○ 2 ●
17	3 2 1 4 ○
18	2 3 ○ 1 4
19	1 ○ 3 2 4
20	○ 2 1 3 4
21	2 1 ○ 3 4
22	2 ○ 3 1 4
23	3 ○ 1 2 4
24	♃ ♃ 3 ○ 4
25	3 2 ○ 1 4
26	4 1 ○ 3 2
27	4 ○ 1 2 3
28	4 2 1 ○ 3
29	4 2 ○ 3 1
30	4 3 1 ○ 2
31	4 3 ○ 1 2

Occultations of Stars by the Planets.

[From *Astr. Nach.*. No. 3073.]

Date			Central Time of Conjunction.		Diff. of Decl.	Maximum Duration.	Magnitude of Star.
			h	m	″	m	
			STARS NEAR VENUS.				
1892.	Sept.	3	12	14 P. M.	+ 73	14.7	9.4
		5	5	35 A. M.	− 9	13.8	9.5
		6	2	17 A. M.	+ 17	13.4	9.4
		6	7	02 P. M.	− 51	13.4	9.4
		9	4	32 A. M.	− 75	12.6	9.3
		9	4	51 "	+ 40	12.6	9.3
		11	6	34 P. M.	+ 38	11.5	8.6
		12	3	44 "	− 40	11.2	9.3
		14	7	00 A. M.	+ 53	10.8	9.0
		19	7	52 P. M.	− 2	10.0	9.2
		21	9	47 "	+ 58	9.7	7.5
		28	8	46 A. M.	+ 41	8.7	9.0
		30	12	12 A. M.	− 9	8.5	8.3
	Oct.	1	3	34 P. M.	− 12	8.2	9 4
		2	12	25 P. M.	+ 29	8.1	9.4
		6	6	19 A. M.	+ 13	7.7	9.3
		8	8	29 P. M.	+ 37	7.5	9.3
		9	7	25 P. M.	+ 57	7.4	9.3
		12	1	58 A. M.	− 30	7.2	4.1
		20	2	34 P. M.	− 69	6.6	9.4
		20	5	26 P. M.	+ 50	6.6	9.3
		20	8	41 P. M.	− 92	6.6	9.3
		27	5	37 A. M.	− 68	6.1	8.7
			STARS NEAR MARS.				
	Sept.	25	8	41 P. M.	+ 17	25.0	9.2
		29	12	31 A. M.	+ 31	22.5	8.5
	Oct.	1		midn.	+ 29	19.8	9.0
		13	9	35 P. M.	− 24	14.0	9.0
		18	1	23 A. M.	− 7	12.8	9.2
		23	9	28 P. M.	+ 23	11.2	9.3
		25	4	41 A. M.	+ 31	11.0	3
			STARS NEAR JUPITER.				
	Oct.	6	2	06	− 38	150	9.5

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A................$0^{h}\ 52^{m}\ 32^{s}$

Decl................$+81° 17'$

Period...........$2d\ 11^{h}\ 50^{m}$

Sept.	5	9 P. M.
	10	9 "
	15	9 "
	20	8 "
	25	8 "
	30	8 "
Oct.	5	7 "
	10	7 "
	15	7 "
	20	6 "
	25	6 "
	30	6 "

ALGOL.

R. A................$3^{h}\ 01^{m}\ 01^{s}$

Decl................ $+40° 32'$

Period...........$2d\ 20^{h}\ 49^{m}$

Sept.	13	3 A. M.
	15	midn.
	18	9 P. M.
	21	6 "
Oct.	3	5 A. M.
	6	2 "
	8	11 P. M.
	11	7 "
	26	4 A. M.
	28	midn.
	31	9 P. M.

λ TAURI.

R. A.............. $3^{h}\ 54^{m}\ 35^{s}$

Decl................ $+12° 11'$

Period...........$3d\ 22^{h}\ 52^{m}$

Sept.	6	2 A. M.
	10	1 "
	13	midn.
	17	11 P. M.
	21	10 "

λ TAURI CONT.

Sept.	25	8 P. M.
	29	7 "

R. CANIS MAJORIS.

R. A............... $7^{h}\ 14^{m}\ 30^{s}$

Decl............... $-16° 11'$

Period ....$1d\ 03^{h}\ 16^{m}$

Sept.	6	2 A. M.
	7	5 "
	13	midn.
	15	4 A. M.
	21	midn.
	23	3 A. M.
	29	10 P. M.
Oct.	1	2 A. M.
	2	5 "
	8	midn.
	10	3 A. M.
	16	11 P. M.
	18	2 A. M.
	19	6 "
	24	10 P. M.
	26	1 A. M.
	27	4 "

U CORONÆ.

R. A..............$15^{h}\ 13^{m}\ 43^{s}$

Decl ....$+32° 03'$

Period...........$3d\ 10^{h}\ 51^{m}$

Sept.	14	11 P. M.
	21	9 "
	28	7 "
Oct.	22	11 "
	29	9 "

U OPHIUCHI.

R. A.............$17^{h}\ 10^{m}\ 56^{s}$

Decl.................. $+1° 20'$

Period. ....$0d\ 20^{h}\ 8^{m}$

Sept.	2	10 P. M.
	3	6 "

U OPHIUCHI CONT.

Sept.	7	10 P. M.
	8	6 "
	12	11 "
	13	7 "
	17	midn.
	18	8 P. M.
	23	1 A. M.
	23	9 P. M.
	28	1 A. M.
	28	10 P. M.
	29	6 "
Oct.	3	11 "
	4	7 "
	8	11 "
	9	7 "
	13	midn.
	14	8 P. M.
	19	1 A. M.
	19	9 P. M.
	24	10 "
	25	6 "
	29	11 "
	30	7 "

Y CYGNI.

R. A...............$20^{h}\ 47^{m}\ 40^{s}$

Decl................$+34° 15'$

Period...........$1d\ 11^{h}\ 56^{m}$

Sept.	3	1 A. M.
	8	midn.
	14	"
	20	"
	26	"
Oct.	2	"
	8	"
	14	11 P. M.
	20	11 "
	26	11 "

Phases and Aspects of the Moon.

		d	h m	
Full Moon	Sept.	6	3 08	P. M.
Perigee	"	8	5 00	"
Last Quarter	"	13	6 50	A. M.
New Moon	"	20	7 16	P. M.
Apogee	"	24	noon	
First Quarter	"	29	12 19	A. M.
Full Moon	Oct.	6	12 12	"
Perigee	"	6	10 30	P. M.
Last Quarter	"	12	3 38	"
New Moon	"	20	12 24	"
Apogee	"	21	9 36	"
First Quarter	"	28	3 26	"

Aurora, July 16.—Mr. W. H. Clute, of Bay City, Mich., reports a very brilliant aurora seen at that place July 16, from 9^{h} to $10^{h}\ 30^{m}$ P. M. The display was very active, covering nearly the whole sky. This aurora was noted at Northfield as was also one July 14. Our photograph of the Sun taken July 18 (the first taken after the 16th) shows that two new groups of spots had formed near the center of the Sun's disk.

COMET NOTES.

Swift's comet is still quite conspicuous in the telescope, and will be visible in ordinary telescopes for some time to come. Winnecke's comet has passed the Sun and is coming out of the morning twilight. It is only visible in southern latitudes. No new comets have been discovered during the past four months, nor have the periodic comets Brooks, 1886 IV, and Tempel, 1867 II, been found. What are all you amateurs doing?

Elements of Comet 1892 I (Swift March 6).—The following elements were computed by Miss F. E. Harpham from three normal places, dated March 11.0, 29.0 and April 17.0, depending upon all the published observations received before June 1. The representation of the middle place is: $d\lambda \cos \beta = -6.6''$; $d\beta = +4.3''$:

$$\begin{array}{l}
T = \text{April } 6.62792 \text{ Greenwich mean time.}\\
\left.\begin{array}{l}
\pi = 265^\circ\ 24'\ 04.7''\\
\omega = 24\ \ 29\ \ 42.4\\
\Omega = 240\ \ 54\ \ 22.3
\end{array}\right\} 1892.0\\
i = 38\ \ 41\ \ 47.4\\
\log q = 0.011536 \qquad q = 1.02692
\end{array}$$

Ephemeris of Comet *a* 1892 (Swift).

From my last elements, as given in the June number of this periodical, I have computed the following Ephemeris:

Gr. M. T.		App. R. A.			App. Dec.		log r	log Δ	Br.
		h	m	s	°				
1892 Aug.	1.5	1	3	38	+ 51	56	0.3196	0.2553	0.12
	2.5		3	30	52	2			
	3.5		3	20	52	8			
	4.5		3	7	52	14			
	5.5		2	51	52	19	0.3295	0.2570	0.11
	6.5		2	32	52	24			
	7.5		2	12	52	29			
	8.5		1	48	52	34			
	9.5		1	23	52	38	0.3391	0.2587	0.10
	10.5		0	53	52	42			
	11.5	1	0	22	52	46			
	12.5	0	59	48	52	49			
	13.5		59	12	52	52	0.3485	0.2602	0.10
	14.5		58	33	52	55			
	15.5		57	53	52	57			
	16.5		57	8	52	59			
	17.5		56	21	53	0	0.3577	0.2618	0.10
	18.5		55	32	53	1			
	19.5		54	41	53	1			
	20.5		53	46	53	2			
	21.5		52	54	53	2	0.3668	0.2635	0.09
	22.5		51	57	53	2			
	23.5		50	59	53	1			
	24.5		49	58	53	0			
	25.5		48	56	52	59	0.3755	0.2653	0.09
	26.5		47	51	52	57			
	27.5		46	45	52	55			
	28.5		45	37	52	52			
	29.5		44	28	52	49	0.3842	0.2674	0.08
	30.5		43	18	52	45			
	31.5	0	42	6	+ 52	41			

O. C. WENDELL.

Harvard College Observatory, July 11, 1892.

Ephemeris of Winnecke's Periodic Comet 1892.

[Continued from page 537.]

Berlin Midnight		App. R. A.			App. Decl.			log Δ	log r	Br.
		h	m	s	°	′	″			
Aug.	16	3	16	34	− 27	35	01	9.5150	0.0533	
	17		14	21	27	52	12	9.5230	0.0567	6.93
	18		12	08	28	08	45	9.5309	0.0601	
	19		09	56	28	24	42	9.5386	0.0635	
	20		07	42	28	40	03	9.5461	0.0669	
	21		05	29	28	54	50	9.5535	0.0703	5.65
	22		03	15	29	09	03	9.5608	0.0737	
	23	3	01	00	29	22	41	9.5680	0.0771	
	24	2	58	45	29	35	46	9.5751	0.0804	
	25		56	29	29	48	17	9.5821	0.0838	4.66
	26		54	12	30	00	14	9.5890	0.0872	
	27		51	54	30	11	37	9.5958	0.0905	
	28		49	35	30	22	26	9.6025	0.0939	
	29		47	15	30	32	41	9.6092	0.0972	3.87
	30		44	54	30	42	21	9.6158	0.1006	
	31		42	32	30	51	26	9.6223	0.1039	
Sept.	1		40	09	30	59	56	9.6288	0.1072	
	2		37	46	31	07	50	9.6353	0.1105	3.22
	3		35	21	31	15	09	9.6417	0.1138	
	4		32	56	31	21	51	9.6481	0.1170	
	5		30	30	31	27	56	9.6545	0.1203	
	6		28	04	31	33	23	9.6608	0.1235	2.70
	7		25	38	31	38	13	9.6671	0.1267	
	8		23	11	31	42	26	9.6734	0.1299	
	9		20	44	31	46	02	9.6797	0.1331	
	10		18	17	31	48	59	9.6860	0.1363	2.27
	11		15	49	31	51	20	9.6923	0.1394	
	12		13	22	31	53	04	9.6986	0.1426	
	13		10	55	31	54	11	9.7048	0.1457	
	14		08	28	31	54	41	9.7111	0.1488	1.91
	15		06	02	31	54	32	9.7174	0.1519	
	16		03	36	31	53	45	9.7237	0.1549	
	17	2	01	11	31	52	21	9.7300	0.1580	
	18	1	58	48	31	50	18	9.7363	0.1610	1.60
	19		56	25	31	47	39	9.7427	0.1640	
	20		54	04	31	44	22	9.7490	0.1670	
	21		51	43	31	40	29	9.7554	0.1700	
	22	1	49	25	31	36	00	9.7618	0.1729	1.35

Denning's comet during August will increase a little in brightness and may be visible in the great telescopes. We have no ephemeris at hand extending beyond August 5, when the comet will be in R. A. $6^h 07^m$; Decl. + 31° 48′.

Search Ephemeris for Comet Tempel. (1867 II).

(From Astr. Nachr. No. 3095).

		Perihelion April 3.5.						Perihelion March 24.				
		App. R. A.			Decl.		Br.	R. A.			Decl.	
		h	m	s	°	′		h	m	s	°	′
Aug.	8	17	50	10	− 33	04.7	0.08	18	14	06	− 34	01
	13		52	16		08.7						
	18		55	07		10.8	0.07	18	14	04	− 34	01
	23		58	38		11.4						
	28	18	02	51	− 33	10.6	0.06					
		Perihelion April 13.5.										
Aug.	8	17	26	52	− 31	53						
	18	17	33	44	− 32	08						

Partial Eclipse of the Sun Oct. 20.—This will be visible throughout nearly the whole of North America. . The eclipse begins at 10:15 A. M. central time, in longitude 133° 22′ west from Greenwich, latitude 65° 25′ north, and ends at 2:57 P. M., in longitude 50° 52′ west, latitude 14° 02′ north. The greatest eclipse will occur a short distance off the S. E. coast of Greenland, where 0.906 of the Sun's diameter will be covered by the Moon. We will give the times of beginning and ending at Northfield in our next number.

Elements of the Asteroids of 1891.

No.	☊	i	φ	a	Computer.
	°	°	° ′		
303	345 15	6 55	3 47	3.12	Millosevich
304	158 51	15 30	12 41	2.42	Berberich.
305	210 34	4 26	11 07	3.10	Berberich.
306	141 33	7 14	8 43	2.36	Berberich.
307	101 38	6 07	8 37	2.91	Knopf.
308	182 22	4 31	1 34	2.73	Berberich.
309	357 52	3 56	5 02	2.63	Berberich.
310	230 24	3 06	6 32	2.76	Berberich.
311	81 13	3 16	1 18	2.89	Berberich.
312	7 29	8 59	0 30	2.79	Masson.
313	176 42	11 29	10 17	2.38	Berberich.
314	171 06	12 25	10 42	3.12	Charlois.
315	161 07	2 25	9 40	2.24	Bohlin.
316	124 47	2 20	7 33	3.18	Gutesmann.
317	150 39	1 45	4 53	2.29	Charlois.
318	162 51	10 33	4 03	3.19	Berberich.
319	188 58	10 43	12 34	3.40	Berberich.
320	221 36	8 55	7 14	3.00	Berberich.
321	40 31	2 39	2 09	2.88	Berberich.
322	253 55	8 09	15 23	2.81	Esmoil.
323					
324	328 54	11 06	18 28	2.67	Berberich.

An Occultation as seen at the Underwood Observatory, Appleton, Wis., by L. W. Underwood.—While observing the moon on the evening of May 30, I detected a telescopic star near her dark limb. A few moments of observation made it certain that an occultation would soon take place. As the moon was crescent her dark limb was in advance, as she journeyed among the stars. This proved a very profitable circumstance on this occasion. I was able to sq adjust the telescope as to exclude from the field the bright limb and still plainly see the dark limb and the star.

A careful study of the light from the star was made from the time it was detected until the occultation took place, but not the slightest change could be detected. It seemed to remain perfectly uniform until the moon's dark limb reached it (8^h 28^m P. M. central time) when it simply went out instantly. This fact would seem to indicate that if the moon possesses any atmosphere whatever it must be very rare indeed, too much so to support life as we know it.

Appleton, Wis., June 6, 1892.

Occultation of Mars.—Below I give the times of the four contacts of the occultation of Mars by the moon last night. It was nearly clear here and the seeing was good. The markings on the planet were well seen, especially the south polar cap. Some of the dark markings near the equator I recognize as ones I have seen at nearly every opposition since 1877. There can be no doubt but that they are permanent. Following are the times of the contacts, 75th meridian time:

	h	m	s
1st...	11	26	4.5
2d....	11	27	5.5
3d....	12	29	6.0
4th...	12	30	12.5

FRANK E. SEAGRAVE.

Seagrave Observatory, Providence, R. I., July 11, 1892.

NEWS AND NOTES.

Our next issue will be for the month of October, and it will be mailed about the first day of that month.

The attention of foreign subscribers is called to the fact that Northfield, the place of publication of this journal, is now a money order office.

Professor Asaph Hall, Jr., has been appointed director of the Detroit Observatory, Ann Arbor, Michigan.

J. A. Brashear is again at his shops in Allegheny, after an extended trip in Europe. His health is improved as the result of his journey.

Mr. Burnham's Resignation.—I have severed my connection with the Lick Observatory and desire to state that hereafter my address will be "Government Building, Chicago."

S. W. BURNHAM.

Professor W. J. Hussey, formerly acting director of the Detroit Observatory of the University of Michigan, has been appointed to the position of Assistant Professor of Astronomy and Instructor in Mathematics at the Leland Stanford Jr., University, Palo Alto, California.

Changes in the Staff at the Lick Observatory.—It has been known for some time, that important changes would be made in the Staff of Lick Observatory. This has been understood by some astronomers acquainted with the personnel at Mount Hamilton, and it has also been noticed in the leading papers of San Francisco during the last two months. Hints that all things were not moving smoothly appeared in the resignation of Professor Keeler in the spring of 1891. Later Mr. Burnham has resigned, and now it appears that Professor Henry Crew is to exchange his place for the professorship of Physics in the Northwestern University at Evanston, Ill.

It is true that Professor Keeler was invited back to the Allegheny Observatory to take its directorship in the stead of our distinguished Langley, an honor indeed that he might well covet, but it was the wonder of his wider circle of friends that he should choose to leave the finest equipment of astronomical instruments in the world for another at present very ordinary, if not positively inferior, for common lines of modern research. Astronomers, the world over, know that Professor Keeler is a leading authority in spectroscopy, and that he had designed and most successfully used one of the most effective instruments in this research now known to the science. It is also well known that he had gained in a short time, for a young man, an enviable reputation at home and abroad by skillful work and astonishing results in the new and difficult spectroscopic study of the nebulæ. So true is this, that his dicta, in regard to the character and meaning of nebular spectra have been received as high authority everywhere by the best talent in astro-physics. Now it seems very strange that Professor Keeler would easily give up all this bright prospect, and be content to wait a long time before it can be possible for him to take up his delightful work where he left it more than a year ago. We think astronomers generally will wonder why Professor Keeler should abandon such a position as he held at the Lick Observatory, and so deprive himself and astronomy of the benefits in spectroscopical research which he was peculiarly fitted to prosecute.

The case of Mr. [illegible] [illegible] [illegible] was chosen [illegible] determine [illegible] be located [illegible] ness of the site at Mount Hamilton [illegible] interest in the growth [illegible] his work of testing the site with his [illegible] ies of double-stars [illegible] that gave the beginning of interest in Mount Hamilton as a [illegible] from which work. Since that time Mr. Burnham has been identified in many important ways with the growth and the success of this great Observatory. His double star work must be acknowledged as without an equal anywhere. His catalogues, his standing in the Royal Astronomical Society of England and in other scientific societies on the continent fully attest this. His practical knowledge of photography and his studious application of it to various fields of astronomical work have gained for him wide reputation as not only an artist but an authority in this branch of science. In view of all this it is a wonder that Mr. Burnham should leave Lick Observatory and accept the position of a clerk in one of the courts of Chicago. It is true that the new position pays higher salary than that of senior astronomer in the Lick Observatory, but we are not aware that Mr. Burnham ever complained of the smallness of salary in any position that he ever held, however small. He is not that kind of a man, his mind and his purpose are too large to be swayed by such motives. This could hardly be true anyway in regard to the positions at Mount Hamilton, for they are all reasonably well paid in view of all the circumstances.

But the thing most to be regretted in these late changes, is the fact that this great Observatory is rapidly losing its great men. As necessary as powerful instruments are to high success in modern research, it must never be forgotten that men are more than instruments. Whatever the position the *man* must rank his place and his instruments or he will degrade both. That Director Holden has done masterful work in building up the Lick Observatory so far is admitted on every hand. That was no small thing to do. It was well done, not perfectly, as he well knows, and himself says, but, still, it was well done. And one of the best things in his part of it was, that he had the foresight to select and the ability to secure, for his staff, some of the best men to be found in the United States. In this he was eminently wise. But, now, that these excellent men are rapidly leaving the Observatory, it is not evident that he is wise in permitting this, if it lies in his power to prevent it. In any phase of the matter it is a calamity to the Observatory and to astronomy. For first-rate men, like any others, can do better work the longer they remain in one position, other things being equal. New men can not master large and delicate instruments in a day. It requires many a day of pains-taking labor and waiting for the skillful astronomer to get from his fine instrument the very best that it can give. It may do for manager Frick at the Homestead Mills to say that he can easily get others to take the places of his trained men to work his improved machinery and turn out just as good armor plate, as in the past, but his skilled workmen know better. Much more is this true in scientific work, and we believe no one knows it better than does Professor Holden, and it is not probable that any course will be taken in the future which shall not be for the best interest of the Lick Observatory and for Astronomy in general.

As we close this paragraph the news comes to us that Professor Henry Crew, of Lick Observatory, has been elected Professor of Physics in the Northwestern University at Evanston, Ill. We are also informed that he will probably accept the position. Mr. Barnard and Mr. Schaeberle are the remaining older members of the staff.

Re-building Dudley Observatory.—Miss Catherine Wolfe Bruce of New York City has recently given twenty-five thousand dollars to the Dudley Observatory for the increase of its permanent endowment. Miss Bruce will be remembered for her munificent gift of $50,000 to the Observatory of Harvard College for the construction of a large telescope of special form, as also for numerous others in aid of astronomical research. In her offer of $25,000 to the Dudley Observatory for increase of endowment, Miss Bruce attached the condition that sufficient funds should otherwise be secured to remove and re-establish the Observatory on a better site. These conditions have been fulfilled. From various sources the sum of $31,700 has been secured to defray the cost of re-building the Observatory on a new site and to furnish it with a new equatorial of twelve inches aperture, together with other improvements in its equipment. The cost of the telescope is provided for by Robert C. and Charles L. Pruyn, sons of the late Robert H. Pruyn, formerly president of the trustees of the Dudley Observatory, and is intended to be a memorial in his honor. It is to be of the most approved modern construction.

The cost of re-establishment of the Olcott Meridian Circle (8 inches aperture), constructed by Pistor and Martins of Berlin in 1858, together with a collimating meridian mark and other improvements, is provided for by the liberality of three sons of the late Thomas W. Olcott, formerly president of the Observatory Trustees and the donor of the original instrument. The donors are Hon. Frederick P. Olcott of New York City and Dudley and John Olcott of Albany.

The working plans for the new Observatory are in process of preparation, and it is expected that the work of re-building will be entered upon during August of the present year.

The old site is very unfavorable to astronomical observation, owing to its proximity to the four tracks of the New York Central railroad which group around the base of Observatory Hill at a distance of about 150 yards from the instruments, with a very heavy traffic. The instruments and observing arrangements of the Dudley Observatory are much in need of improvement, and the necessary additions and alterations in the apparatus and observing rooms would have cost so large a proportion of the cost of absolute reconstruction on a new site that this consideration was regarded as a very strong factor in the determination to make the change. The new site is about two miles southwest of the present location, and in the southwestern part of Albany, upon a plot of about six acres, and surrounded by property in possession of the city park commission.

Civil Administration at the Naval Observatory.—Bills have been introduced in both houses of Congress, at the winter session of 1891-2, providing for a civil administration of the Naval Observatory, but retaining that institution in the Navy Department. The House bill was reported upon adversely by the committee on Naval affairs to which it had been referred; though it is not known that there were any public hearings at which opinions adverse to the general principle of the measure were expressed by any who addressed the committee. During the April session of the National Academy of Sciences. A hearing also [illegible] was had before the Senate committee on Naval affairs. The attitude of the Senate committee is supposed to be favorable to the proposition that the Government Observatory should be placed under the direction of a [illegible] astronomer.

Late in the session an attempt was made to tack an amendment to the naval appropriation bill providing for the appointment by the Secretary of the Navy of a commission to report a plan for organization of the new Observatory in time for consideration at the next session of Congress. This amendment was passed by the Senate, but with some thirty other amendments fails to receive the concurrence of the House committee.

As the matter stands the bill for re-organization of the Naval Observatory is before each branch of the National Legislature, but rests under the cloud of an adverse report in the House. There is no legal reason why this measure or some substitute for it may not be pressed to a vote at the next session of Congress.

The principal contentions made in the adverse report of the House committee on Naval affairs by the advocates of continued control of the Observatory by line officers of the Navy appear to be first—that the Observatory was founded solely by the efforts of Naval officers and that for some years it has been efficiently managed by them (though not so well of late); and second—that astronomers (scientific men generally) are not fitted for the large administrative duties connected with scientific work. It will be difficult to convince any man conversant with the history of scientific work and with the circumstances under which this decision was reached that there is any force in such arguments, or that they are the real ones which inspired the report.

It appears to be the opinion of many prominent public men in Washington that this agitation, which is only in its initial stage, must soon result in the control of the Observatory by a competent practical astronomer.

The Star Camera at the Sydney Observatory.—We have been favored by H. C. Russell, Government astronomer at Sydney, Australia, with a [illegible] in board covers bearing title "The Star Camera." The frontispiece is a [illegible] photogravure of the 13.5-inch photographic telescope [illegible] with a [illegible] portion of the observing room. [illegible] description and illustrations of the instrument and its working parts are given in this [illegible]. We note with interest that two combinations of lenses are used with the enlarging camera—one giving a magnifying power equivalent to a focal length of [illegible] feet, and the second equal to a focal length of [illegible] feet. With the first of these, pictures of the Moon five and five and one-half inches in diameter can be taken in three or four seconds; but it is found that the best results are obtained by reducing the aperture of the 13.5-inch lens to four inches and increasing the time of exposure to 20 seconds. Very satisfactory pictures of Jupiter and its moons [illegible] have been obtained in which the belts are shown and the red spot [illegible] more conspicuous than it is to the eye aided by the 11-inch equatorial.

The construction of the enlarging lenses is unusual. In each two lenses of equal foci are placed convex to convex, and they are separated by one-eighth of the sum of the foci of the two lenses. The pictures are said to be sharp and the field very nearly flat.

Professor Hall's Double Star Observations [illegible] Made at the Naval Observatory, Washington, have been received. The measures were made with the 26-inch equatorial during the last sixteen years. The stars observed are mostly known binaries.

Professor W. H. Pickering's Note on the Color of Mars.—The following note on the color of Mars was sent by Professor W. H. Pickering, Arequipa, Peru, hoping that the same would reach us in time to accompany his article which was leader in our June issue. It was intended for a note to accompany matter found on page 451.

NOTE.—Since the blue light reflected from the Earth's atmosphere, superposed upon the red light reaching us from Mars, combines to produce upon our eyes the effect of orange,—the color which Mars appears by daylight,—it seems likely that the atmosphere of Mars may tend to produce the same effect, causing the planet to appear less red than is really the case. This would explain why the limb of Mars always appears less red than the center, and would not involve the assumption of an atmosphere about the planet capable of absorbing the red rays. That is, the appearance of the planet's limb may be due to reflection and not to absorption and we need not necessarily assume an atmosphere at all different from our own. Since the color effect at the limb is strongly marked, it would appear, if the above proposition is correct, that the atmosphere of Mars is probably not very different from our own in density. W. H. P.

In Professor Pickering's private letter accompanying the above note, he speaks of finding, in a recent expedition to one of the neighboring mountains a bed of red lava. Some of this lava exactly matches in color what Professor Pickering considers from his experiments to be the true color of the planet Mars.

Photographic Chart of the Sky.—The first part of volume two of the Bulletin of the International Committee has just come to hand. It contains a number of important papers by the members of the committee. M. Loewy discusses a method of determining the co-ordinates of the centers of the plates, making them depend not only on the few well determined stars which may occur on each plate but also upon those found on overlapping plates. In this way each plate may be referred to so many stars that it will not be necessary to undertake the labor of re-observing with meridian circles the 60,000 or 70,000 reference stars.

The committee charged with distributing screens to be used at the different observatories in determining the proper length of exposure for 11th magnitude stars, obtained discordant results in their experiments, the time ranging from $1^m\ 20^s$ to 7^m. It is probable that the plan of making three exposures of 6^m, 3^m and 20^s respectively on each region on the same night will be adopted for the plates from which the catalogue is to be constructed. The exposure for the chart plates will be uniformly 60^m. H. C. W.

Magnet-Meteorologico Observatorio Coimbra, Portugal.—We are indebted to Dr. Antonio de M. Garrido, Director of Observatorio Magnet-Meteorologico at Coimbra Portugal, for his annual publication for the year 1891. It gives an interesting cut of Observatory, the first we have seen of it.

Publicazioni Della Specola Vaticani Fascicolo II.—We are pleased to have received from the Observatory of the Vatican, Rome, Italy, by the kindness of the Director, P. François Denza, the above named publication for the year 1891. Besides the usual records pertaining to Meteorology and Astronomy, a series of fine plates are given showing the Observatory building, photographic instrument, plates of the Pleiades, Cluster on Sagittarius, Ring Nebula, real photographs of portions of the Moon and three photographs of Jupiter, two of which plainly show the red spot, and all give the belts with great distinctness. The equatorial diameter of the pictures of Jupiter is quite exactly one-half inch.

The Photo-chronograph applied to Determinations of Latitude.—This is the title of a paper just published by the Georgetown College Observatory. The new form of instrument used is that of a floating zenith telescope, similar to Dr. Chandler's Almucantar, with a photo-chronograph attached in the place of the micrometer eye-piece. The objective is a single combination of two lenses, corrected for photographic rays, aperture 6 inches and focal length 36 inches. It was made by Brashear and is found to be excellent, readily giving trails of stars below the 7th magnitude. The photo-chronograph was designed by Professor Geo. A. Fargis, S. J., and constructed by Mr. Saegmuller. It consists essentially of two occulting bars, which, by means of electro-magnets in connection with a clock, are made to alternately cover and uncover the portions of the sensitive plate upon which the star trail is being made, one of the bars serving for the north, the other for the south star. Pairs of stars are selected, as in the ordinary method of determining latitude with the zenith telescope, having nearly equal zenith distances, north and south, and the two stars are allowed to leave their trails on the same plate. The trails are broken up into series of dots by the clock moving the occulting bars each alternate second, and the beginning and middle of each minute is marked by the omission of a certain number of breaks. It is thus easy, knowing the time of transit of each star, to find the position of the meridian on the plate, so that the distance between the star trails may be measured in the meridian with a micrometer. The reductions are the same as in Talcott's method, except that the level correction and reduction to meridian are omitted.

A few preliminary results are given for the latitude of the Georgetown Observatory, which seem to indicate that the method can be relied upon to give more accurate results than the visual method, besides being much more comfortable for the observer. At the close of the paper the following announcement is made:

"The intention is to make this Observatory a *permanent station for studying the periodic variations of the Pole.* A second permanent latitude station is, at our instance, being erected at Manila, in the Philippine Islands. It will be furnished with a floating zenith telescope and latitude photo-chronograph like those here described. The future director of that station, Father Joseph Algué, S. J., is now at the Observatory, with the view of familiarizing himself with this method. Since Manila is almost opposite Washington in longitude, these two stations seem to be well adapted for controlling the periodic variations of the Pole by a uniform method, in a direction almost perpendicular to the meridians of Berlin and Honolulu, where simultaneous observations are carried on at present."

H. C. W.

Brilliant Aurora at Mt. Hamilton, June 26.—Last night at $12^h\ 15^m$, while photographing the Milky Way, my attention was attracted to a bright fiery illumination in the north and northeast. This proved to be a brilliant aurora. The northeast sky was suffused with a bright reddish glow extending nearly as high as the pole. Bright yellowish white streamers were shooting up from the horizon, but there was no arch. For the next half hour the display was very active and towards the last streamers made their appearance to the west of the pole. The activity gradually ceased, but the brightened glow continued visible in the north and northeast as late as $14^h\ 30^m$, when it could still be seen through the breaks in the clouds which then covered the sky.

The point of maximum action and illumination was about 15° east of the north point.

This makes the second aurora that I have seen at Mt. Hamilton, the first being on May 18 this year. See ASTRONOMY AND ASTRO-PHYSICS for June, 1892.

E. E. BARNARD.

Mt. Hamilton, 1892, June 27.

Comparison of Celestial Photographs.—In *Astr. Nach.*, No. 3101, Mr. Barnard suggests a very simple and rapid method of detecting changes on celestial photographs, due to motion or variability of the celestial bodies. This requires the two negatives to be on exactly the same scale. A positive on glass is made from the first negative and superposed upon the second, film to film. Since the scale is the same in each case the black images of the negative number two will blot out the white images of the positive, except where there has been change of position or loss of brightness of a star. Increase of brightness would be detected by superposing the first negative upon a positive of the second.

Another quite novel method of comparing plates was suggested to me this summer by Mr. Ritchey at Chicago. It was to project the two positives upon a screen at the same time with complementary colored lights, for instance red and blue of the proper shades. When the positives are carefully adjusted so that the corresponding images fall upon the same points of the screen, all stars having the same intensity of image on both plates will appear white. A star occurring on only one plate will be red or blue according to the color of the light projecting that plate. Variations of brightness of stars will be indicated by different tints of color, red or blue according as the star is more intense in the one plate or the other. H. C. W.

Visit to Kenwood Physical Observatory.—We spent two very pleasant and profitable weeks at Mr. Geo. E. Hale's private Observatory at Kenwood, Chicago, during this summer. The equipment of this Observatory and the discoveries which have been made in it have been described in the earlier numbers of this journal, but one must actually see the apparatus and the photographic plates to fully appreciate what has been accomplished in the way of photographing the solar prominences and faculæ. The photographs of the faculæ are a revelation to one who has watched them visually or photographed them by the old methods from day to day and realizes over what a small portion of the solar disk they are thus seen. The extent of the area covered by the faculæ in these photographs is surprising. I have before me a positive of a photograph taken in February when the great spot was near the center of the Sun's disk. The faculous area is so conspicuous and extensive that the great spot in its center is almost insignificant in comparison. In another photograph taken a few days later when the great spot was near the west limb, the whole spot zone in the northern hemisphere is sprinkled over with brilliant faculæ. The careful examination and measurement of these photographs, taken daily and often many times each day cannot fail to add greatly to our knowledge of the Sun.

Mr. Hale has just added a new photographic objective to the telescope, making it a twin telescope, but with only one tube. The method of mounting the objectives is a novel one. They are placed in a twin cell which is hung on an axis at the side of the tube in such a way that either glass may be brought by rotation in front of the tube. They may thus be inter-changed in a few seconds. The tail-piece carrying the eye-pieces is also mounted at the side of the tube so that for visual observations the telescope without a tube is used. The definition seems not to suffer but rather to be possibly improved by this arrangement.

H. C. W.

Color of Sirius in Ancient Times.—Perhaps I may be allowed to offer a few remarks on Mr. See's interesting papers on this subject, particularly as he does me the honor in the second portion to refer to a letter of mine in the tenth volume of the *Observatory*. He has gone into the matter exhaustively, and has somewhat altered my views in respect to it.

The color attributed by Al Sufi to a few of the stars would seem to be his own and not Ptolemy's, as he differs from the latter in calling Algol red and not Sirius. Plato Tibertinus appears to have made a very remarkable error in representing that the Arabian astronomers found only five red stars in their copies of Ptolemy, whereas they wrote five *nebulous* stars, his own enumeration of the latter. But it does seem strange that Schjellerup did not consult the Arabic originals, instead of this translation.

I withdraw my remark in the *Observatory* concerning the peculiarity of the expression *καλούμενος κύων καὶ ὑπόκιρρος*, because on consulting older editions of Ptolemy than that of Halma, I do not find the *καὶ* between the substantive and the adjective, Sirius being called *ὑπόκιρρος* exactly as Antares and Arcturus are.

We may differ with regard to the weight to be attached to the "rutilo cum lumine" of Cicero or the "rubra Canicula" of Horace. But Seneca really seems to have compared the color of Sirius with that of the planets and noticed that the star was more red than Mars, whilst Jupiter was not red at all. This last remark appears to me, on further consideration, to take away all probability from the suggestion of the Delphin editors that the true reading should be "fulgor" and not *rubor*. For Seneca could hardly have meant to say that the fulgor (brightness) of Jupiter was *nullus*. W. T. LYNN.

Blackheath, London, S. E., 1892, May 25.

Chicago Academy of Sciences.—*Section of Mathematics and Astronomy.*—At a meeting of the Chicago Academy of Sciences on May 10, 1892, it was moved by George E. Hale that authority be granted for the formation of a Section of Mathematics and Astronomy. The motion was duly seconded, and referred to the General Committee, which reported favorably at the general meeting of the Academy on June 14, 1892.

The first meeting of the Section was held at the Kenwood Astro-Physical Observatory, Chicago, on June 15, 1892, in joint session with the Chicago Section of the Astronomical Society of the Pacific. Gayton A. Douglas was in the chair. The Chair announced that several Sections of the Academy had recently been formed, and that all of them had met with marked success. Any present who wished to become members of the Academy could make application on blanks provided for the purpose.

The Section proceeded to elect officers to serve until January, 1893, with the following result: Chairman, George W. Hough; Recorder, George E. Hale; Executive Committee, Sherburne W. Burnham, Gayton A. Douglas, E. H. Moore, with Chairman and Recorder *ex officio*. The committee will prepare by-laws to be acted upon by the Section.

Professor Hough not being present, Mr. Douglas remained in the chair.

Professor Hale made some remarks on the work of the Academy and its signal success in the formation of Sections. He congratulated Chicago scientists in general and the Astronomical Section in particular on the fact that Mr. S. W. Burnham has returned to Chicago from the Lick Observatory, and will permanently reside here.

The Chair remarked that the present meeting occurred on the first anniversary of the dedication of the Kenwood Observatory, and called on Mr. R. W. Pike for remarks.

Mr. Pike spoke of the work accomplished at the Observatory during the first year of its existence, and said that he had found some interest taken in this work by astronomers whom he had recently met in various European observatories.

Professor Hale followed with an account of the investigations now in progress on the application of photography in recording the forms and spectra of the solar spots, faculæ, chromosphere and prominences. During the year 19 lines have been discovered in the ultra-violet prominence spectrum, the H and K lines have been found to be reversed in all spots and faculæ, and a practical method of photographing the chromosphere, prominences, spots and faculæ in a single picture has been devised, and is now in daily use.

The Chair introduced Dr. S. H. Peabody, President of the Academy, and Chief of the Liberal Arts Department of the World's Columbian Exposition. Dr. Peabody spoke of Newton's early experiments with a round hole instead of a slit, and of the immediate results of Wollaston's substitution of a narrow slit years later. He thought that the advantages resulting from the application of photographic methods to solar study were almost comparable with that advance. He also alluded to Schwabe's long years of patient observation of Sun-spots, and pointed out the important aid of photography in such work.

The meeting then adjourned, and those present (about 125 in number) were given an opportunity of observing Saturn with the 12-inch telescope.

Applications for membership in the Academy have been received by the Recorder from the following persons, and placed in the hands of the Secretary of the Academy:

Resident Members.—R. W. Pike, 166 La Salle St.; Frank H. Dickey, 3626 Ellis Ave; W. H. Hine, 324 Ogden Ave.; Mrs. W. H. Hine, 324 Ogden Ave.; F. W. S. Brawley, 3010 Lake Park Ave.; Cynthia L. Stone, 4544 Greenwood Ave., Chicago.

Associate Member.—Clifford C. Smith, No. 1036 "The Rookery," care of Ill. Steel Co., Chicago. GEORGE E. HALE, Recorder.

Astronomical Society of the Pacific.—*Minutes of the meeting of the board of directors held at the Lick Observatory June 11, 1892.* President Schaeberle took the chair and a quorum was present. The minutes of the last meeting were approved. The 18 members following were elected: Mrs. H. R. Arndt, San Diego, Cal.; William W. Austin, Vineland, Cumberland Co., New Jersey; W. H. Devine, Nagasaki, Japan; W. S. Eichelberger, Wesleyan University, Middletown, Conn.: Professor R. Lee Hamon, Hyannis, Grant Co., Nebraska; Daniel Hanlon, 1627 Jackson Street, S. F., Cal., Mrs. Phebe Hearst, Care of W. R. Hearst, "Examiner," S. F., Cal.; Charles W. Holden, 30 Congress Street, Boston, Mass.; C. G. Hubbard, San José, Cal.; Donald King, 8 Church Lane, Strand, London, England; Frank McClean, M. A., F. R. A. S., Rusthall House, Tunbridge Wells, England; F. Martens, College Point, Queen's Co., New York; J. Messer, care of Carl Ricker, Nevsky Prospect, No. 14, St. Petersburg, Russia; Judge F. W. Miner, Providence, R. I.; James L. Park, Braddock, Pa.; T. J. J. See, Zimmer Str. 97 Berlin, Germany; W. T. Sulzer, Louisville, Ky.; Professor L. Weinek, Imperial Observatory, Prague, Austro-Hungary. The treasurer presented his report which was received and filed.

Mr. Pierson, of the committee on Observatory in San Francisco, reported that the Park Commissioners had kindly granted a site in Golden Gate Park for the proposed Observatory.

The following resolution was moved and seconded and postponed for further consideration:

Resolved, That the By-Laws (Art. II) be amended by abolishing the status of Honorary and Corresponding members and making the necessary verbal changes. (See *Publ. A. S. P.*, Vol. III, page 194.)

Minutes of the meeting of the Astronomical Society of the Pacific held at the Lick Observatory, June 11, 1892. President Schaeberle presided. The minutes of the last meeting as printed in the *Publications*, were approved. A list of presents was read by the Secretary, and the thanks of the Society voted to the givers.

Special attention was called to the beautiful album of engravings of the buildings and instruments of the Nice Observatory, presented by Mr. Bischoffsheim, the founder of the Observatory, and to the very rare medal of the Great Comet of 1680 referred to in *Publ.* A. S. P., Vol. II., page 124, presented by Professor Holden.

The Secretary read the names of members duly elected at the meeting of the Directors. The following programme was presented:

1. The Lunar Eclipse of January, 1888, by Professor Weinek, of Prague.
2. The Proper Motions of Stars with different Spectra, by W. H. S. Monck, of Dublin.
3. The McCormick Observatory, by H. A. Sayre, of the University of Virginia.

4. A Trial of Foucault's Pendulum Experiment, by [illegible], of Denmark.
5. Notice regarding the Astronomical Exhibit at the World's Fair, by Geo. E. Hale, of Chicago.
6. Verbal Accounts by Professors Schaeberle and Campbell, of Observations of the spectrum and magnitude of the new star in Auriga, of photographic observations of the Great Sun Spot of February, 1892, and of observations of the spectrum of Swift's comet. Illustrated by photographs made at the Lick Observatory.

Recent enlarged photographs of Venus and of Saturn made with the 36-inch equatorial and an enlarging lens by J. A. Brashear were exhibited to the members as well as similar photographs by Professor Schaeberle of the region near the New Star in Auriga; photographs and drawings by Professor Campbell of the spectrum of the New Star and of Swift's comet; and some very fine [illegible] photographs of stellar spectra taken in the 3d and 4th orders of a Rowland grating of 14,000 lines; etc., etc. Adjourned. [illegible], Secretary.

The Astronomical and Physical Society of Toronto.—We notice with interest the reports of the meetings of the Astronomical and Physical Society of Toronto in the various papers of that place. Since our last issue several extended reports of the society's meetings have been published, which not only indicate an unusual interest in the chosen field of the society, but also show it to be doing some useful work in lines of science open to this new organization.

The meeting of July 4 presented an excellent programme, and a [illegible] full report of it is given below, as it appeared in the Toronto [illegible].

Among the communications read were letters from Miss Agnes M. Clerke, of London, England, a writer of high rank in astronomical science, and a corresponding member of the society, who sent in a paper entitled [illegible] from Mr. J. Ellard Gore, F. R. A. S., and from the directors of the observatories at Melbourne, Australia, and Bothkamp, Germany. Letters of thanks for copies of the society's last report were also received. [illegible] Wilson, of Toronto, was elected a life member, and several names were proposed for active and corresponding membership. A committee was appointed to take action in respect to the proposal to induce astronomers to reckon the astronomical day from midnight instead of from noon, as now. Interesting drawings of solar prominences were received from Mr. A. F. Miller, and of Mars from Mr. Arthur Harvey, who also reported having observed on the 25th of June a well-defined parhelion, a phenomenon unusual at this season of the year.

The paper for the evening, "Stellar Distances and Motions," had been received from Mr. J. Ellard Gore, a valued contributor to scientific publications and the author of several excellent works on astronomy. It consists of a chapter from his forthcoming book, "The Visible Universe," and had been sent in advance of publication by special permission of his publishers, Messrs. Crosby Lockwood & Son, London, England, who own the copyright. In his lucid and attractive style Mr. Gore showed that the determination of the distance of the stars from the Earth has always formed a subject of great interest to astronomers, and that a knowledge of the relative distances of bright and faint stars is of the highest importance in the study of sidereal astronomy, it being evident that if we could accurately find the distance of every star and also the distances of the brighter and fainter portions of the Milky Way, the problem of the construction of the stellar heavens would be immediately solved. Notwithstanding the use of modern instruments of precision, the distances of but few stars have been ascertained with any approach to accuracy. In the course of his admirable paper, the author referred to the earlier astronomers, including Tycho Brahe, Kepler and Huyghens, some of whom thought the stars had no measurable parallax, and others that the determination of the stellar distance by observations was impossible; Sir William Herschel, who, while working vainly upon the problem, made the splendid discovery of binary systems; to the parallax of fixed stars and the method of determining it; to the methods of computing a star's distance in miles by simply multiplying the Sun's distance by 206,265, and dividing by the observed parallax, and of reducing distances to "light-years;" to the fact that the brightness of a star is no test of its distance; to the use of the spectroscope in determining the motion of stellar objects moving in the line of sight, and, among other branches of his subject, to the discovery that the solar system is itself in motion towards a point in Hercules, a constellation overhead at Toronto every evening at an early hour.

The predictions included the occultation by the Moon of 25 Scorpionis at 12:41 A. M., July 7; of B.A.C. 6,666 at 7:40 P. M, July 9, of 35 Capricorni at 8.23, July 11, and, on the same evening, of the planet Mars shortly after 11 o'clock. The Moon, which will be about two days past the full phase, will rise at 9.41 with the planet a little to the east of it. Mars will disappear behind the bright limb of the Moon, and should reappear from behind the shaded limb about 12 minutes after midnight. The phenomenon, which will be visible to the naked eye, is not a common one, and will prove to be worth careful observation by amateurs; any telescope, and almost any opera-glass, will greatly add to the interest of the occultation.

BOOK NOTICES.

High School Algebra, embracing a complete course for High Schools and Academies. By William J. Milne, Ph. D., L.L. D., President of New York State Normal College, Albany, N. Y. "Milne's Inductive Algebra" revised and enlarged. Published by the American Book Company, New York, Cincinnati, and Chicago.

In the revision of this Algebra, the author has kept steadily in mind the "inductive idea" in teaching, which he thinks worthy of a prominent place. In this he is certainly right in a very important sense. In training a student in Algebraic processes, it is one thing to work mainly for a result, it is quite another thing to seek for a result by a clear and definite logical process. The student naturally will work for an answer, often think little, and sometimes care little about his method of argument, provided it does not involve manifest absurdity. At this point, more than any other, are the book and instructor valuable. If these guide the student wisely, interest and growth of mental power always follow.

The inductive plan, so called, consists in first giving a considerable number of mental exercises which are intended to bring to the mind of the student the ideas of the definitions to be stated in careful way later, and which are appropriate to the subject under consideration. After the definitions belonging to the topic are given there follows a statement of principles, set out plainly in suitable type, so as to gain the attention fully and properly relate them to other secondary work intended only for illustration. It is a hard thing for a student to learn that a problem or, an example even, is intended *only* to illustrate a principle. The plan of this book, in this respect, is quite like that used by Mr. E. E. White in his complete arithmetic. That book is well known among teachers for its excellence.

The range of topics of this algebra is abundantly wide, examples varied and numerous, and there is a useful series of review exercises at its close. The printing and paper are excellent and it is the best bound text-book we have seen in many a day.

A Treatise on Plane and Spherical Trigonometry, by E. Miller, A. M., Professor of Mathematics and Astronomy in the University of Kansas. Publishers, Messrs. Leach, Shewell and Sanborn, Boston and New York.

Within a compass of 110 pages, Professor Miller has given us the essentials of Trigonometry in this new book. His definitions are well stated, illustrations clear, figures good, and examples sufficient for practice, though not as abundant as in some late authors. Almost exactly one-half of the book is devoted to spherical Trigonometry, which treats this part of the study more generally than elementary text-books usually do. The formation of the fundamental formulæ is at once undertaken by the aid of geometrical figures which involve the use of the polar triangle. While this is an excellent way to instruct students in Trigonometry who have had some experience, it seems to us that it would be a severe method for those who are pursuing the study for the first time, especially if they have not had the preparatory training in Plane Trigonometry which involves large use of formulæ and functions. We are aware that the author has adopted Chauvenet's good ideas here, and we know they are good from actual test in past studies in this branch, but what we fear in the arrangement of matter is the difficulty of the task which the beginner will be asked to undertake before he has sufficient foundation in spherical thinking to enable him to carry the processes without undue strain or discouragement. If sufficient time be given to the work, and the daily assignments of lesson be sufficiently limited, of course the book may be used successfully. The instructor would have to be on his guard continually to avoid assigning too much or he would overtax the student or cause him to make imperfect preparation. We have little doubt but that Professor Miller would know how to use this book, but we fear many others would fail in trying it. The sets of examples furnish a thorough review of principles of Trigonometry, and the student who masters them all would certainly be entitled to a good standing in the branch in any college.

The publishers have made a neat and a very attractive book, and we are sure that those interested in teaching Trigonometry will be profited by its thorough examination. The book is not provided with logarithmic or trigonometric tables.

A Drill Book in Algebra. By Professor George William Jones, of Cornell University. First edition. Published by George W. Jones, Ithaca, N. Y., 1892, pp. 272, 12 mo. Cloth. By mail 60 cents. An answer book and a box of question cards in preparation.

This is the fourth book in the mathematical series by Professor Jones already published, and is designed for the more advanced classes in the High Schools and Academies and for lower classes in the Colleges. The name of Drill-book is well chosen. It is exactly that. The book presents nine different topics, viz.: The primary operations of arithmetic, the primary operations of algebra, simple equations, measures and multiples, variations, proportions, inequalities, incommensurable numbers, powers and roots, quadratic equations, the three progressions, logarithms, permutations, combinations and probabilities. Under each of these topics there are from four to seven sub-heads, or sections, which discuss the different features of the topic, closing a series of questions for review appropriate to the same. It is easy to see how a live teacher with such a book as this in hand could easily arouse a class of students to high endeavor and useful result. We are sure teachers of algebra will be interested in examining this new book. Its cost is remarkably small.

Determinants. An introduction to the study with examples and applications by G. A. Miller, Ph. D., Professor of Mathematics in Eureka College, and published by the D. Van Nostrand Company, 23 Murray and 27 Warren streets, New York. 18 mo. Boards, pp. 110. Price 50 cents, 1892.

This little book is No. 105 of Van Nostrand's Scientific Series, and it is the first of that series that we have seen. We think enough of it, to put it into our pocket to read at odd spells, so as to have a little mental recreation when chance opportunity is offered. Any student wanting a good introduction to Determinants in convenient form, may profitably examine this book. The topics briefly and plainly treated are as follows: History of Determinants, nature of Determinants, Inversions and permutations, meaning of notation, different methods of notation, Determinants of the second order, Determinants of the third order, increasing the order by borders, Complementary minors, applications to linear equations, consistence of linear equations, factors of a Determinant, multiplication of Determinants, symmetrical Determinants and elimination.

Abroad and at Home is a neat book of 251 pages by Morris Phillips, editor of "Home Journal," New York, published by the Brentanos, Paris, Washington, Chicago and London, containing practical hints for tourists.

Within so narrow a compass this book gives to the tourist a good introduction to principal points on main thoroughfares in Great Britain and Paris if going abroad, and if traveling in the United States, of course, the sight-seer must visit Georgia, Florida or California, and the resorts in these directions are alluded to in the latter part of the book in helpful way.

Errata in Article on Color of Sirius.—Below will be found a list of corrections which Mr. See wishes to be noted in reading his article on the History of the Color of Sirius. Some errors were due to proof readers. The copy of the Greek words was in script and some of them very uncertain. A number of changes indicated were not in the copy, as we notice by comparison:

Page 270, line 3, *ἐπικλησιγ*; line 6, read *χαλκὸς*; line 8, read *πυρετός*; line 16, read *the* Scorpion, [*the* was not in copy]; bottom line read *παμφαίνῃσι*. Page 272, under Aratus line 6, Myron. Under Geminus, first line of Greek read (*κύων*); last line *κυνὸς*. In this passage *ἀποφορά* had better be translated "influences" instead of "exhalations." Page 273, line 2, read Matthiæ. In the Greek of Erastosthenes the semi-colons (·) should be inserted after *λέγεται* and *καλουσι*. Page 374, in the second quotation from Cicero read candoremque, (copy bad). Page 375, first quotation from Plutarch the accent on *Ἴσιδος* is somewhat misplaced. In the second quotation from Plutarch the first word should be *Λίβυες*; in the last, read *τὸν δὲ Κύνα*. In the last word cited from Photius there should be a final *ν*, it was not in copy. The king of Egypt referred to should be Ptolemy III-Euergestes I. Page 375 last line, read *εἰμι*. Page 376 under Horace first line of quotation read reducto. Page 377, in quotation from Seneca read Martis. Page 378, in quotation from Columella, first line, read Dionaeis, and insert comma after hortus; the comma after Cultu should stand after Hortorum (omitted from copy in both cases). Page 379, under Festus, 9th line from bottom, the comma after word should stand after Catularia (not in copy). Page 380, under Ptolemy, *καλουμενος* should not have capital *κ*, and *Κύων* should be accented (copy uncertain). Mr. Bailey's name is Francis. The summary is capitalized exactly as the copy. Copy of this kind in the future will not be accepted unless better.

PUBLISHER'S NOTICES.

The subscription price to ASTRONOMY AND ASTRO-PHYSICS in the United States and Canada is $4.00 per year, in advance. For foreign countries it is $4.40 per year which is the uniform price. Messrs. Wesley & Son, 28 Essex Street, Strand, London, are authorized to receive subscriptions. Payment should be made in postal notes or orders or bank drafts. Personal checks for subscribers in the United States may be used.

Currency should *always* be sent by registered letter.

Foreign post-office orders should *always* be drawn on the post-office in Northfield, Minnesota, U. S. A.

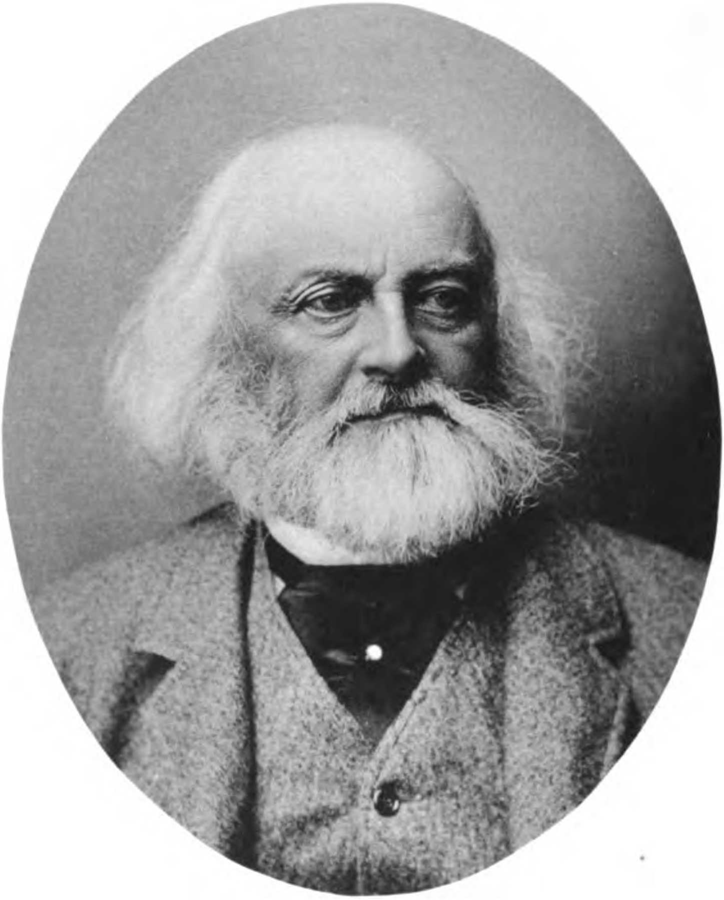
All communications pertaining to Astro-Physics or kindred branches of Physics should be sent to George E. Hale, Kenwood Astro-Physical Observatory Chicago, Ill.

All matter or correspondence relating to General Astronomy, remittances, subscriptions and advertising should be sent to Wm. W. Payne, Publisher of ASTRONOMY AND ASTRO-PHYSICS, Goodsell Observatory of Carleton College, Northfield, Minn.

Manuscript for publication should be written on one side of the paper only, and *special care should be taken to write proper names and all foreign names plainly*. All drawings for publication should be *smoothly* and *carefully* made, in *India ink* with lettering well done, because such figures are copied exactly by the process of engraving now used. If drawings are made about double the size intended for the printed page, better effect will be secured in engraving than if the copy is less in size. As a rule the publishers have had to re-draw the figures sent during the last year at considerable expense. We hope to avoid this in the future. It is requested that manuscript in French or German be type-written. If requested by the authors when articles are sent for publication, *twenty-five* reprint copies, in covers, will be furnished free of charge. A greater number of reprints of articles can be had if desired, at reasonable rates.

Rates for advertising and rates to news agents can be had on application to the publisher of this magazine.

PLATE XXVII.



LEWIS MORRIS RUTHERFURD.

Astronomy and Astro-Physics.

NEW SERIES No. 8. OCTOBER, 18[illegible] WHOLE No. 1[illegible]8

GENERAL ASTRONOMY.

ON ASTRONOMICAL PHOTOGRAPHY WITH COMMERCIAL [illegible]

WM. H[illegible]

Since Barnard, Russell and Wolf have [illegible] what excellent photographs of the heavens can be [illegible] with ordinary commercial lenses, persons anxious [illegible] that line of work frequently make such inquiries [illegible]:

What sizes and makes of [illegible] are suitable for stellar work?

What is the best ratio of [illegible] distance?

Is it worth while to try any [illegible] less than six inches aperture?

Can good work be [illegible] portrait lens, and is it probable that a [illegible] that kind [illegible] be obtained which will prove satisfactory [illegible] refigur[illegible]

The proper answer [illegible] questions [illegible] depend upon a few simple principles which [illegible] be stated [illegible] as follows:

A.—The focal dista[illegible] determines the scale of the resulting pho[illegible] maps of the heavens whereon each [illegible] of declin[illegible] represented by a space equal to one-57th [illegible] the equ[illegible] of the generating lens; or more ac[illegible].

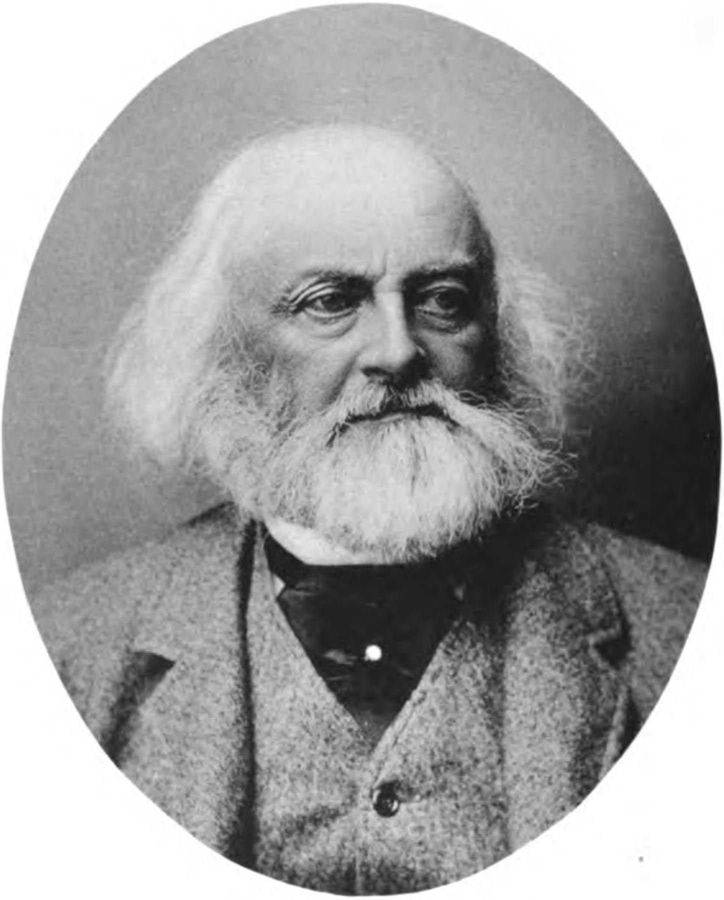
One degree = 0.0174[illegible] alent focus [illegible] lens;

For example, a lens of [illegible] inches equiv[illegible] focus will give photographs on the sam[illegible] as Argelander's Uranometria Nova; one of ten inches [illegible] will give [illegible] on the scale of Proctor's large star [illegible] one of 44.[illegible] focus [illegible] give photographs on the sca[illegible] Argelander's [illegible] star charts; and one of the [illegible] inches focus [illegible] photographs on the scale of Chacornac [illegible] Ecliptic[illegible] In [illegible] work a minute of arc is represe[illegible] space of [illegible] and that is the scale which has [illegible] for the great [illegible]

---

* Communicated by the author.

PLATE XXVII.



LEWIS MORRIS RUTHERFURD.

Astronomy and Astro-Physics.

NEW SERIES No. 8. OCTOBER, 1892. WHOLE No. 108

GENERAL ASTRONOMY.

ON ASTRONOMICAL PHOTOGRAPHY WITH COMMERCIAL LENSES.*

WM. HARKNESS.

Since Barnard, Russell and Wolf have shown what excellent photographs of the heavens can be made with ordinary commercial lenses, persons anxious to attempt that line of work frequently make such inquiries as the following:

What sizes and makes of photographic lenses are suitable for stellar work?

What is the best ratio of aperture to focal distance?

Is it worth while to try any lens of less than six inches aperture?

Can good work be done with a common portrait lens, and is it probable that a lens of that kind can be obtained which will prove satisfactory without refiguring?

The proper answers to these questions all depend upon a few simple principles which may be stated briefly, as follows:

A — The focal distance of the lens employed determines the scale of the resulting photographs, which are simply maps of the heavens whereon each degree of declination [illegible] space equal to one-57th [illegible] of the [illegible] rating lens; or more accurately:

One degree = 0.017452 equivalent focus.

For example, a lens of [illegible] inches equivalent [illegible] photographs on the same scale as Argelander's [illegible] one of ten inches [illegible] give [illegible] scale of Proctor's large star [illegible] give photographs on the scale [illegible] star charts; and one of the [illegible] graphs on the scale of Chacornac's [illegible] latter work a minute of arc is re[illegible] millimeter and that is the scale which [illegible] for the great in[illegible]

---

* Communicated by the author.

PLATE XXVII.

MORRIS RUTHERFURD

[illegible]

Astronomy and Astro-Physics.

NEW SERIES No. 8. OCTOBER, 1892. WHOLE No. 108

GENERAL ASTRONOMY.

ON ASTRONOMICAL PHOTOGRAPHY WITH COMMERCIAL LENSES.*

WM. HARKNESS.

Since Barnard, Russell and Wolf have shown what excellent photographs of the heavens can be made with ordinary commercial lenses, persons anxious to attempt that line of work frequently make such inquiries as the following:

What sizes and makes of photographic lenses are suitable for stellar work?

What is the best ratio of aperture to focal distance?

Is it worth while to try anything of less than six inches aperture?

Can good work be done with a four-inch portrait lens, and is it probable that a lens of that kind can be obtained which will prove satisfactory without refiguring?

The proper answers to these questions all depend upon a few simple principles which may be stated briefly, as follows:

A.—The focal distance of the lens employed determines the scale of the resulting photographs, which are indeed maps of the heavens whereon each degree of declination is represented by a space equal to one-57th part of the equivalent focus of the generating lens; or more accurately:

One degree = 0.017452 (equivalent focal distance of lens).

For example, a lens of eight inches equivalent focus will give photographs on the same scale as Argelander's Uranometria Nova; one of ten inches focus will give photographs on the scale of Proctor's large star atlas; one of 44.5 inches focus will give photographs on the scale of Argelander's Durchmusterung star charts; and one of the 134.6 inches focus will give photographs on the scale of Chacornac's Atlas Ecliptique. In the latter work a minute of arc is represented by a space of one millimeter, and that is the scale which has been adopted for the great inter-

---

* Communicated by the author.

national photographic chart of the heavens. The focal distance of ordinary commercial lenses rarely exceeds three feet, and the maximum scale attainable with them is only about one-quarter that of the great international chart, or say 0.01 of an inch to a minute of arc.

B.—The ratio of aperture to focal distance affects the time of exposure, directly for nebulæ, and indirectly for stars. As all nebulæ have sensible angular magnitude, the time of exposure for them is given by the well known formula

$$t = C'\left(\frac{f}{a}\right)^2 \qquad (1)$$

where t is the duration of the exposure, f the focal distance of the objective, a its clear aperture, and C' the exposure coefficient, which must be determined experimentally.

Notwithstanding the differences in their brightness, the stars themselves are all mere points without sensible diameter, but such is far from being the case with their photographic images. On account of imperfection in the lenses employed, atmospheric disturbances, spread of chemical action, and possibly other causes, the image of a first magnitude star sometimes attains a diameter as great as 0.18 of an inch by the time the image of a fourteenth magnitude star is just beginning to become visible. Hitherto no thoroughly satisfactory formula has been obtained for the time of exposure required by very faint stars, but as a rough approximation, sufficient for our present purpose, we may take

$$t = C''\frac{L^{(m-1)}}{a^2} \qquad (2)$$

where L is the photographic light ratio, and m the magnitude on Argelander's scale. C'' must be deduced from the time of exposure of photographs of very faint stars made with lenses of known aperture, and in doing so one of the greatest obstacles is the difficulty of determining the true magnitude of the smallest stars shown. Insuperable systematic differences arise in the case of colored stars, but aside from them the best method of procedure is probably to make an experimental determination of the minimum time necessary for photographing the faintest white stars visible to the eye in an achromatic refracting telescope of known aperture. The visual magnitude of such stars can then be computed on Argelander's scale by means of the well known formula.

$$m = 9.2 + 5 \log a \qquad (3)$$

where *a* is the clear aperture of the telescope, expressed in English inches.

As a guide to what should be aimed at in the photographs, it is desirable to know the magnitude of the smallest stars ever seen by human eyes, and for that purpose we have only to substitute for *a* the aperture of the largest telescope in existence—namely, that of the Lick Observatory, having an objective of 36 inches inches clear aperture—and thus we find $m = 16.98$, or say the seventeenth magnitude.

C.—Special care should be exercised in deciding upon the angular diameter of the field of view, because it limits the size of the photographic plates, and to a certain extent determines the amount of distortion which shall be tolerated.

In commercial photographic lenses the usual angular diameters of the fields of view, measured across the diagonals of the plates, are approximately as follows:

For wide angle lenses, 90°, or $2.0 f$.

For rapid rectilinear lenses, when used for taking views, 60°, or $1.1 f$.

For rapid rectilinear lenses, when used for taking portrait groups, 48°, or $0.9 f$.

For portrait lenses, 33°, or $0.6 f$,

where f is the equivalent focal distance of the lens.

When complete freedom from distortion is essential, the field must be very much more restricted. For their standard instruments of 13 inches aperture and 134.6 inches focal distance, the Paris International Conference adopted a square field measuring two degrees on each side. The celebrated optician, Mr. Alvan G. Clark, than whom there can be no better authority, told the present writer that according to his experience five degrees is the maximum possible diameter of field for photographing stars sharply with specially corrected portrait lenses. At the Cape of Good Hope, Dr. Gill uses plates six degrees square with a rapid rectilinear lens of about 60 inches focus and six inches clear aperture. When only pictorial effect is aimed at, somewhat larger fields are desirable, and with ordinary portrait lenses of about six inches aperture and 31 inches focus, Barnard, Russell, and Wolf use plates which give fields about fifteen degrees in diameter.

D.—It must never be forgotten that no matter how well commercial lenses may be corrected, and no matter how sharply they may define, they are ill adapted to any work requiring exact measurements because upon fairly large plates they give rise to serious distortion which is usually symmetrically distributed about the centre of the field. A fine example of the careful determination of this distortion may be found in Sir G. B. Airy's Account of the British Observations of the Transit of Venus of December, 1874, Appendix V, pp. 14-19. As already pointed out, the only way of avoiding this distortion is by diminishing the angular diameter of the field, but if that expedient is adopted, other lenses will be found cheaper and more advantageous than those of the portrait or rapid rectilinear types.

As a guide to what may be expected from any given lens, it is desirable to have at least approximate values of the constants entering formulæ (1) and (2). An abstract of the data available for determining them is given in Tables I and II (pp. 646, 647).

The headings of the various columns in Tables I and II require no explanation beyond the statement that the letters f, a, t, m and C' have the same signification as in formulæ (1), (2) and (3). The values given for t and C' refer to fairly sensitive gelatine plates. For wet collodion they should be multiplied by six.

In Table I, each value of C' has been derived from the values of f, a and t given upon the same line with it; the formula employed being

$$C' = t\left(\frac{a}{f}\right)^2 \qquad (4)$$

which follows directly from formula (1).

In view of the fact that the plates employed by different experimenters doubtless had various degrees of sensibility, and their optical apparatus various degrees of perfection, it is scarcely worth while to adopt any very refined method in deriving C'' and L from the data in Table II. By plotting the logarithms of ta^2 to the argument m, and drawing the best possible straight line through them, we find with sufficient accuracy

$$\begin{aligned} \log ta^2 &= 1.86 \text{ for } m = 9 \\ &\ 4.95 \text{ for } m = 15 \end{aligned}$$

And as formula (2) gives

$$\log ta^2 = \log C'' + (m-1)\log L$$

we have

$$\begin{aligned} 1.86 &= \log C'' + 8 \log L \\ 4.95 &= \log C'' + 14 \log L \end{aligned}$$

whence, by solving the equations

$$\log ta^2 = 7.740 + 0.515\,(m-1) \qquad (5)$$

$$t = \frac{0.00550 \times 3.27^{(m-1)}}{a^2} \qquad (6)$$

where t is expressed in mean solar minutes.

When the Paris international committee for the production of a photographic chart of the heavens began their labors, they naturally assumed L to be identical with Argelander's light ratio for visual star magnitudes, namely 2.512, and it is not easy to show why that assumption was erroneous, but the fact is now beyond question. In connection with our own result, it may be well to give some of the values found by other investigators.

In the "Réunion du Com. Int. Per., 1891, pp. 93-96," Dr. J. Scheiner gives

From plates exposed on the Pleiades

$$L = 2.5 \div 0.53 = 4.72$$

From plates exposed on artificial stars

$$L = 2.5 \div 0.71 = 3.53$$

From the diameters of stellar disks in the negatives of the Pleiades

$$\text{1st negative, } L = 2.5 \div 0.75 = 3.34$$
$$\text{2nd negative, } L = 2.5 \div 0.66 = 3.79$$

From a comparison of two plates of the region surrounding ϵ Orionis, one exposed one hour, the other eight hours,

$$L = 2.5 \div 0.63 = 3.97,$$

and from these data he concludes that L must lie between

$$2.5 \div 0.5 = 5.0 \text{ and } 2.5 \div 0.75 = 3.34.$$

In the *Monthly Notices* of the Royal Astronomical Society, 1892, Vol. 52, p. 265, Mr. R. L. J. Ellery gives, from experiments made at the Melbourne Observatory, $L = 3.16$.

Although these values of the photographic light ratio by Scheiner and Ellery are based upon a comparatively small range of star magnitudes, they acquire importance on account of the near agreement which they exhibit between results derived from so many radically different methods. The mean of all Scheiner's results, except the first, is 3.66, Ellery's result is 3.16, and our own is 3.27.

Reverting now to the questions propounded at the beginning of this article, and attempting to answer them in accordance with the principles developed, we are led to the following conclusions:

1. Thoroughly good photographs of the heavens may be taken with any commercial photographic lens giving sharp definition, and having an aperture not less than one-tenth of its focal distance, but the scale of the picture will depend upon the

TABLE I.—DATA RELATING TO PHOTOGRAPHIC TELESCOPES, AND EXPOSURES ON NEBULÆ AND STAR CLUSTERS.

Ref. No.	Experimenter.	Instrument.	f.	a.	Object.	t.	C′.
			Inches.	Inches.		Min.	Min.
1	E. E. Barnard	Willard (N. Y.) portrait lens	31.	5.9	Nebula in Andromedæ	258	9.35
2	H. C. Russell	Dallmeyer portrait lens	32.3	6.	Nebecula Minor	480	16.57
3	Max Wolf	Kranz euryscope	30.3	5.28	Milky Way about α Cygni	785	23.84
4	Max Wolf	Steinheil aplanatic	7.68	2.17	....	......	....
5	Isaac Roberts	Reflecting telescope	100.	20.	Various nebulæ	240	9.61
6	A. A. Common	Reflecting telescope	204.	36.	Great nebula in Orion	37	1.15
7	A. A. Common	Reflecting telescope	......	18.	....	......	....
8	Warren De la Rue	Reflecting telescope	120.	13.	....	......	....
9	L. M. Rutherfurd	Photographic refractor	153.6	13.0	....	......	....
10	Harvard Col. Observatory	Portrait lens, cor'd by Alvan G. Clark	45.12	8.27	....	......	....

Authorities for Table I; Arranged in Accordance with the Reference Numbers.

1. ***Monthly Notices***, Royal Astronomical Society, London, 1890, vol. 50, p. 310. *Knowledge*, London, 1890, vol. 13, p. 174; *Ibid.* 1891, vol. 14, p. 232.

2. ***Knowledge***, London, 1891, vol. 14, pp 50 and 112

3 and 4. *Journal of the British Astronomical Society*, London, 1891, vol. 1, pp. 252 and 254. *Knowledge*, 1891, vol. 14, pp. 188, 231, and 232. The exposure for No. 3 occupied two nights.

5 *Knowledge*, 1889, vol. 12, pp. 108, 145, 148, 188 and 206.

6. *Monthly Notices*, Royal Astronomical Society, 1883, vol. 43, p. 255. *Publications of the Astronomical Society of the Pacific*, San Francisco, 1891, vol. 3, pp. 57 and 61.

TABLE II.—DATA RELATING TO PHOTOGRAPHIC TELESCOPES AND EXPOSURES ON STARS.

Ref. No.	Experimenter.	Instrument.	*f*.	*a*.	*t*.	*m*.	Log ta^2
			Inches.	Inches.	Min.	Magn.	
1	Lick Observatory	36-inch telescope with photographic corrector	570.	33.0	20.	13.2	4.3381
2	Lick Observatory	36-inch telescope with photographic corrector	570.	33.0	90.	15.	4.9913
3	Isaac Roberts	Reflecting telescope	100.	20.	205.	15.	4.9138
4	A. A. Common	Reflecting telescope	204.	36.	37.	14.8	4.6808
5	L. M. Rutherfurd	Photographic refractor	....	11¼	0.50	9.	1.8014
6	Henry Draper	Photographic refractor	....	11	137.	13.5	4.2195
7	Potsdam Observatory	Star Camera	135.	13.	0.40	9.5	1.8299
8	Oxford Observatory	Star Camera	135.	13.	0.92	9.	2.1917
9	Oxford Observatory	Star Camera	135.	13.	6.	11.	3.0060
10	Oxford Observatory	Star Camera	135.	13.	80	14.	4.1222
11	Sydney Observatory	Star Camera	135.	13.1	0.50	9.	1.9336
12	Sydney Observatory	Star Camera	135.	13.1	2.	11.	2.5356
13	Sydney Observatory	Star Camera	135.	13.1	30.	12.5	3.7117

Authorities for Table II; Arranged in Accordance with the Reference Numbers.

1. ***Publications of the** Astronomical Society **of the** Pacific*, 1891, Vol. 3, pp. 60 and 61.

2. *Ibid.*, p. 60.

3. *Ibid.*, pp. 57 and 60.

4. *Ibid.*, pp. 57 and 60.

5. *American Journal of Science*, New Haven, 1865, Vol. 39, p. 308. With an exposure of 3 minutes Mr. Rutherfurd obtained photographs of 9th magnitude stars upon wet collodion plates. In Table II the 3 minutes have been reduced to 30 seconds, because fairly rapid gelatine plates are about six times more sensitive than wet collodion.

6. ***Washington Observations***, U. S. Naval Observatory, 1878, Appendix I, pp. 226–228.

7. ***Institut de France.*** Acad. des Sci., Reunion du comité International Permanent pour l'exécution de la carte photographique du ciel a l'observatoire de Paris en 1891, pp. 93 and 96.

8, 9, 10. *Ibid.*, p. 72.

11, 12, 13. Preparations now being made in Sydney Observatory for the photographic chart of the heavens. By H. C. Russell. Read before the Royal Society of N. S. Wales, July 1, 1891, pp. 3 and 4.

focal distance of the lens. Nevertheless, if the original negatives are inconveniently small, it will usually be possible to make enlargements from them.

2. In order to get photographs of nebulæ showing as great an extent of nebulosity as those taken by Barnard, Russell and Wolf, it is only necessary to use the same exposure coefficients as they have done. That is, the times of exposure must be calculated from formula (1) with the values of C′ given in Table I.

3. Formulæ (1), (5) and (6) show that the time of exposure for nebulæ is proportional to the square of the ratio of the focal distance of the lens to its aperture, and is independent of the size of the lens; while the time of exposure for a star depends only upon the aperture—that is, the size of the lens—and is independent of the ratio of focal distance to aperture. From this it follows that a small lens may photograph a nebula as rapidly as a large one, or even more rapidly; but in order to photograph faint stars, the lens must either be very large, or the exposures very long. The limiting magnitude reached on any negative can be calculated quite approximately by formula (5) or (6).

On account of the undue confidence in photography which is now so much the fashion, it seems desirable to point out that a photograph of a nebula may present a very different appearance from the object itself. To illustrate this, imagine two negatives of the same nebula, one exposed $4^h\ 22^m$ with Barnard's portrait lens of 5.9 inches aperture and 31 inches focus, and the other exposed $3^h\ 58^m$ with Robert's telescope of 20 inches aperture and 100 inches focus. According to formula (1) these two negatives will have the same exposure coefficient, and will be quite identical with respect to the amount of nebulosity shown, but according to formula (5), the first will show stars down to the 13.1 magnitude, while the second will show them down to the 15.1 magnitude; or in other words, the second negative will exhibit three or four times as many stars as the first. Of course the two pictures will present a very different appearance. Which is correct, and does either of them represent anything that can ever be seen by examining the heavens visually through a telescope? Furthermore, in view of such facts, have we any reason to be surprised at the differences which notoriously exist between the best drawings of nebulæ and photographs of the same objects?

WASHINGTON, D. C., August 13, 1892.

THE PLANET SATURN AND ITS SATELLITES.*

WILLIAM H. PICKERING.

The planet Saturn has proved to us of all bodies in the solar system perhaps the most disappointing. With superb definition, and almost unlimited magnification, it was hoped that its assumed analogy with Jupiter would permit us to observe something not visible under more adverse circumstances. Nothing has been found, however, that could not be seen with a six-inch telescope at home. The planet is of course a very beautiful object under one thousand diameters, every belt and shadow perfectly defined, and presenting, save for the loss of light, the same appearance that it would have with the naked eye from one of its own satellites, but nothing new is seen, no more detail is developed. The planet seems to be a mere dead mass of cloud,—and saving for a few faintly marked belts, to be as structureless, and uninteresting as the planet Venus. It gives no evidence of those rapid currents and violent outbursts, due presumably to intense internal heat, that render Jupiter such an interesting body when viewed through a large telescope. The surface seems perfectly quiescent like that of Uranus and Neptune, as if the planet had entered upon a phase of its existence where the central nucleus still gave out sufficient heat to retain gases such as steam in the form of cloud, but where violent upheavals can no longer occur, except under exceptional circumstances. The three outer planets it seems to me should be classed together, while Jupiter stands alone by itself.

A careful study of the surface has been made upon eighteen different nights since the first of February, in the hope of finding some spot or other detail similar to that recently described by Mr. Williams. Unfortunately nothing has been found, and we must consider him to have been unusually favored by fortune, and his observations to be the more important on account of their rarity. It is to be hoped that in the future, should distinct markings be discovered upon either Venus or Saturn, that the matter will be communicated at once to astronomers generally, by telegraph, in order to secure as many observations upon them as possible. Hazy and indistinct markings upon Venus are of course often seen, and it is possible that some of them are genuine, and not due to our own atmosphere. I have noticed how-

---

* Communicated by the author

ever, that it is much easier to find such markings when the limb of the planet is wavering than when it is sharp and well defined. Spots upon Venus to be of any real interest to astronomers should be sufficiently well marked to admit of exact measurement and subsequent identification.

While no detail other than the belts has been found upon Saturn, a mere statement of that fact may, on account of our favorable opportunities for observation, be worthy of record. In regard to facts pertaining to the satellites, however, we have been more favored. Titan readily yields to a power of 700 diameters, and presents a sharply defined disc appreciably darker than that of the planet. On the evening of May 6, while making a careful scrutiny of the surface of Saturn, a small semi-circular projection was suddenly noticed upon the following limb just north of the ring. This was seen to grow in size, and it was soon recognized that we were watching a reappearance of Titan from behind the planet. In about three minutes from the first observation the emergence was complete, and a narrow black thread separated the two discs.

The eye-piece which was furnished with our micrometer gives a magnification of 350 diameters, but it was found that for the delicate work required of it here this power was quite inadequate and another eye-piece was made by remounting the lenses of one which had been fitted for use directly in the telescope. With this latter eye-piece all of our more recent measurements have been conducted. Our first measures of the diameter of Titan were made in the ordinary manner, by setting the micrometer threads at a distance apart of one second, and estimating the diameter of the satellite in terms of this distance. This gave a result of 0″.8. Later it was found that it was better to use as our standard dimension the diameter of one of the threads itself. The thread was found to measure .010 mm. and to subtend 0.″4. The thread could be illuminated until it was of about the same brightness as the satellite, and much more satisfactory comparisons could thus be made. By this means it was found that the diameter of Titan subtended about 0″.7 and that it did not exceed 0″.8, nor was it less than 0″.6. These measurements were made in the early part of June; they would therefore correspond to a diameter of exactly 3,000 miles. Employing Stone's value of the mass, $\frac{1}{4600}$ that of its primary, this would give a density of .38 that of the Earth. Previous determinations of the diameter of Titan, given by Young and Chambers, are 3,500 and 3,300 miles respectively. I have not been able to find the original authorities, as our library here is somewhat limited.

Observations upon Iapetus give a diameter of 0.″4, corresponding to 1,700 miles. It is much more difficult to measure than Titan, and the result is accordingly liable to a greater uncertainty. Tethys, Dione and Rhea appeared smaller and brighter than Iapetus, which, when these observations were made, was in the eastern part of its orbit, two days before opposition. As is well known, Iapetus undergoes a considerable change of brilliancy in different portions of its orbit, being darkest on the eastern side. As the Arequipa telescope is of only 13 inches aperture, even a geometrical point like a star gives a disc 0″.3 in diameter, and no matter how perfect the atmosphere, or how great the magnification, no disc smaller than this can be measured with it from theoretical reasons. The diameters of the smaller satellites can therefore only be measured with an instrument of larger aperture giving smaller diffraction images.

There are, however, still two methods left to us for determining the approximate diameters of these satellites. One is to watch them during eclipse, and note the time that elapses from the instant when the satellite clearly begins to fade, as compared with the others, until it entirely disappears. This time, compared with the velocity of the satellite in its orbit, will give us a minimum value for its diameter. This method was actually employed by Professor Young a few years ago with regard to Rhea, although I have not his results at hand. The other method depends on the assumption that they all have the same albedo as Titan. Then, given their photometric magnitudes, their true diameters can be computed. From observations made here, we know that this method could be safely applied to the three inner satellites of Jupiter. If we apply it to those of Saturn, we shall get the following results:

Satellite.	Magnitude.	Apparent Diameter. ″	Diameter.	Young.	Chambers.
Mimas	12.8	0.15	600	600	1000
Enceladus	12.3	.18	800	800	?
Tethys	11.4	.28	1200	1100	500
Dione	11.5	.27	1100	1200	500
Rhea	10.8	.35	1600	1500	1200
Titan	9.4	.70	3000	3500	3300
Hyperion	13.7	.10	400	500	?
Iapetus (mass)	11.4	.28	1200	2000	1800

In the above table the photometric magnitudes given in the second column were determined by Professor E. C. Pickering, and will be found in the Harvard Annals, Vol. XI, p. 276. The third column gives their computed mean apparent diameters upon the above assumption, the fourth their corresponding diameters in miles, and the fifth and sixth, their diameters in miles according to Young and Chambers. It is probable that the albedo of Iapetus is less than that of Titan, and that its diameter is therefore greater than that given in the table, as indicated by the direct measurements.

Attempts have been made here to see the shadows of the satellites cast upon the planet; but hitherto entirely without success. The most favorable satellite for this purpose is Titan, which casts a shadow whose umbra measures 0″.52 in diameter. Unfortunately no transits of this satellite have occurred at a time suitable for observation. The satellite casting the next largest shadow is Rhea, the diameter of its shadow being 0″.28. Its shadow was looked for most carefully on the nights of May 21, and June 8, at a time when it was central on the disc. Although the conditions were very favorable, and various powers of from 450 to 2100 were employed, the search was entirely without result. The shadows of Mimas and Dione have also been sought for without success. In the latter case I was aided by my assistant, Mr. A. E. Douglas, and various powers from 160 upwards were employed. Neither of us were able to even glimpse the shadow, although the night was unexceptionable. When we consider how difficult it is with a small telescope to see the dark space between two moderately faint stars, separated by 0″.28, even when we can select two stars of the most suitable brilliancy, it is perhaps not to be wondered at that with such a brilliant light as the disc of Saturn surrounding the dark space upon all sides, the shadow is a very difficult object to detect.

AREQUIPA, Peru, June 27, 1892.

SOME ADDITIONAL POINTS RELATING TO COMETS.*

GEORGE W. COAKLEY.†

In ASTRONOMY AND ASTRO-PHYSICS, No. 102, an attempt was made to demonstrate, that there was no repulsion by the Sun of any portion of a comet. Several mathematical friends of the writer, after careful examination of that paper, have testified their opinion of the solidity of the demonstration. In conducting the argument, the statement was made that a comet may best be regarded as a *mass of purely gaseous matter.* But the present

---

* Communicated by the author.

† Professor of Mathematics and Astronomy, University of City of New York.

prevailing view of a comet's constitution is that given by Professor Young in Art. 737 of his "Text-Book of General Astronomy, for Colleges and Scientific Schools." Professor Young states it as follows:

"Perhaps on the whole the most probable hypothesis is the one which has been hinted at repeatedly, that a comet is, as Professor Newton expresses it, nothing but a 'sand-bank'; *i. e.*, a swarm of solid particles of unknown size and widely separated, (say pin-heads several hundred feet apart), each particle carrying with it an envelope of gas, largely hydrocarbon, in which gas light is produced either by electric discharges between the particles, or by some other light-evolving action due to the Sun's influence. This hypothesis derives its chief probability from the modern discovery of the close relationship between meteors and comets."

The writer proposes, after disposing of another question, to discuss this theory of comets, proposed by Professor Newton of Yale College.

Admitting, for the present, Professor Newton's theory, as stated by Professor Young, how does it affect the demonstration, in No. 102, that there can be no repulsion by the Sun of any portion of a comet?

The particles of this "sand-bank," whether "pin-heads several hundred feet apart," or larger pieces of "gravel," or great boulders weighing many pounds, or even tons (all of which are required by the supposed "close relationship" between meteors, or rather meteoric stones, and comets), must form first the nucleus and head of the comet, which are always *attracted by the Sun.* Secondly, these particles must also form the train or tail of the comet, stretching away behind the head during its approach to perihelion.

If these "pin-heads or finer or coarser gravel, or large stones and metalic masses, forming the train are *repelled* by the Sun with a force greater than their *attraction* by the comet's head and nucleus, then they must be *retarded* in their approach to perihelion, while the head and nucleus are *accelerated* by the Sun's attraction. They must therefore separate from the comet's head, and move in a curve *convex to the Sun*, because of his *repulsion*, while the head and nucleus must move in a curve concave to the Sun because of his *attraction.*

Indeed, just as in No. 102, it was proved that if any of the comet's *gaseous matter* were subject to the Sun's repulsion *before perihelion passage*, it must be entirely *sifted out*, so that all of the comet that passed the perihelion was necessarily subject only to his *attraction*, so the same thing must be true of the "pin-heads," or other solid matter. Indeed it ought to be evident that the demonstration in No. 102 is quite independent of the nature and distribution of the matter composing a comet, provided it be of a sufficiently loose and rare nature. The more *solid* the particles of which the comet is composed, the more closely they ought to be aggregated by their mutual attractions, and tend to form a *single solid body*, like the planets, provided the whole number of these particles forms a sufficient *mass*, somewhat comparable to the masses of the planets, though far less.

It seems worth while to consider whether we have not some clearer evidence of the limits of a comet's mass than is generally supposed. La Place has assigned a *superior limit*, at least of Lexell's comet, which passed very close to the Earth, and to Jupiter and his satellites, without appreciably disturbing the motions of either of these bodies. He assigns this comet a mass *not exceeding* $\frac{1}{5000}$ of the Earth's mass. Many astronomers have reduced this limit to almost nothing. Professor Young, whose work is quoted as one of the most recent, full and accurate on general astronomy, says: "Some have gone so far as to say that a comet, properly packed, could be carried about in a hat-box or a man's pocket, which, of course, is an extravagant assertion. The probability is that the total amount of matter in a comet of any size, though very small compared with its bulk, is yet to be estimated as *many millions of tons*. The Earth's mass is expressed in tons by six with twenty-one ciphers following (6000 millions of millions of millions of tons). A body, therefore, weighing only one-millionth as much as the Earth, would contain 6000 millions of millions of tons." This last is just about the weight or mass of the Earth's atmosphere. But in the edition of Professor Young's work from which I quote, that of 1888, he goes on to say, "The atmosphere of the Earth alone constitutes about $\frac{1}{250000}$ of the Earth's mass, and contains more than twenty-four millions of millions of tons." Here are two mistakes, oversights no doubt, and probably corrected in future editions which I have not seen. The mass of the Earth's atmosphere is stated about four times too large, and the *consequent* value in tons about one thousand times too small. La Place's limit of a comet's mass makes it about two hundred times the mass of our atmosphere. The writer has verified approximately Professor Young's statement of the Earth's mass in tons, considering it as a sphere with its mean radius.

The clouds that float in our atmosphere have no definite form; they have not sufficient mass to gather themselves up into any definite shape by their own attraction, whether in a globular mass, or any regular geometrical shape. Yet they are capable of pouring down upon the Earth many hundreds of tons of water. But when a comet is first seen at its greatest visible distance in a telescope, it usually presents the *circular disc of a spherical body*. In the case of Donati's comet, when first discovered, it was more than 180,000 miles in diameter. Yet the attraction of its mass must have reached out more than 90,000 miles to cause the particles at its surface to arrange themselves spherically about it. Even after its train was formed, the regular geometric figure of the greater portion of the train shows that the attraction at the nucleus was maintaining a certain *equilibrium* with the tidal action of the Sun in the direction away from him. The action of this mass then extended, with a prevailing force, to some millions of miles from the nucleus, or centre of gravity.

Professor Benjamin Peirce, of Harvard College, was, therefore, more nearly right in his opinion than Professor Young seems to think, with regard to the amount of a comet's mass. Professor Young says (Art. 719), "The late Professor Peirce based his estimate of a comet's mass upon the extent of the nebulous envelope which it carries with it, assuming (what may be doubted, however), that this envelope is gaseous, and is held in *equilibrium* by the attraction of solid matter in and near the nucleus; and on this assumption he came to the conclusion that the matter in and near the nucleus of an average comet must be equivalent in mass to an iron ball as much as 100 miles in diameter. This would be about $\frac{1}{300000}$ of the Earth's mass." This ratio of the iron ball's mass to that of the Earth has also been verified by the writer.

Professor Young says farther, "While this estimate is *not intrinsically improbable*, it cannot, however, be relied upon. We simply do not know anything about a comet's mass, except that it is exceedingly small as compared with that of the Earth."

To this the writer has to say that the *equilibrium* by the attraction of the comet's *mass*, at and near its centre of gravity, the nucleus, as stated by Professor Peirce (without the necessity of any *solid body* there placed), is *beyond all doubt;* and that, by means of this *equilibrium*, we do know, from Professor Peirce's calculation, that the *average mass* of a comet is *very probably* the $\frac{1}{300000}$ of the Earth's mass, or about 20,000 millions of millions of tons. This is a little more than three times the mass of our atmosphere.

The mass of the Earth is sufficient to control the motion of its moon in a relative orbit about its centre, at the distance of nearly a quarter of a million of miles. Also the Earth's gravity extends many millions of miles to disturb the motions of Mercury, Venus and Mars. It even has some slight effect on the more distant planets. Hence it is certain that a mass one-millionth part of the Earth's mass, like that of our atmosphere, would likewise, as a separate mass, extend its attraction to the distance of millions of miles, though in a proportionally less degree.

Suppose, therefore, that a mass of gas like our atmosphere, containing the same weight of 6000 millions of millions of tons, were placed as far as Jupiter is from the Sun, but moving in a plane highly inclined to the ecliptic, so that it should be far away from all planets of the solar system. Would it not at first gather itself up into a spherical form by virtue of the general attraction of its mass? Owing to the elasticity of the gas, its size would, of course, be far greater than the volume of our atmosphere, which is condensed by the Earth's attraction, one million times as great as that of the gas. We should expect it to expand to a diameter of perhaps 200,000 miles, its mean density being very small, but having a greater density at the centre of the sphere, or at its centre of gravity.

If this atmospheric mass were describing a nearly circular orbit about the Sun, it is quite certain, from the formulæ investigated in ASTRONOMY AND ASTRO-PHYSICS, No. 103, that the Sun would exert a tidal force upon it, not only drawing it out into an ellipsoidal figure, with the major axis directed towards the Sun, but also transferring the centre of gravity of the atmospheric mass towards the Sun. This centre of gravity of the atmospheric mass, during its revolution, would be always directed towards the Sun. The ellipsoidal mass would have a nearly constant *figure of equilibrium*, depending upon the contest between the attraction of its own mass and the tidal disturbing force of the Sun, at that nearly constant distance. The atmospheric mass would also necessarily rotate around an axis through its centre of gravity, perpendicular to the plane of its orbit. It would also constantly turn the same face towards the Sun, for the same reason that our moon turns the same face towards the Earth.

Since one of the foci of the ellipsoid, and the centre of gravity of the mass, have both been displaced *towards the Sun*, we may suppose the centre of gravity always to coincide with this focus, as was the case when the figure was spherical.

If, now, we change our supposition as to the form of the orbit described about the Sun, and suppose it to be an ellipse of great eccentricity, and that the atmospheric mass is approaching the perihelion of its orbit, it is evident that, on account of the diminishing distance from the Sun, his tidal disturbing force is increased, and that the previous *equilibrium*, between this force and the attraction of the atmospheric mass, can no longer exist.

A new equilibrium must be established by a farther change of the ellipsoidal figure, which must become more eccentric, the focus nearest the Sun, and the centre of gravity of the atmospheric mass, retreating together towards the Sun more than they had previously done. With each change of distance from the Sun, the *figure of equilibrium* for the atmospheric mass would have to be constantly renewed. It was undoubtedly the investigation of such figures of equilibrium, actually observed with regard to several comets, that enabled Professor Peirce to determine the mass of an average comet. There can be *no doubt at all* of its *probable accuracy*. Indeed, would not the atmospheric mass, which we have been supposing to revolve around the Sun in a very eccentric orbit, present all the phenomena of a comet?

Among the phenomena of comets, noticed by Professor Young, is the diminution of the comet's *head* as it approaches perihelion, and its increase in passing away from this point. It has been shown in No. 103, ASTRONOMY AND ASTRO-PHYSICS, that the radius of the *spherical head* is the distance from the nucleus, or centre of gravity, to the surface of the comet *nearest to the Sun;* and that this distance is constantly *decreasing* as the comet approaches the Sun, and necessarily *increases* on its retreating from perihelion. So that the cause of this phenomenon is fully explained by the Tidal Theory of the Forms of Comets.

The cause of multiple tails of some large comets may perhaps be found in the necessary change of eccentricity of the comet's *figure of equilibrium* as it approaches perihelion, or retreats from it. It is evident, on this theory, that when the tail is first formed the eccentricity must have increased from less than unity, while the figure was *ellipsoidal*, to the full value of unity, for a *paraboloidal figure*. But, as the comet approaches the Sun still nearer, the focus and centre of gravity must still retreat towards the Sun. So that the eccentricity will be greater than unity, or the *figure of equilibrium* will become an *hyperboloid*. Moreover, the interior strata of the comet's figure may, both in the case of the parabolic form and the hyperbolic, have each its own eccentricity, or separate centre of gravity. The nucleus must therefore be divided, as it is sometimes seen to be, especially in the great comet of 1882. These separate foci of the several strata of the comet, one within the other, would produce different divergencies of the hyperbolic branches especially, and thus account for the differently diverging tails of a great comet.

In Art. 727 of Professor Young's work, he gives a fine cut of the "head of Donati's comet, Oct. 5, 1858, (Bond)," showing the way in which, at that date, about five days after perihelion-passage, it threw off "jets and streamers of light," "more or less symmetrical envelopes," which followed each other at intervals of some hours.

These phenomena may perhaps be explained by the fact that, as the head of the comet grew smaller, on approaching perihelion, with the *same mass* at its general centre of gravity, the pressure from the *greater attraction* towards the centre of the head, due to the diminished distance from this centre of gravity, would be greatly increased, and the elastic strata of gas would have to yield to this pressure. On retreating from perihelion, the head increases its radius, and the attraction towards the centre of gravity, and consequent pressure on the elastic strata within, *must diminish.* These compressed strata of elastic gas therefore naturally *push their way outwards* towards the surface of the comet's head, where the relief of pressure had taken place. On retreating farther from the Sun, other such remittances of pressure occur, and new envelopes rise symmetrically towards the Sun. Thus these phenomena seem to derive an easy explanation from the Tidal Theory of the Forms of Comets and have received no explanation from any other source.

Let us now consider the constitution of comets consisting of "pin-heads several hundred feet apart, each particle carrying with it an envelope of gas, largely hydrocarbon." Or, as Professor Young elsewhere expresses it, "the head of a comet is a swarm of meteoric stones; though whether these stones are many feet in diameter, or only a few inches, or only a few thousandths of an inch, like particles of dust, no one can say. In fact it now seems quite likely that the greatest portion of a comet's mass is made up of such particles of solid matter, carrying with them a certain quantity of enveloping gas."

How much "gas, largely hydrocarbon," or otherwise, could be condensed upon one of these "pin-heads," or even upon one of the meteoric stones, "many feet in diameter," unless the many feet were many millions of feet? A meteoric stone, one hundred feet in diameter, would be incapable of confining by its gravitating power, its mass, any considerable amount of gas; and the pin-heads hardly any at all. If the great mass of the comet itself were chiefly gaseous, then a comparatively small number of these stony masses might be imbedded in it.

But what would be their position in the cometary mass? Clearly, on account of their superior density, at the very center of gravity where the nucleus is. Not only so, but the attraction of the comet's great mass, nearly 20,000 millions of millions of tons, according to Professor Peirce's calculation, would forbid their remaining several hundred feet apart from each other, and would aggregate them all, whether "pin-heads" or larger, into one *compact solid mass* at the nucleus or center of gravity. It would be quite impossible for any *loose, scattered solids*, large or small, distant from each other several hundred feet, to constitute a mass any way comparable to that computed by the late Professor Benjamin Peirce, one of our first mathematicians and astronomers. It would require an enormous repulsive force, such as we see nowhere in nature, except in the elastic force of a gas, to prevent these solids from rushing down towards, and adhering as closely as possible to, the comet's center of gravity. But the elastic force of the gaseous comet would not prevent this rushing inwards of the *solids*, on account of their greater density.

These considerations are probably sufficient to justify the rejection, in all its forms, of Professor Newton's "sand-bank," or "gravel-bank," or "meteoric stone" theory of a comet. But, says Professor Young, "this hypothesis derives its chief probability from the modern discovery of the close relationship between meteors and comets." The close relationship between comets and meteors, that is, shooting stars, so-called, and meteoric swarms, like those of the Leonids, the Perseids, the Andromedes, and other similar meteoric showers, is freely admitted as conclusively proved. But what evidence is there that the phenomena of the *fall of meteor stones* or *meteorites*, as distinguished from *meteors*, has any such relationship with comets?

Professor Ball, the Astronomer Royal of Ireland, has closely considered this question. He shows that while the meteors, or shooting stars, have generally a very swift motion, passing out of sight in from half a second of time to nearly one second, the meteorites, from which the stony masses are derived, frequently remain in view for a minute or more, having thus a velocity about one sixtieth of those of cometary meteors, if at the same distance from us. He points out other differences; but the most important is that, during even the greatest shower of meteors, like the great November showers of the Leonids, while the meteors seem to fall by the million, and for hours, like flakes in a snow-storm, yet nothing solid has been found to fall to the Earth's surface at such times; "with one exception," says Professor Young, in the case of the Mazapil meteorite. The account of this by Professor Young is as follows:

"As has been said, during these showers" (of meteors proper), "no sound is heard, no sensible heat perceived, nor do any masses reach the ground, with one exception, however, that on Nov. 27, 1886, a piece of meteoric iron, mentioned in the list given in Article 758, fell at Mazapil in northern Mexico during the shower of Andromedes which occurred that evening. Whether the coincidence is accidental or not, it is interesting. Many high authorities speak confidently of this particular iron meteor as being really a piece of Biela's comet itself."

But we may reasonably ask, on what grounds do these "high authorities" speak so confidently? Professor Newton tells us that meteoric stones fall nearly or quite every day on some part of the Earth. Hence it would not be unreasonable to expect one at Mazapil, or elsewhere, on Nov. 27, 1886, whether the Andromedes were then bombarding our atmosphere or not. But why should only one of the great number of Andromede meteors of 1886 reach the Earth, and no other of these, nor any of the millions from the Leonids, the Perseids, and other swarms be found to reach the Earth? Clearly the Mazapil *meteorite* has only an accidental coincidence with the Andromede *meteors*.

The perfect transparency of a comet, through many thousands, or millions of miles of its volume, tells us that it is a very rare gas. In Article 720, Professor Young states, "This estimation of the density of a comet is borne out by the fact that small stars can be seen through the *head* of a comet 100,000 miles in diameter, and even very near its nucleus, with hardly any preceptible diminution of their lustre." Other astronomers have frequently observed the passage of the *central portion* of the comet's head at or near the nucleus, over a small star without any sensible loss of the star's light. From such facts we can only infer that even the densest part of a comet is a very rare, transparent gas.

Observations of comets with the polariscope prove that nearly all their light is the Sun's light *reflected* by a rare gas. Observations with the spectroscope seem to show that a *small portion* of their light, when sufficiently near the Sun, is somehow excited within the comet itself, but that the substance of the comet is largely, if not "wholly gaseous, chiefly hydrocarbon."

If the comets were *self-luminous*, or largely so with only the addition of some sunlight, then they should be easily visible at all distances. They could not escape the reach of the telescope at their aphelions. But instead of this being the case, they are only visible when comparatively near the Sun and the Earth. Their brightness at various distances from us and from the Sun follows the same law of increase or diminution as that of the non-luminous planets. Professor Young mentions some slight exceptions to this law in the brightness of certain comets; but perhaps this may be sufficiently accounted for by the irregular transparency of our own atmosphere. All astronomers know that there are times when no clouds are apparent, and yet there is no *good seeing* with the telescope, on account of the condition of the upper strata of our atmosphere. On the other hand, even when there is a light mist, there may be *good seeing* and *sharp definition* in the telescope.

From the ascertained mass of an average comet, and from its transparency, the "sand-bank" theory of the constitution of comets, proposed by Professor Newton of Yale, must be rejected. There is no close relationship between comets and meteorites, or meteoric stones. These latter can be explained, with great probability, as having a quite different origin from the meteoric ring-systems which produce the swarms of gaseous meteors, the Leonids and others. In rejecting Professor Newton's theory of comets, I should regret saying anything that could detract from the great merit of his investigations relating to the great November showers of meteors, the Leonids, which investigations prepared the way for computing the orbit of this meteoric ring, and thence of its connection with a comet pursuing the same orbit.

THE DOUBLE STAR, *OΣ* 224.*

S. W. BURNHAM

This pair has been under observation since 1843, and there is no doubt now concerning the physical relation of the components. The period is evidently a long one, since the angular motion is only about 60° in the time covered by the measures. It is always close enough to be difficult with most of the instruments used in measuring it, and therefore some of the observations have large errors in the position-angles. The total change, how-

---

* Communicated by the author.

ever, is sufficient to obtain the approximate elements, and for this purpose I have collected all the measures, and give them below in chronological order:

	°	″		
1843.22	13.7	0.35	Madler	2*n*
1844.31	20±	——	O. Struve	2*n*
1845.30	13.6	0.20	Madler	1*n*
1851.27	352.6	0.48	O. Struve	1*n*
1851.28	17.5	0.25	Madler	1*n*
1857.34	3.6	——	Secchi	1*n*
1861.26	348.8	0.59	O. Struve	1*n*
1868.03	339.2	0.5±	Dembowski	4*n*
1871.31	328.4	0.59	O. Struve	1*n*
1872.31	336.8	0.55	O. Struve	1*n*
1873.23	329.8	——	Dembowski	4*n*
1879.32	315.7	0.35	Shiaparelli	4*n*
1880.16	334.3	0.62	Burnham	1*n*
1881.25	316.6	——	Doberck	2*n*
1882.27	309.9	——	Doberck	1*n*
1883.71	330.2	0.53	Engelmann	7*n*
1884.21	326.0	0.55	Perrotin	4*n*
1887.27	315.6	0.52	Schiaparelli	4*n*
1892.37	313.6	0.48	Burnham	4*n*

The last set of measures were made by me with the 36-inch refractor before leaving Mt. Hamilton. The place of the star (1880) is:

R. A. $10^h\ 33^m\ 26^s$ }
Decl. + 9° 28′ }

This pair should be carefully measured every few years for some time to come.

CHICAGO, Aug. 8, 1892.

THE DOUBLE STAR, Σ 1216.

S. W. BURNHAM.

The angular change in the components of this binary is about 70° since its discovery by Struve. No orbit has yet been computed, and as it is probable that an approximate period could now be found, I have collected all the measures I have been able to find, and give them below in proper order:

	°	″		
1825.20	109.5	0.53	W. Struve	1*n*
1831.24	115.2	0.45	W. Struve	1*n*
1837.60	130.5	0.46	Madler	—
1842.20	178.4	0.8	Madler	1*n*
1844.30	178.2	——	Madler	1*n*
1851.28	139.4	0.49	O. Struve	2*n*
1853.25	148.3	——	Madler	1*n*
1855.24	152.1	0.57	Madler	2*n*
1857.34	150.0	——	Secchi	1*n*

	°	"		
1865.28	151.4	——	Secchi	1*n*
1865.48	166.5	0.56	Engelmann	5*n*
1866.55	151.5	——	Dembowski	14*n*
1867.32	131.5	——	Harvard Obs.	5*n*
1873.13	165.3	——	Brunnow	1*n*
1874.16	165.3	——	Wilson & S	2*n*
1874.18	167.0	——	Glenhill	1*n*
1875.27	165.5	——	Wilson & S.	2*n*
1877.18	164.6	0.35	Schiaparelli	2*n*
1878.20	158.8	0.61	Burnham	4*n*
1878.47	165.4	——	Cincinnati	5*n*
1879.21	160.8	0.37	Burnham	2*n*
1879.24	170.0	0.57	Schiaparelli	2*n*
1880.22	166.4	——	Cincinnati	1*n*
1880.32	167.6	——	Seabroke	2*n*
1880.91	166.7	0.36	Hall	3*n*
1887.24	173.8	0.45	Schiaparelli	5*n*
1891.26	183.2	0.46	Hall	4*n*

This star is Lalande 16375, and its place (1880) is:

$$\left.\begin{array}{ll}\text{R. A.} & 8^{h}\ 15^{m}\ 15^{s} \\ \text{Decl.} & -10^{\circ}\ 13'\end{array}\right\}$$

The measures by Madler in 1842-44, which are credited to this pair in the *Dorpat Observations*, Vol. XI, evidently belong to some other pair. Madler's observation of 1837 I have not seen in the original publication. It is included here on the authority of Secchi.

CHICAGO, Aug. 8, 1892.

NOTE ON THE MOUNT HAMILTON OBSERVATIONS OF MARS, JUNE-AUGUST, 1892.*†

EDWARD S. HOLDEN

Agreeably to the request of the Editor of ASTRONOMY AND ASTRO-PHYSICS the following paragraphs relating to the Mount Hamilton observations of Mars in 1892 (which are of course not finished at the date of writing, August 18), are presented. In merely describing the work done so far I am more or less speaking for my colleagues. They are, however, not responsible for the opinions expressed, naturally. Although the situation of Mars in this opposition is very unfavorable it was desirable to obtain as many observations as possible. The altitude of the planet ranges from about 28° to about 32° above the horizon

---

* Communicated by the author.

† The present note may serve a useful purpose in correcting certain erroneous statements regarding our work which have been widely circulated and which require correction.

(May–September), which is too low for satisfactory images of so difficult an object, even at Mt. Hamilton. These altitudes were, however, six degrees greater than the corresponding altitudes in Southern Europe.

The weather has been favorable and no pains have been spared to obtain all that could be got. The large telescope has been regularly used on Mars on the nights of Saturday, Sunday, Monday, Tuesday and Wednesday of each week by Professors Holden, Schaeberle and Campbell of the Observatory, and by Professor Hussey of the Stanford University (who has been spending the summer here in special work), and on Friday by Professor Barnard. The 12-inch telescope was also employed by Professor Barnard on other nights. Thus Mars has been under observation with the great telescope on six nights of each week, generally for the whole night.

PHOTOGRAPHS OF THE PLANET.

In May some experiments in photographing the planet (enlarged five times) were made by Professor Campbell and myself. While the larger markings and the polar caps were plainly shown, it was soon found that drawings would give far better results for the purpose in hand than photographs. A series of such photographs in connection with a set of eye-drawings and measures would be extremely valuable as a means of fixing the longitudes and latitudes of the principal points on the planet's disc. A serious practical difficulty in this plan is that the photographic lens of the great telescope ought not to be put on or taken off after dark. When it is once adjusted to the telescope it should remain during a whole observing night, and thus after a few photographs had been made, the rest of the night would be useless, so far as measures and drawings of the planet were concerned. At the opposition of 1894 the altitude of Mars will be 61°, and satisfactory photographs can then be secured.

DRAWINGS OF THE PLANET.

The earliest drawings of the planet with the great telescope were made by Mr. Schaeberle and myself on June 16, and since that time several drawings each night have been secured by Messrs. Schaeberle, Barnard, Campbell and Hussey. I have myself examined the planet on nearly every observing night and compared its appearance with my previous drawings made in the oppositions from 1875 onwards. Up to the middle of August, considerably more than one hundred sketches have been secured.

Some of these are very beautiful and complete. Most of them are still in the observing-books, but it is intended to copy them all on to forms of a uniform size and to publish what is important, after it has received a suitable discussion at the hands of the observers. Most of the drawings with the 36-inch have been made with a magnifying power of 350 diameters; a few with a power of 260. The planet has occasionally been examined with 520, but the air has not once been steady enough to employ this power throughout the night with advantage. How unfavorable the circumstances have been can be estimated when it is remembered that powers of 1000 and even more have been employed on Jupiter and Saturn with good results.

EXPERIMENTS ON THE CONDITIONS OF THE BEST VISION.

Various instructive experiments on the condition of the best vision have been tried. The planet has been viewed in the morning and evening twilight; through colored shade glasses; with diminished apertures; in an artificially illuminated field as well as in a dark one. As the color-curve of the telescope shows that the focal-points will be different for rays of different colors, (see *Publications* A. S. P. Vol. II, page 160), I have tried the experiment of looking at the dark canals, for example, with a focus suitable for the best vision of the larger markings on Mars which are of the same dark color. The theory of this process appears to be correct, but I have not noticed any material improvement in the vision.

MEASURES OF THE SATELLITES.

Whenever it would not interfere with more important work the satellites have been referred to the centre of the planet, by micrometer measures of position and distance. These measures have usually been made by Messrs. Schaeberle and Campbell. It is to be noted that most of these measures have been made when the planet was low, or the air unsteady, saving the moments of best vision for examination of the surface features. The measures have been made with the magnifying powers 350 and 520.

They will be reduced and published shortly.

ECLIPSES OF PHOBOS.

All the eclipses of Phobos occuring during the periods of observation have been observed, usually by Messrs. Shaeberle and Campbell. The time of disappearance of the satellite in the shadow of the planet could be very accurately noted. The error of estimation was probably not more than two or three-tenths of a second of time. The observation of these eclipses will be extremely valuable in fixing the elements of the satellite's orbit.

RELATIVE BRIGHTNESS OF THE SATELLITES.

At the request of Professor Hall we have made estimations of the relative brightness of the two satellites. Phobos is, of course, considerably brighter than Deimos. The observations are not yet reduced.

MEASURES OF THE INCLINATION OF THE PLANET'S AXIS.

Measures to determine the position of the axis of Mars have been made on many occasions, usually by Messrs. Schaeberle and Campbell. Like all other micrometric measures, they have been made at times when the vision was inferior, reserving the times of best seeing for an examination of the planet's surface. Some measures of the diameters have also been made.

MEASURES OF THE SIZE OF THE POLAR CAP.

These measures have been made so frequently that they will give a complete account of the decided and remarkable changes in the size of this marking. The polar-cap has diminished in size with the advance of the summer of Mars. It is worth inquiry whether a cap composed of dense clouds would not exhibit changes similar to those to which a snow or ice-cap would be subjected; or rather to those which have actually been observed.

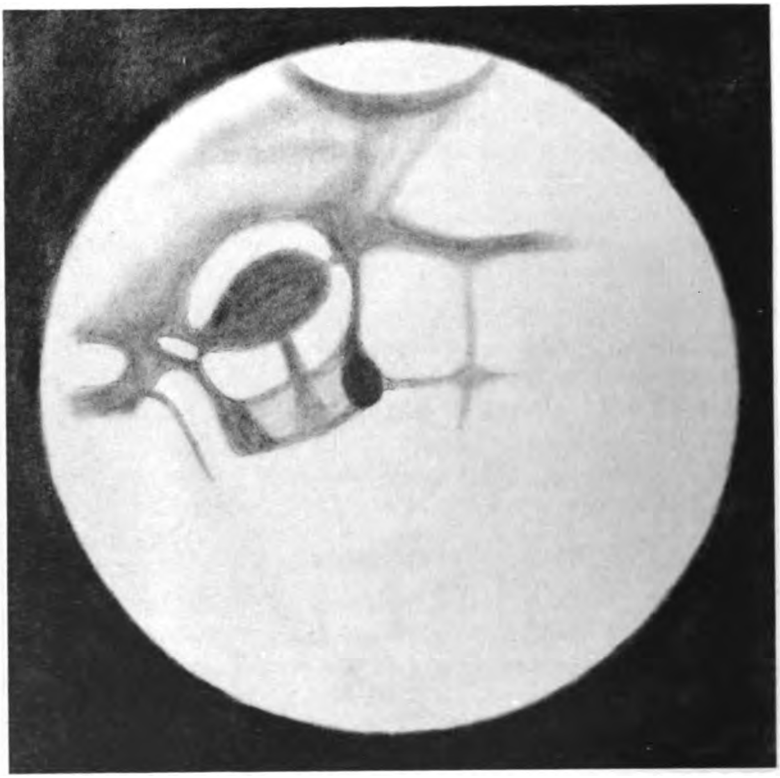
SMALL STARS NEAR THE PLANET.

With a telescope so powerful as the 36-inch, small stars of something like the brightness of the satellites are frequently seen. All cases of such objects which might be new satellites have been carefully noted when they were fairly near to the planet.

OBSERVATIONS OF BRIGHT PROJECTIONS ON THE TERMINATOR OF THE PLANET.

A very interesting series of observations of bright projecting points on the terminator of the planet was begun by Mr. Schaeberle and myself early in June and was continued till the middle of July, and will be resumed (no doubt) towards the end of August. Measures to fix their positions have been made. During the opposition of 1890, similar observations seemed to show that these projections were the prolongation of white streaks on the planet (clouds?), (see *Publications* A. S. P., Vol. II, page

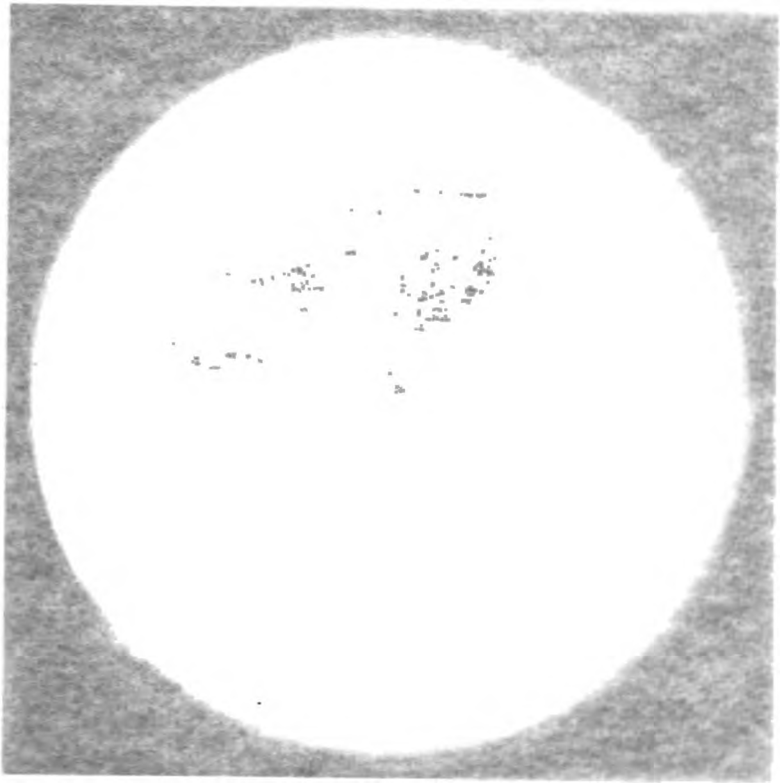
PLATE XXVIII.



λ = 111°

Mars, 1892, Aug. 14, 11h 15m P. S. T.

W. W. Campbell.



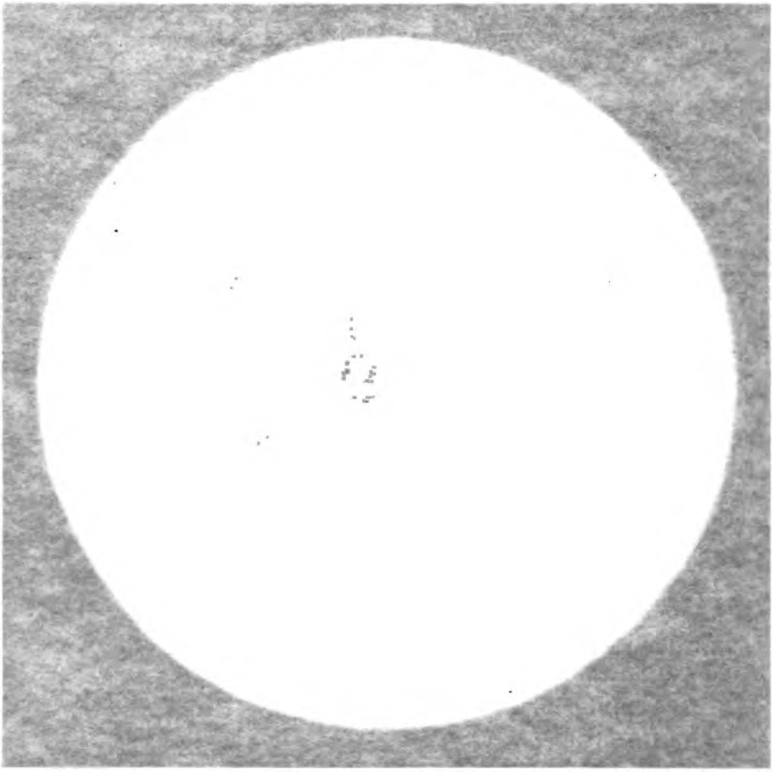
[illegible] 84

Mars, 1892, Aug. 17, 11 [illegible]

W. J. Hussey.

[illegible]

PLATE XXVIII

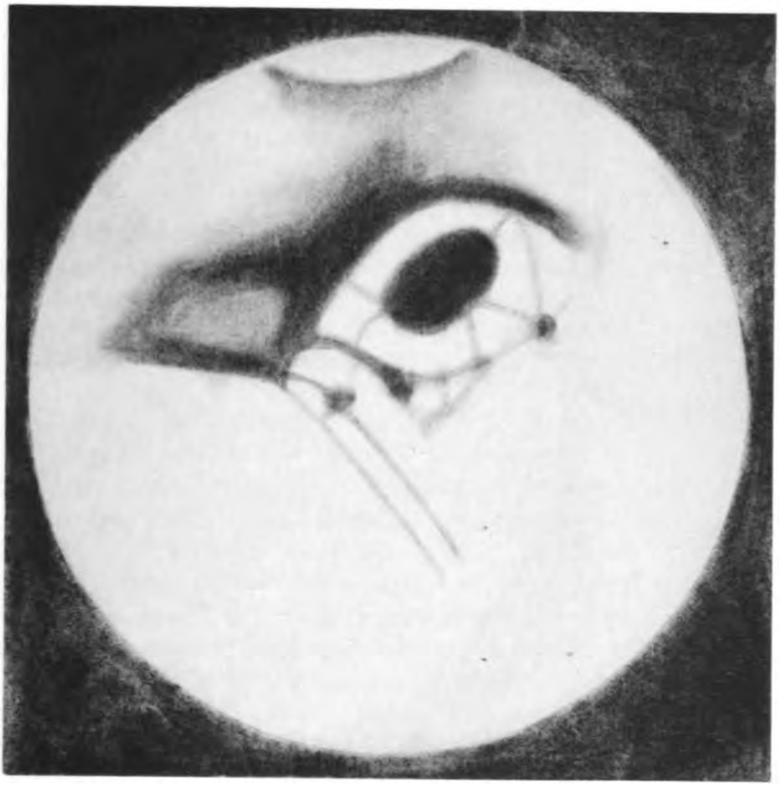


λ = 111

Mars, 1892, Aug. 14, $11^h 15^m$ P. S. T.

W. W. CAMPBELL.

PLATE XXIX.



$\lambda = 84^\circ$

Mars, 1892, Aug. 17, $11^h\ 15^m$ P. S. T.

W. J. Hussey.

248), and the phenomena of 1892 have been examined to see if a similar conclusion would hold. The results have, so far, been indecisive.

CHANGES ON THE PLANET.

It is not practicable to describe the remarkable changes that have been noted on the surface of the planet without a set of copies of the drawings for reference. There have been very many such. Marked changes have occurred in certain regions during the present opposition (notably in the polar cap, in the region north and east of Lacus Solis, in the Fons Juventæ etc.).

In many cases a feature has remained tolerably constant during the whole opposition but is markedly different in its present form or color from the representations made in former years (notably the region about Fons Juventæ, the Lacus Solis, again, etc. etc.).

In some instances we have change of form alone; in others change of color; in a few cases the changes of form and color seem to be associated.

Nothing more definite can be stated in this regard until a series of published drawings is available to which references can be made.

I am able to enclose with this, however, copies of sketches which these gentlemen have copied for me, Messrs. Campbell and Hussey, and which I hope can be published to accompany this note. They are direct copies from the observing books and, like all other such drawings, have been made absolutely independently without any consultation between the observers. In general, only the parts of the planet's disc which are nearest the centre, and therefore best seen, are drawn. A combination of the hundred or more excellent drawings of this class ought to give some material additions and improvements even to the best existing map—that of Professor Schiaparelli.

SCHIAPARELLI'S CANALS AND DOUBLE CANALS.

Up to the middle of August many of the canals of Professor Schiaparelli were mapped. None were seen double until the night of August 17, when Professors Schaeberle, Campbell and Hussey made three entirely independent drawings each of which shows the canal marked Ganges on Schiaparelli's map to be distinctly double. Thus the Lick Observatory has the pleasure of confirming the discovery which Professor Schiaparelli made in 1881. I am especially glad to announce this fact as recent dispatches purporting to be sent from Mount Hamilton "announced" that those double canals (which however had been seen here during the opposition of 1890), did not exist.

CONCLUSION.

I may briefly state my individual conclusions, as derived from a comparison of my own observations of Mars at the opposition of 1875 and at all succeeding ones, to be that the changes in the surface-features of Mars as we now know them are probably not capable of being completely explained by terrestrial analogies. What are we to make of the lake called Fons Juventæ, for example, which was a single object in 1877, which was not visible in 1879, and which has been both single and double during the present year?* The dark areas on Mars may be water and the red areas land; but how are we to explain the faintly colored areas like Hesperia, or Deucalionis Regio? Are they vast shoals like the Grand Banks of Newfoundland? Are they solid land, or are they water?

Is it conceivable that an observer on Mars, examining the earth in any part of its recent history, would have seen any such amazing topographic changes as we have this year observed, not to speak of the changes from opposition to opposition? It appears to me that a careful examination of the long series of drawings of Mars which we owe to Professor Schiaparelli and to others, up to the present time, will make it evident that there are enormous difficulties in the way of completely explaining the recorded phenomena by terrestrial analogies unless we also introduce serious modifications.

LICK OBSERVATORY, August 18, 1892.

MARS.†

WILLIAM H. PICKERING.

In my last paper upon this planet an endeavor was made to show that actual changes did occur upon its surface, besides the well known annual change in the size of the snow caps. This effort has perhaps proved unnecessary since the changes which have actually occured at the present opposition have been so conspicuous and startling that they might easily be detected even

---

* It became single just at the time of the appearance of the double canal through it.

† Communicated by the author.

by the possessors of six-inch telescopes. The canals can now be observed readily any evening. Many of those that we have seen here agree with Schiaparelli's, and several do not. Several of his more strongly marked ones have not been found at all. This, however, I am quite prepared to attribute to seasonal changes. Some very well developed canals cross the oceans. If these are really water canals and water oceans, there would seem to be some incongruity here. When the snow melts, it seems that there really should be some oceans, and a careful study has been made of the dark spot previously referred to, at the northern end of the Syrtis major. Although sometimes dark gray, yet in the great majority of cases when the seeing is satisfactory, and the spot is central, it appears of a clearly defined dark blue color. Another spot presenting a precisely similar appearance occupies a portion of the Sinus Sabæus or Herschel Strait.

These two spots when near the limb have on several occasions been observed to be of a beautiful bright blue color. If they are really oceans, they must, under these circumstances, be reflecting to our eyes the color of the Arean atmosphere, as water would, under similar conditions, do upon our Earth.

Viewed with a double image prism these spots when near the limb seem to present faint traces of polarization, the plane being radial to the planet. Until very recently they were much darker than any other spots visible, although a dark region near Solis Lacus (Terby Sea) has upon one occasion appeared quite black. It is my impression that these two areas are really water, and in the present article they will be referred to provisionally as the Northern and Equatorial Seas respectively. As I have stated in former articles I very much doubt if what are usually known as oceans and canals contain any water at all. That is to say, any water which is visible as such, for it is quite possible and perhaps probable that they may owe this color indirectly to the presence of water, stationary or running.

The boundaries of the Equatorial Sea (Fig. 2) are all sharply defined. It is 1300 miles in length, east and west, and averages a trifle over 200 miles in breadth, with two deep bays slightly curved, and almost precisely alike, opening southward, at its western end. In this article I have adopted the precedent set by Professor Schiaparelli in applying the terms east and west with the same signification as is given to them in maps of the Earth. That is they are reversed as compared with other celestial maps. Its total area is 275,000 square miles. The shape of the Northern Sea (Fig. 3) is that of an irregular quadrilateral, 750 miles in length by 600 in breadth. On the north its outlines are as clearly defined as those of the other sea, but on the south it is bounded by a dark gray region, never seen hitherto to be blue and which I am inclined to ascribe for reasons which will appear later to low land. If its shores were indented, this might account for their rather indistinct appearance. Its area is nearly equal to that of the Equatorial Sea, being approximately 225,000 square miles. What we may therefore speak of as the permanent water area upon Mars amounts to about half a million square miles. This is exactly one half the area of the Mediterranean Sea. A glance at the map of the World in two hemispheres will give the reader an idea of the enormous disparity in the water area of the two planets. From this circumstance we might expect the climate of the smaller planet to be on the whole much the dryer of the two, and if all is not a desert, at least that the deserts would be much more prominent than upon the Earth.

In this connection we may refer to the green areas situated near the poles, and described in the June and August numbers of this periodical. It was then stated that after the vernal equinox the greens almost entirely disappeared and the question was raised whether the same effect would be noticed this year. We can now reply in the affirmative, for although we have searched for them with the utmost care of late, when the seeing was both better and worse than before, scarcely a trace of them have we been able to detect. There is also a green area to the west of the Equatorial Ocean, but this region we have not been able to inspect carefully of late. In case they should reappear before the present opposition is over, as is possible, it is hoped that others will be upon the watch to detect them, and accurately locate their positions. While their reappearance might with some show of probability be attributed to the presence of one of the great branches of organic life upon the planet, and with this branch, as an almost necessary corollary, the other one, we must still consider the matter merely in the light of a tentative hypothesis, until further observations are accumulated, and content ourselves with the statement that no facts have as yet been observed inimical to this idea. The one fact which we have so far attempted to demonstrate is the presence upon the planet of water in the liquid form, and the attempt has been made to determine its exact location, and the area and shape of the surfaces permanently covered by it.

As might have been expected from the position of the planet's axis, the snow cap is much more conspicuous at this opposition than it was at the last. On June 23, the northern limit of the southern polar snow cap was, on the average, in latitude — 65°. This in our northern hemisphere would correspond to the latitude of northern Siberia, Iceland, and northern British America. As this date was but thirty days after the passage of the vernal equinox, it will be seen that the line of melting snow was rather nearer the pole than we might expect to find it upon on our own Earth at the same period. The area of this snow cap was some 2,400,000 square miles. Upon this date a small dark spot was noted near the center of the snow. The spot was then well developed, and must have been already existing for several days. Since that time it has grown rapidly, soon splitting the snow cap into two unequal parts, and of late changing its shape materially. The snow cap in the mean time has rapidly diminished in size, so rapidly in fact, that considering the weakened power of the sunlight at that distance, we are forced to believe that its depth is much less than that of the similar deposit covering the poles of our Earth. It will thus be seen that the comparatively small snow caps of Mars by no means necessarily imply a warmer climate than that of the Earth, as some writers have assumed, but merely a drier one. If the snow fell to a less depth, a larger proportion of the heat absorbed in the higher latitudes could be employed in raising the temperature, and a less amount absorbed in the latent form. This would involve a somewhat higher temperature during the summer, but a longer period of intense cold during the winter, than exists upon the Earth, in proportion to the length of the year.

Upon July 26 it was found that the area of the snow cap had diminished to 800,000 square miles. An area of 1,600,000 square miles of snow had, therefore, been converted into water, in the space of thirty-three days. With our extensive oceans this would produce no material change upon the Earth, but what must be the effect upon Mars, whose total permanent water area amounts to less than one-third of this figure? Moreover, upon the Earth the semi-annual transfer of the melted snow from pole to pole is conducted by means of the oceans, but upon Mars this transfer must take place across the land. We should naturally expect that a considerable proportion of the water would be absorbed or deposited upon the way. It will therefore be interesting to notice what has actually been observed.

Eastward of the stem of the Y mark, that is south of Libya, there was observed by Mr. A. E. Douglass upon May 8, and by myself quite independently, upon May 9, a light colored triangular region with a bright triangular center (Fig. 1). The angles of the central region were so distinct that they were selected as stations for our micrometric survey of this surface. At the next presentation of this phase, a month later, the central triangle had entirely vanished, being of the same tint as the outer triangular area, thus rendering it quite impossible to employ the selected stations. The whole area was however still much lighter than the stem of the Y. June 11, it had a decidedly greenish gray tint when central, and two days later it had assumed the same gray color as the stem of the Y from which it was indistinguishable. July 17, that portion of this region south-east of the Northern Sea had become extremely dark (Fig. 4), being only exceeded in tint by the sea itself, which differed from it mainly in color, the sea being blue and this region gray.

Upon July 10, the region south-west of the Equatorial Sea was extremely faint, and but little darker than the reddish region to the north of it. A similar effect had been suspected in June. This seems the more singular, since after the Seas this is usually one of the very darkest and most conspicuous markings upon the planet. The region west of this has also been subject to various changes, which need not however be described in the present article.

Upon May 12, it was noticed that the southern snow cap was bounded by a very fine black line. By June 23 this had become quite conspicuous in some places. By July 10, that portion of the line lying upon the Arean meridian was as dark as the Equatorial Sea, and appeared quite like it. On July 16, a small elongated black spot was noticed upon the western side of the stem of the Y (Fig. 3). It was then so conspicuous, that I was surprised I had not noticed it before. My measurements indicated that it was about 125 miles in length by 75 miles in breadth. This would make it of about the same size as Lake Erie, and it was connected with the Northern Sea by a very narrow straight black line. This line did not at all resemble the so called canals, being much finer and blacker. This spot was again seen by myself upon July 17, and by Mr. Douglass upon July 22, after which it disappeared unexpectedly in a way which I shall presently relate.

Changes were now coming thick and fast upon the planet, and when evening came round, and we put our eyes to the telescope, we never knew what we should see next. In my August paper reference is made among other suspected changes to the two arms of the Y, which in the opposition of 1890 were always

PLATE XXX.

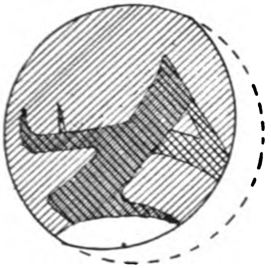


Fig. 1.

May 9, 21^h 05^m

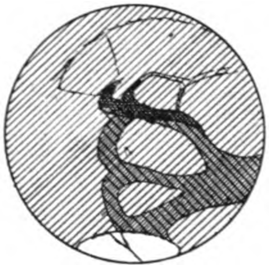


Fig. 2.

July 14, 16^h 50^m

Fig. 3.

July 16, 17^h 45^m

Fig. 4.

July 17, 15^h 50^m

Fig. 5.

July 23, 17^h 30^m

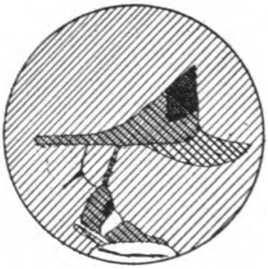


Fig. 6.

July 25, 20^h 40^m

drawn of approximately equal width. The statement was then made: "At present there is no doubt but that the eastern arm is much the wider of the two, perhaps twice as wide." This paper was completed May 13, 1892. This statement still remained true upon June 10 and 11, but at the next presentation upon July 12, a central arm was shown, converting the Y into a trident. This arm connected directly with the dark streak or split in the snow cap (Fig. 2). The eastern arm was still much the widest, but in two days the difference between it and the western was much less marked, and by July 17, they were equal in breadth, just as they appeared in 1890 (Fig. 4). In the mean time the central arm of the trident had become much more prominent being about equally conspicuous with the other two, and now, to my astonishment was seen a large dark area south-east of the Northern Sea and of fully double its area. This dark region is the one referred to earlier in this paper as having formerly been very light colored. It was now nearly as dark as the Sea, and much darker than that part of the Y to the south of it. In color it was gray, and not blue. This observation was independently confirmed by Mr. Douglass the next evening. By July 23, this darkening had greatly diminished, the color of the dark region being of the same depth as that of the rest of the Y (Fig. 5), which latter had now materially changed its shape, owing to eastward extensions of the eastern arm. In the mean time the central arm, recently so strongly marked, had completely disappeared. But what was most extraordinary was that the Northern Sea had now extended far to the south-west, completely concealing the little lake and the channel connecting the two. This result was also confirmed independently by Mr. Douglass the next evening. By "independently" I mean that he made his drawing without having seen mine, or knowing at all what I had seen. Indeed, both of us were doing so much observing at this time that we had little opportunity to compare results, and unfortunately, did not fully appreciate the extent of the changes we were observing, and so devoted a considerable share of our attention to other matters. This will account for the apparent breaks in this record, for, with the exception of July 9, when some repairs were being made upon the telescope, continuous observations have been maintained since July 4.

To return to the observations, it is not clear from the record, whether the southern extension of the Northern Sea was blue or gray. It was merely recorded and drawn "as dark as the Northern Sea." On July 24 Mr. Douglass also recorded a large southern dark spot which appeared to him as dark as the Northern Sea, but which I had not noticed upon the 23d. Upon July 25 the original outlines of the Northern Sea were again well seen (Fig. 6), the region south-west of it now being much lighter colored. The southern dark area seen by Mr. Douglass, and of which he had told me, was also noted. As a whole this area was not now as dark as the Northern Sea, but it contained a smaller spot which seemed quite as dark. There was also a narrow white channel extending northwards from the snow. The eastern arm of the Y, formerly so wide, was now reduced to a mere thread, while a trace of the central arm was again visible.

The Y is now so placed that it is only visible to the observatories to the west of us, and we shall not be able to observe it again until the middle of August. A striking difference may be noted in the arrangement of the dark channels in figures 3 and 4. In both instances they were well seen, and carefully drawn, and I do not see how the difference could be due to an error. The latter arrangement was subsequently confirmed by two other drawings. Regarding the former I find the record, "The dark parts are usually not more than 150 miles broad." I can scarcely think, however, that they could have been as broad as that.

The central branch of the Y was only noted by me upon one occasion in 1890, and that was upon May 25, when it was extremely faint. The date corresponding to July 12, 1892 in the previous opposition was August 24, 1890. At that time the Y was not visible in Cambridge. The corresponding date at the next opposition will be May 31, 1894. If the appearance of this central branch is in any way connected with the seasons upon Mars, it will be of interest for those observatories which are favorably situated at that time to look for it, since, should it then be as conspicuous a phenomenon as it has been this year, it could be readily detected by comparatively small telescopes.

In seeking to explain these observations, I would merely point out the fact that the changes occurred at a time when the snow was melting with great rapidity, that a dark channel suddenly appeared July 12, which had not been seen at the last previous observation of this region June 13, that it shortly disappeared again, and that a few days after this event the Northern Sea largely increased in area temporarily, or at least that its southern shores became much darker. I think these changes cannot be explained by Arean cloud effects. We have already observed large whitish patches upon the planet, which undergo considerable changes in shape and extent from night to night. We are now studying them carefully, although we find them rather difficult of observation. These changes we are inclined to refer to clouds, although the matter is not so simple as it might at first appear. If these effects are really due to clouds, they are quite different in character from the other changes noted above.

If the reader is inclined to be surprised at the extraordinary character of the phenomena now apparently occurring upon our sister planet, as revealed by the telescope, I can assure him that he is no more so than were the observers themselves. Nor do we insist upon any explanation of these changes, but only upon the accuracy of the observations themselves. Owing to our remote and isolated position, we know nothing at the present writing of what has been done and seen at the northern Observatories, and it is possible that when this strikes the reader's eye, it will not be as new to him as it is new to us. Nevertheless, I am inclined to think that owing to our splendid atmosphere, and southern latitude, portions of what precedes may still be new, although the larger northern telescopes will doubtless have detected all the more important changes.

AREQUIPA, PERU, August 1, 1892.

Note in Regard to the Figures. In the above figures north is placed at the top. The date is given in Greenwich Mean Time. The scale is $\frac{1}{200000000}$ or 200 kilometers (125 miles) to the millimeter. In the last five figures 1″ = 1.4 millimeters.

OBSERVATIONS OF MARS AT THE HALSTED OBSERVATORY, PRINCETON, N. J.[*]

BY PROFESSOR C. A. YOUNG, HALSTED OBSERVATORY.

The planet was observed by me at Princeton with the 23-inch telescope on every available night between July 6th and July 28th, but owing to interruptions by bad weather and other causes the actual number of satisfactory views obtained was not large. On about half a dozen occasions, however, the seeing was good enough to permit the use of magnifying powers of from 500 to 700, and on the two nights of July 23d and 25th it was especially fine.

The most conspicuous feature upon the planet's surface was the

---

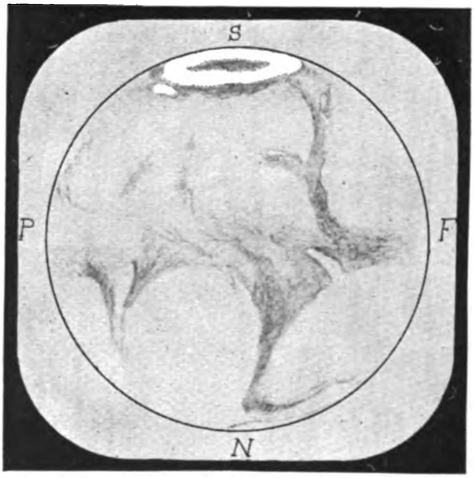
[*] Communicated by the author.

great southern ice-cap: on July 6th it measured very nearly 10″ across—about 1900 miles,—but it melted away rather rapidly, and on July 25th was not more than 1200 miles across by estimation. At first it was dazzlingly brilliant, and uniformly so over its whole extent, but on the 23d I noticed a dark streak in it, as if it had melted away at the centre: the length of the streak was about a third of the diameter of the cap, and at 11^h 45^m P. M. (Eastern Standard Time) its direction was, as nearly as I could judge, perpendicular to the central meridian. No satisfactory estimate of its width could be made of course, on account of its nearness to the limb; but that it was a "streak," and not in reality nearly circular, was evident from the fact that two hours later it had obviously changed its direction and was no longer perpendicular to the meridian. This central melting of the southern ice-cap is quite in accordance with the appearance indicated upon Schiaparelli's map of 1877, which shows an elongated patch entirely one side of the pole.

The edge of the cap was separated from the general surface by a rather conspicuous dark streak, which was by no means uniform in width. On the 25th two small bright patches were noted just at the edge of the cap; one in areographic longitude of about 300° (probably Schiaparelli's "Novissima Thyle"), and the other about 210° ("Thyle II"). On the night of the 24th the planet was observed for a few minutes with the 9½-inch telescope, and I was able to see the central dark spot in the southern cap, though only with difficulty.

The appearance of the planet in general corresponded much more closely to the drawings of Green, made at Madeira in 1877, than to any others with which I am acquainted. The principal features near the planet's equator were well seen at different times; especially the Syrtis magna (or Kaiser Sea) and its surroundings on July 23 and 25. Of course I tried very earnestly to make out the 'canals,' which figure so conspicuously in Schiaparelli's maps, but mostly without success. There were, indeed, various faint markings some of which with a low power seemed to correspond fairly in position and general direction with 'canals' shown upon the map; but under higher magnifying powers the resemblance disappeared; that is, instead of being narrow lines well defined and nearly straight, they became mere shadings, irregular, indefinite and vague in outline, and often discontinuous. But I should not like to be understood as denying the reality of the features described and depicted by the Italian astronomer. The 'seeing,' though it was unusually fine for Princeton on the

PLATE XXXIII.



Mars July 26, 1892, 6:30 A. M., Greenwich Time.

OBSERVED AT PRINCETON, N. J., WITH 23-INCH TELESCOPE.

23d and 25th, was probably not equal to th[illegible] prevails in the Italian atmosphere, nor can I pretend [illegible] remarkable keenness of vision. I can only say that m[illegible] to confirm' those of Schiaparelli, and h[illegible]

The continuation of the northern c[illegible] which bears on the map the names of [illegible] however clearly traceable; also cert[illegible] southern continent, corresponding [illegible] marked Xanthus, Scamander, and Sim[illegible] ern) portion of the Syrtis magna, th[illegible] streak which bears the name of Oenotr[illegible] also certain others, less brilliant a[illegible] but in a general way resembling [illegible] ture—perhaps the Ausonia and Li[illegible] of the [illegible]

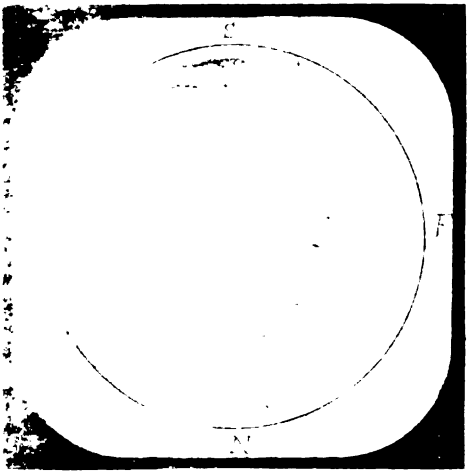
On July 6th at midnight the region of the [illegible] (Solis Lacus) was nearly central; the seeing was n[illegible] good, but the principal features of the region could b[illegible] in pretty close accordance with the drawings of Green [illegible] ferred to. On the evening of the 14th, the 'forked bay' Sinus) was in good position, and well seen; but no [illegible] canals could be detected, though the whole disc was cove[illegible] a mass of beautiful detail of varying shade and color, [illegible] fying my power of delineation.

I send a somewhat enlarged copy of a sketch made [illegible] of the 26th (E. Standard time). It does not profess [illegible] accuracy of detail, but shows fairly well the p[illegible] they appeared to me. The preceding limb w[illegible] what shaded, while the following one was ve[illegible] near the southern ice-cap.

The satellites were always, when not behind [illegible] disc, visible even with the planet in the [illegible] spicuous when it was put behind a s[illegible] mented to the field lens of the eyepiece. [illegible] tric measures were made, but they hav[illegible] Deimos usually ceased to be visible a[illegible] planet's limb less than 10″. Phobos on t[illegible] seen when within 5″ of it. So far as coul[illegible] reduction of the micrometer observations, [illegible] satellites given by Hall's tables is almost a[illegible]

On the night of July 23-4, the planet [illegible] about the 10th magnitude nearly centr[illegible] the point of contact being about 120 [illegible] nearly, but not quite in contact, at 1[illegible]

PLATE XXXIII.



ly 26, 92, 6:30 A. M., Greenw Time.

D AT PR TON, N. J. WITH 23-INCH TELESCOPE.

-PHYS No. 108

23d and 25th, was probably not equal to that which prevails in the Italian atmosphere, nor can I pretend to any remarkable keenness of vision. I can only say that my observations 'failed to confirm' those of Schiaparelli, and left me rather skeptical.

The continuation of the northern extremity of the Syrtis Major which bears on the map the names of Nilo Syrtis and Nilus, was however clearly traceable; also certain short dark streaks in the southern continent, corresponding, perhaps, to the 'canals' marked Xanthus, Scamander, and Simois. At the upper (southern) portion of the Syrtis magna, the curious curved bright streak which bears the name of Oenotria was conspicuous, and also certain others, less brilliant and more indefinite in outline, but in a general way resembling it in their direction and curvature—perhaps the Ausonia and Libya of the map.

On July 6th at midnight the region of the 'Lake of the Sun' (Solis Lacus) was nearly central; the seeing was not remarkably good, but the principal features of the region could be made out, in pretty close accordance with the drawings of Green already referred to. On the evening of the 14th, the 'forked bay' (Sabæus Sinus) was in good position, and well seen; but no trace of canals could be detected, though the whole disc was covered with a mass of beautiful detail of varying shade and color, quite defying my power of delineation.

I send a somewhat enlarged copy of a sketch made 1:30 A. M. of the 26th (E. Standard time). It does not profess any minute accuracy of detail, but shows fairly well the principal features as they appeared to me. The preceding limb was of course somewhat shaded, while the following one was very bright, especially near the southern ice-cap.

The satellites were always, when not behind the planet or its disc, visible even with the planet in the field; and they were conspicuous when it was put behind a shade of neutral glass cemented to the field lens of the eyepiece. Several sets of micrometric measures were made, but they have not yet been reduced. Deimos usually ceased to be visible at any distance from the planet's limb less than 10″. Phobos on the other hand could be seen when within 5″ of it. So far as could be judged before final reduction of the micrometer observations, the ephemeris of the satellites given by Hall's tables is almost absolutely accurate.

On the night of July 23-4, the planet occulted a small star of about the 10th magnitude nearly centrally, the positive angle of the point of contact being about 120°. The star was last seen, nearly, but not quite in contact, at $1^h\ 43^m\ 15^s$ (July 25 A. M.), and I judge the actual contact was about 15 seconds later; the seeing at the time was poor, so that it was not possible to make out any changes of form or color due to the planet's atmosphere.

I was obliged to leave Princeton on July 29th. Observations were kept up until Aug. 15th by my assistant, Mr. Reed, but he reports nothing new or of special interest.

HANOVER, N. H., Sept. 7, 1892.

MEAGER NEWS FROM MARS.*

LEWIS SWIFT.

The observations of Mars made at this Observatory during the present favorable opposition have been a series of disappointments, save on two or three nights when the sky was clear; the seeing, from atmospheric disturbances, has been unusually poor. At almost any opposition for many years I have, I think, seen more of detail with my 4½-inch comet seeker than I have at this time been able to secure with my 16-inch telescope. The great southern declination of the planet will, of course, account in part for this, but, in my opinion, not wholly.

On the evening of July 31 both Professor Todd, then my guest, and myself saw both the satellites, and on two occasions since I have been able to see them though not both at the same time.

The snow zone has been steadily decreasing and is now too small to be easily observed with small instruments.

The most important of the observations I have made was that of a small, black, circular spot, one-half of which was superimposed on the following side of the snow zone, the remainder being outside, the edge of the zone cutting the spot through the center. Though I saw this on three occasions, yet it was visible only during moments of good definition. I judged it to be equal in size to the shadow of Jupiter's smallest satellite. Its cause I can ascribe only to a denudation of the land from snow by the heat of his Antartic summer. Besides myself, this spot was also seen on one evening by a visitor at this Observatory.

Though carefully sought for, nothing resembling canals, single or double, has been observed. Previous to the opposition a rather large dark spot, quite irregular of outline, was seen directly under the snow-cap but became invisible at and near opposition.

I have observed in nearly all my studies of this body since

---

* Communicated by the author.

opposition, a large darkish spot, resembling in appearance and shape a bear-skin rug, which covers a large portion of the planet's disk.

Except these perhaps inconsequential notes, nothing worthy of extended remark has been viewed. This opposition has furnished to northern observers no new evidence as to the planet being an inhabited world.

WARNER OBSERVATORY, Rochester, N. Y., Sept. 1, 1892.

OBSERVATIONS OF MARS AT THE WASHBURN OBSERVATORY.*

GEO. C. COMSTOCK, WASHBURN OBSERVATORY.

Two series of observations of Mars have been made at Madison during the present opposition in addition to a careful examination of the disk of the planet and such occasional measurements as were suggested by its appearance.

I. A series of meridian circle determinatious of the declination of the planet and neighboring stars in accordance with the programme issued from the Naval Observatory by Professor Eastman. The programme has been rigorously followed with the exception that owing to delay in securing a reversing prism the early part of the observations were necessarily made without reversal of the images. The later observations will, however, furnish abundant material for the determination of any systematic differences arising from this cause. Between June 25 and Sept. 9 the planet was observed on forty-five nights and the observations will be continued up to Sept. 23. It would be premature to attempt to state at present any results of this series of observations.

II. With the 15½-inch equatorial telescope a series of measurements of the position angle of the south polar cap on the planet has been made for a determination of the position of the rotation axis of Mars. In order not to interfere with the meridian circle work the observations were usually made about an hour before and after the meridian passage of the planet and, in order to avoid, as far as possible, the effect of defective illumination of the disk, they were confined to a period of about three weeks preceding and following the opposition. During this period fifty-four observations upon twenty-nine nights were secured, and although the definitive reduction of the observations is not yet completed, a

---

* Communicated by the author.

provisional discussion indicates a considerable correction, approximately — 2°, to the position angle of the axis given in Marth's ephemeris.

Especially noteworthy is the small polar distance of the center of the cap when compared with previous determinations as shown in the following summary, for the major part of which I am indebted to Houzeau's *Vade-Mecum de l'Astronomie*:

Date.	Observer.	Polar Distance.	Longitude.
		°	°
1783	W. Herschel	8.1	
1830	Bessel	8.1	
1837	Beer and Maedler	8.0	
1858	Secchi	17.7	
1862	Kaiser	4.3	192.3
1877	Hall	5.2	20.7
1877	Schiaparelli	6.1	29.5
1892	Comstock	1.6	8.2

The Areographic longitude of the center of the spot in 1892 differs but little from that determined in 1877, but both of these determinations are widely different from that of 1862, as is shown in the last column of the summary above. These numbers appear to indicate a considerable change in the position of the cap from year to year, but the anomalous result obtained by Linsser, who estimated a polar distance of *about 20°*, simultaneously with Kaiser's determinations of 4°.3, indicates very great possibilities of systematic error inherent in the observations.

Concurrently with the determinations of the position of the polar cap a series of measurements of its diameter was made and these will be continued as long as the cap admits of accurate observation.

PRELIMINARY REMARKS ON THE OBSERVATION OF MARS 1892, WITH THE 12-IN. AND 36-IN. REFRACTOR OF THE LICK OBSERVATORY.*

E. E. BARNARD.

My observations of Mars have been confined principally to the 12-inch. Since July 1st I have been able to observe the planet once a week with the 36-in. The greatness of the intervals between the observations with the large telescope has prevented in many cases verification of important details, since different portions of the planet's surface were presented at the weekly observa-

---

* Communicated by the author.

tions, and no one portion of Mars was ever under examination at successive observations. A bad night, which several times occurred, still further lessened the value of the work with the 36-inch. From these circumstances my own work at this opposition is not as satisfactory to me as I should wish.

I have carefully avoided putting anything on record that was not certainly seen, and this may account in the main for any lack of detail in my drawings. What is shown, however, can be relied on as having been seen and will in general be found fairly well located.

In observing the planet I have found that the lower powers were much more preferable. With the 36-in. 260 diameters was best for details but the measures have all been made with 520 diameters. Some of the stronger details have been more satisfactory with the higher power. An intermediate power of 320 has also been usefully employed.

With the 12-inch a power of 175 has shown the details best, but the measures, as with the other instrument, were made with a much higher power.

I have paid strict attention to the polar cap which has shown many singular and interesting phenomena. The diameter and position angle of the southern cap (the northern one was never visible) has been repeatedly measured with both instruments in the hope of detecting the relation between its decrease and the Martian season. There was a pretty regular decrease until the last of August when the cap rather rapidly diminished to a very insignificant light speck scarcely distinguishable from the limb. So far the cap has decreased from 10″, about the last of June, to about 3″ in the first part of September. The actual decrease has been somewhat greater than this. Reduced to the time of opposition these values become 12″.4 and 3″.5 respectively. The area of the cap during the above interval has diminished fully nine-tenths. If this is snow and ice, and every thing seems to point that way, and the water therefrom is distributed in the equatorial regions, it would almost suggest a possible oscillation of the axis of rotation due to the transportation of vast masses of water from the poles to the tropical regions as the seasons progress.

I believe it has been suggested by some one that large dark diffusions apparently streaming from the polar cap equatorward, are water produced by the melting of the ice cap. Doubtless this is the sheerest fancy. There are, however, long dusky areas emanating in the cap and tending equatorward, which doubt-

[illegible]

[illegible]

[illegible]

[illegible] a very great difference in the depth of shade of the various markings of Mars. Certain of the so-called seas [illegible] and there are some so faint as to [illegible] which are in the south polar regions. [illegible] is not altogether due to being seen at a [illegible]. There is a great preponderance of markings and [illegible] the equator even to the pole, while in the north [illegible] could be made out. There are certain [illegible] between the present appearance of the planet and the older charts. If the charts are at all correct—and they doubtless were—important changes are at work on the planet. A short distance following the *Solis Lacus*—the Terby sea of some charts—is a small dark spot that is not shown on Schiaparelli's celebrated chart. This small spot seems to vary very much in depth of shade. It has been seen very dark and

less gave rise to the idea. But there are changes here that are so vast and so rapid as would hardly be warranted by the action of the Sun on the ice cap unless the ice and snow on Mars are very different from our own. In the latter half of June an irregular dark area appeared near the middle of the polar cap. On at least one occasion this was reddish like the so-called continents.

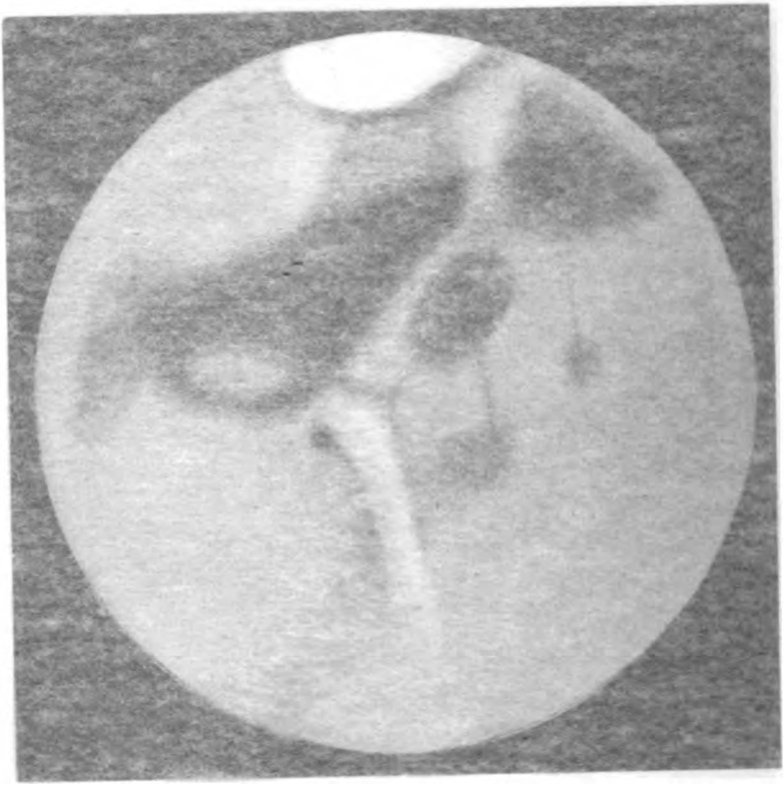
By the latter part of July the entire polar cap, presented to the earth, seemed to be heavily obscured and dusky, while two brilliant white spots appeared on it. It had, however, again resumed its brilliancy by the first week in August. On several occasions detached portions were seen lying close to the parent cap.

About August 19th an irregular portion or bay in the cap was brought into view by the rotation of the planet. By the 21st, this was seen to be abruptly terminated on its preceding side by a sharp notch and projection. At first there was no perceptible separation, but gradually a dark line crept across near the edge of the cap and finally separated a large mass from the main portion by a dark channel. This seemed to be the forerunner of rapid changes, for later, at the end of August near this same region, a large portion of the cap seemed to become obscured or dissipated. The entire cap rapidly diminished in size until a few days later only a tiny glimmer of the once brilliant cap remained.

On several occasions, the sharpness of outline, and the brilliancy of the cap has been almost startling in its vividness. At these times the color of Mars has appeared very strong—a deep rich orange.

There is, of course, a very great diversity in the depth of shade of the surface markings of Mars. Certain of the so-called seas are much darker than others, and there are some so faint as to be scarcely discernible—such are in the south polar regions. Their feebleness of tint is not altogether due to being seen at a great latitude. There is a great preponderance of markings and details south of the equator even to the pole, while to the north scarcely any detail could be made out. There are certain remarkable differences apparent between the present appearance of the planet and previous charts. If the charts are at all correct—and they doubtless were—important changes are at work on the planet. A short distance following the *Solis Lacus*—the Terby sea of some charts—is a small dark spot that is not shown on Schiaparelli's celebrated chart. This small spot seems to vary very much in depth of shade. It has been seen very dark and

PLATE XXXIV.



Mars 1892, Aug. 19, $12^h 1^m$

36-in. Equatorial of the Lick Observatory.

E. E. BARNARD *Del.*

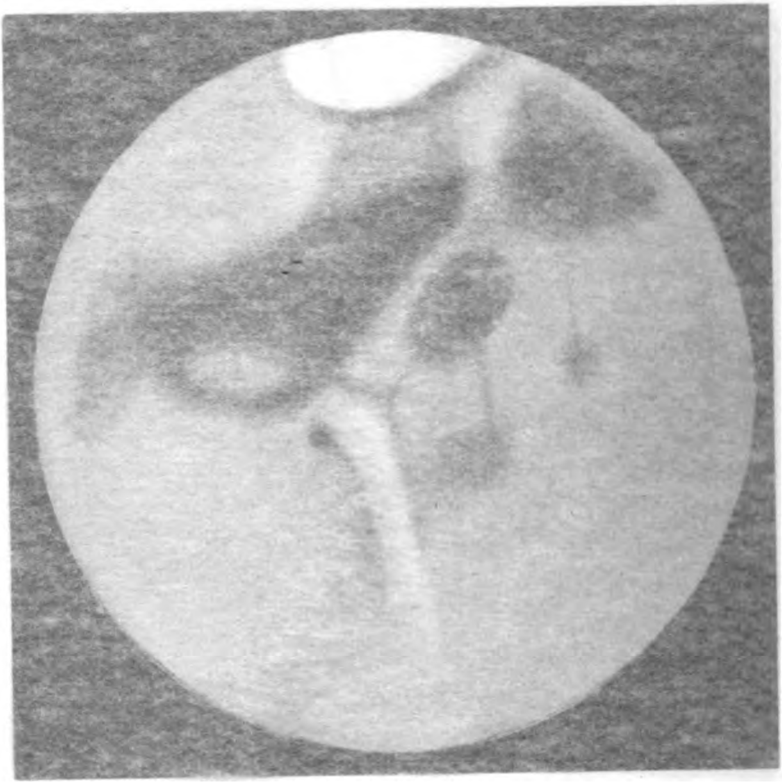
PLATE XXXV.

Mars, 1892, Aug. 21, $8^h\ 58^m$

12-in. Equatorial of the Lick Observatory.

E. E. Barnard, *Delt.*

PLATE XXXIV.

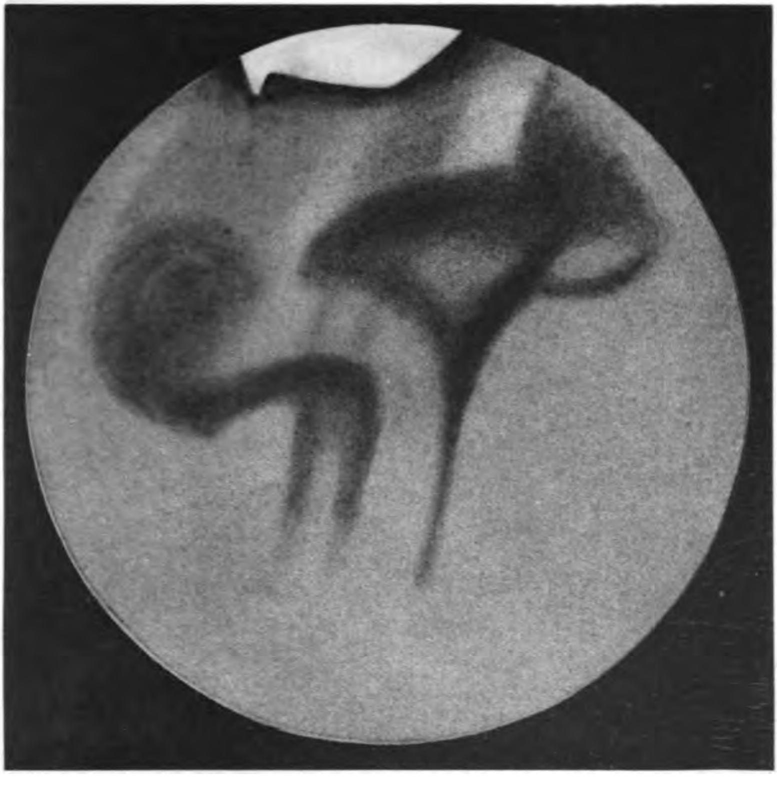


Mars 1892, Aug. 13, $12^h 1^m$

36-in. Equatorial of the Lick Observatory.

E. E. BARNARD Del.

PLATE XXXV.



Mars, 1892, Aug. 21, 8h 58m

12-in. Equatorial of the Lick Observatory.

E. E. Barnard, *Delt.*

then again [illegible] by a [illegible] north from [illegible] not appear [illegible] Lacus seems [illegible] self is [illegible]

There [illegible] points [illegible] changes [illegible] what we [illegible] like [illegible] whether [illegible] when [illegible] surface [illegible] ing. [illegible] Mars is not [illegible]

The [illegible] rather [illegible] and appear [illegible] the seas [illegible] have noticed [illegible] might possibly [illegible] this spot was [illegible] It was small [illegible] in longitude [illegible] measures were made [illegible] with subsequent [illegible] I could not see [illegible] ture, it must have been [illegible]

I have measured [illegible] number [illegible]

The satellites have been [illegible] every possible occasion [illegible] made. These will [illegible] chiefly the [illegible]

They have both been seen [illegible] was permitted by [illegible] cap.

I have not been able to [illegible] of Schiaparelli, though this phenomenon has been [illegible] for.

I send two drawings of the [illegible] with the 12-in., as specimens of what I have been [illegible]

then again quite pale. It is connected with the great sea south by a slender thread-like line. There is a small canal running north from the *Solis Lacus* to a diffused dusky spot which does not appear on Schiaparelli's chart. The region about the Solis Lacus seems to differ much from Schiaparelli, while the lake itself is much larger than he has shown it.

There are other differences fully as marked as these at other points which will be discussed in a later paper. These striking changes are enough to make us pause and question whether what we see before us in the heavens is really another world like our own, with relatively fixed oceans and continents, or whether it is not a world like our own in its younger days when continents were shifting and oceans changing, before the surface of the earth became firm and fixed by the process of cooling. If the latter is the case we can quite readily decide that Mars is not inhabited by the higher orders of life.

The so-called continents are not uniform. Bright areas being rather frequent and long luminous streaks have been observed and appear to be as much a feature of the planet's surface as are the seas; if the observations of one opposition are to count, I have noticed only one object of a very transient nature—such as might possibly be a cloud. On August 3d a conspicuous luminous spot was visible in the 12-inch that I had not noticed before. It was small and elongated about 2″ or 3″ in diameter. It was in longitude 219°, latitude about 30° or 40° north. Careful measures were made of its position on the disc to be compared with subsequent observations of it. Though carefully looked for, I could not see it on succeeding dates. If it is a permanent feature, it must have been much brighter on the 3d.

I have measured the positions and observed the transits of a number of markings on the planet during the opposition.

The satellites have been carefully observed and measured on every possible occasion and estimates of their relative brightness made. These will presently be published. Phobos has been decidedly the brighter of the two at all times.

They have both been seen with the 12-inch. On July 8th a star was occulted by Mars—passing behind the planet at the polar cap.

I have not been able to verify the duplicity of any of the canals of Schiaparelli, though this phenomenon has been carefully looked for.

I send two drawings of the planet, one with the 36-in. and one with the 12-in., as specimens of what I have been able to see. In the second of these the region shown in the first is just disappearing at the preceding limb. The following are the longitudes and latitudes of the center of the pictures:

Aug. 19, $\lambda = 79°.5$ $\beta = -11°.7$
Aug. 21, $\lambda = 16\ .3$ $\beta = -11\ .7$

MT. HAMILTON, 1892, Sept. 8.

OBSERVATIONS OF MARS AT GOODSELL OBSERVATORY.

H. C. WILSON.

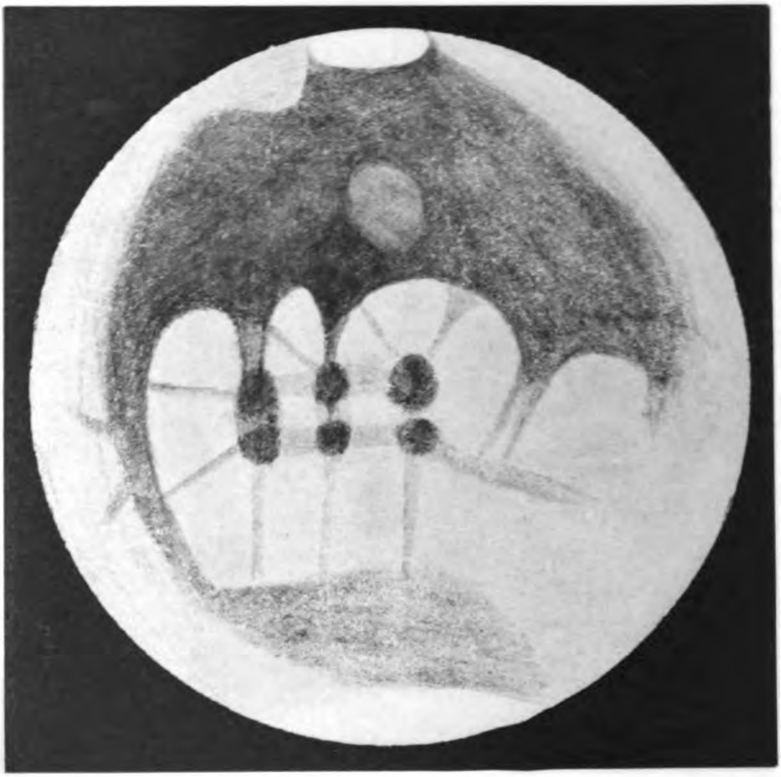
At Northfield the altitude of Mars during August was never greater than 22°, so that the seeing was seldom good. On a few nights, however, we were able to make out not only the prominent markings but some of the "canals" of Schiaparelli. These latter were extremely difficult to hold in vision for any length of time, but were at moments distinctly seen. Sketches were made at the telescope on ten nights. We reproduce two of the sketches (Plates XXXI and XXXII) made on the nights of best seeing, Aug. 13 and 26.

The satellites were always seen with comparative ease, when near elongation, when the planet was covered by an occulting bar. They could be seen without the aid of the occulting bar when the seeing was good enough to allow the use of a power of 800 or more. Phobos was always estimated brighter than Deimos.

The magnifying power which generally showed the markings best was about 300. When the seeing was poor it was sometimes improved by capping down the objective to 8 inches.

Up to Aug. 11 the only canals seen were Titan, Tartarus, Cyclops and Cerberus as one, Hephaestus and Propontis. On this date at 11^h the Solis Lacus region was near the center of the planet's disk. This region differs so much from Schiaparelli's map that it is difficult to identify the features drawn with those in the map. The area above and to the left of Solis Lacus, in which Schiaparelli has the canals Nectar and Ambrosia, is all nearly as dark as the so-called seas. Lacus Phœnicis is so large that in comparing the drawing with the map I at first mistook it for Lacus Solis. The canals Easphoros, Phasis, Sirenius and Eumenides and another connecting Lacus Solis and Lacus Tithonius are shown in the sketch. The same features are shown

PLATE XXXI.



Drawing of Mars by H. C. Wilson,

at Goodsell Observatory, Northfield, Minn., Aug. 13, 1892, at 12^h Central Time; Longitude of Center 102°.

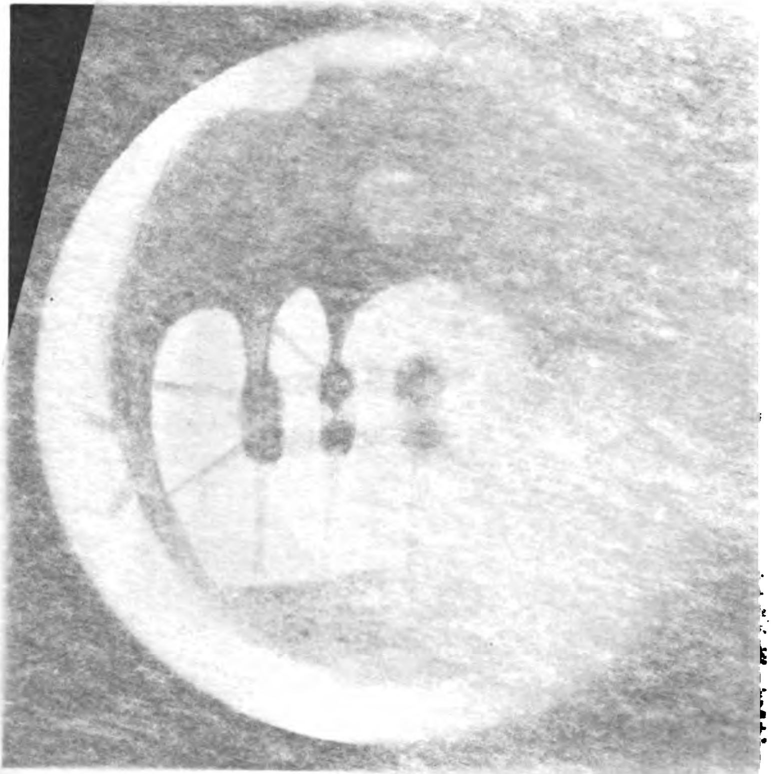
PLATE

Drawing of Mars

at Goodsell Observatory, Northfield,

Time, Longi

ASTRONOMY AND ASTRO-PHYSICS, No. 1

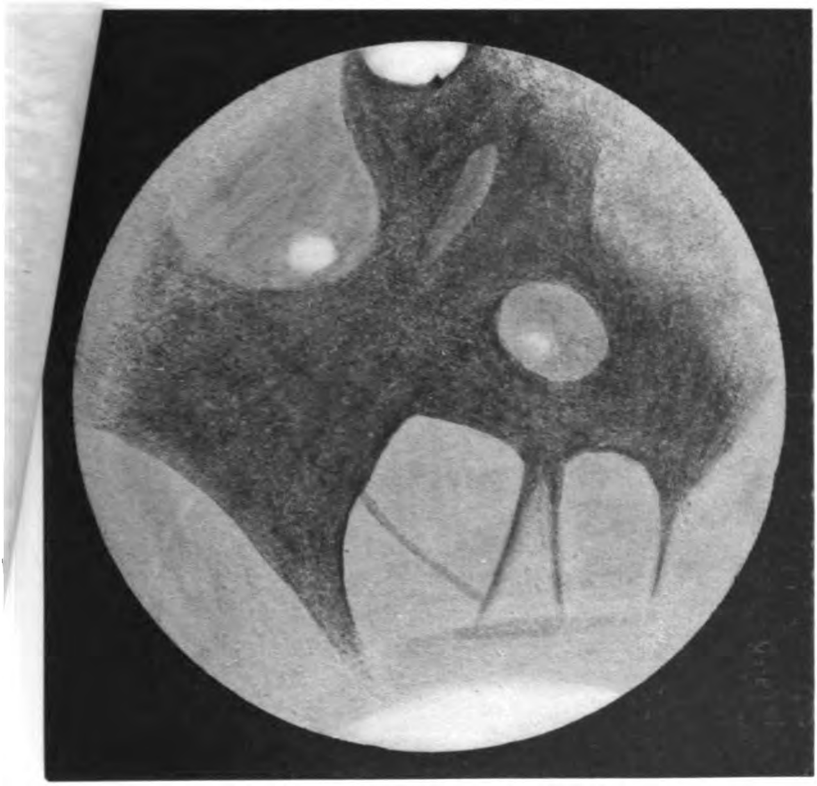


Dra

Go [illegible] ate

[illegible] ms

PLATE XXXII.



Drawing of Mars by H C. Wilson,

***at** Goodsell Observatory, Northfield, Minn., Aug. 26, 1892, **at** 10h 45m Central Time; Longitude of Center 328°.*

with others on the drawing made Aug. 13 from 11^h to 13^m, which is reproduced in Plate XXXI. The seeing on this night was for a time excellent but became poorer before the drawing was completed. The most prominent markings were located in the drawing during the first half hour. The three double spots near the equator were seen by Professor Crusinberry, of Drake University, Des Moines, Ia., as well as by the author of the drawing. We may perhaps identify the right hand pair with Lacus Phœnicis, the middle pair with Tithonius Lacus and the others with Fons Juventæ and portions of Auroræ Sinus. The faint streaks it is difficult to identify with certainty with Schiaparelli's map, though the three parallel streaks running northward may be Ganges and Fortunæ and Iris. The doubling of these spots was noticed only at brief moments. The appearance was generally that of three single spots. The same spots were seen again on Sept. 14 and 15, when the definition was not good enough to allow the canals to be seen.

August 24 at 10^h the seeing was good and the appearance of the planet essentially the same as on the 26th at 10^h 45^m. The sketch for the latter date is reproduced in Plate XXXII. The streaks on the lower portion may be identified as Typhon, Hiddekel, Gehon, Deuteronilus and Oxus. The whole of Syrtis Major and Libya is drawn dark. The region Hellas is considerably larger than in Schiaparelli's map published in *l'Astronomie* 1889. In the lower part of this region was a small white area. Another white area was noticed in the lower left portion of Deucalionis Regio. In fact, in the moments of best seeing, the whole of the dark area on the planet seemed to be sprinkled over with very small cloud-like white spots. Noachis Regio appeared as a light streak to the right of Hellas.

The south polar cap has always appeared perfectly white and round (elliptic by projection), except on Aug. 26, when there was a suspicion of a slight notch in the edge as shown in the sketch. At the north edge of the disk a much larger white area, less well defined, was always seen.

RECENT OBSERVATIONS OF JUPITER—THE GREAT RED SPOT AND ITS CHANGES.*

E. E. BARNARD, LICK OBSERVATORY.

Many changes have taken place on the surface of Jupiter since last opposition. Three heavy conspicuous belts now cross the face of the planet. The distance of these belts from the northern limb, measured on July 31, were 13″.5, 18″.4, 26″.1. There are other and narrower belts, but these three are the leading features.

The detail in the Southern Hemisphere, as has been strikingly characteristic of that region for at least the last 12 years, is very much broken and irregular, consisting of strips, patches and spots.

The great red spot is still visible, but it has just passed through a crisis that seemingly threatened its very existence. For the past month it has been all but impossible to catch the feeblest trace of the spot, though the ever persistent bay in the equatorial belt close north of it, and which has been so intimately connected with the history of the red spot, has been as conspicuous as ever. For a while there was only the feeblest glow of warmth where the spot ought to be. This has been the case under the very best seeing. It is now, however, possible to detect a feeble outline of the following end and the feeblest traces of the entire spot. An obscuring medium seems to have been passing over it and has now drifted somewhat preceding the spot.

Among the interesting features of the northern hemisphere is a small, rather conspicuous black spot on the north edge of the northern of the three large belts. This object, which is similar to the small northern black spots of last year, is interesting since its motion seems to be about the same as that of the great red spot. Indeed the observations might imply a longer rotation period which would be very extraordinary as the red spot seems to be alone in reference to slowness of rotation.

Following are a few notes on the appearance of the great red spot this year:

July 24. There are only the feeblest traces of the great red spot. It is exceedingly faint and pale. The following end alone can be made out. The spot seems to blend into darker regions south and preceding it. Seeing = 5. As near as possible the

---

* Communicated by the author.

remnants of the spot transitted at 15^h 18.7^m Mt. Hamilton M. T., $\lambda = 357°.2$.

July 29. Observed with the 36-inch. The following end of the great red spot in transit at 14^h 41^m. There is a diffused pinkish glow where the red spot ought to be, but there is no form whatever to it. Seeing = 3–4. This observation would give $\lambda = 354° \pm$ for the red spot's centre.

Aug. 3. The spot seems to blend into the general surface preceding which is dusky. There is only a feeble trace of the following end. At 14^h 0^m the following end is some 10^m past transit.

Aug. 5 with the 36-inch. 15^h 10.2^m the remnants of the red spot central. The corresponding $\lambda = 355°.5$ The spot has no outline at all. There is nothing to show its presence but a feeble glow. There is a white spot on it near where the preceding end ought to be. Seeing = 5.

Aug. 8. 12^h 40^m red spot in transit. $\lambda = 355°.9$. Seeing = 4. The spot is now a little more definite. It would seem that the cause of its almost total disappearance is passing away. The following end is faintly seen and the entire outline is vaguely made out.

Aug. 12. (36). Red spot central 15^h $59^m.4$ $\lambda = 357°.3$.

The following measures of its position were made:

Center of spot from north limb = 29″.1 (2 obs.).
" " " " south limb = 13″.1 (2 obs.).

It will be interesting to watch the small white spot to see if it leaves the red spot. It resembled the ordinary white spots which have been so abundant south of the red spot the past few years.

If it is one of these it would show that the red spot is in a lower stratum than this one.

The small northern dark spot, previously mentioned, has been observed on the following occasions:

July 24. 14^h $55^m.8$. The small spot in transit and its longitude 343°.3.

Aug. 5, with 36-in. 14^h 56^m. The small spot in transit $\lambda = 347°.4$.

Aug. 8. 12^h 28^m. The small spot in transit. $\lambda = 348°.6$.

Aug. 12 (36). Small spot in transit at 15^h $47^m.9$. $\lambda = 350°.4$.

On account of its high latitude, great exactness in observing its transits is not possible, and so the apparent increase of longitude may not be real.

On July 8—at transit, its position was measured with the micrometer.

From north limb 9″.3 (2 obs.).
From south limb 29″.7 (2 obs.).

The following observations of the satellites have been obtained. Mt. Hamilton Mean Time.

July 22. Satellite I leaving the Disc.

1st contact	15^h	22^m	42^s
½ off	15	25	12
Last contact	15	28	7

July 29. Satellite I going on the Disc.

1st contact	15^h	$7^m.5$
½ on	15	10 .0
Last contact	15	11 .6

Aug. 5. Shadow of Satellite I going on.

½ on	15^h	$44^m.2$

Aug. 7. Satellite I leaving the Disc.

1st contact	13^h	$33^m.5$
½ off	13	35 .5
Last contact	13	36 .9

Aug. 8. Satellite IV going behind the Disc.

½ under	12^h	$54^m.3$

The satellite disappeared at a very high north latitute.

Aug. 12. Reappearance of Satellite II from Occultation.

½ out	16^h	0^m	14^s
Last Contact	16	2	29

Observations with the 36-inch. Seeing perfect. No trace whatever of the satellite through the edge of Jupiter. The limb of the planet cut the satellite sharply. II was very much brighter than the limb. I have previously observed several other occultations of the satellites with the 36-inch under good conditions but have never been able to see the least trace of a satellite through the planet, the limb always appearing perfectly opaque. A similar negative result has occurred in a great many observations of occultations with the 12-inch, and smaller instruments.

Aug. 14, 1892.

LEWIS MORRIS RUTHERFURD.[*]

JOHN K. REES.

In the death of this eminent man astronomical science has lost one of its most efficient workers; one who loved devotedly his chosen labor, and who did much to originate means and methods and gave most invaluable direction and impulse to astronomical photography.

Mr. Rutherfurd was born at Morrisania, N. Y., on November 25th, 1816.[†] John Rutherfurd, his grandfather, was of Scotch descent, and served as Senator of the United States from New Jersey from 1791 to 1798. He was also one of the commissioners for establishing the boundary lines between several states, and assisted in laying out a portion of New York City. The Earl of Stirling, Major General William Alexander, was an uncle of John Rutherfurd. General Alexander took a distinguished part in several battles of the Revolution. He is said to have been an excellent mathematician and somewhat of an astronomer. Lewis M. Rutherfurd's mother was a direct descendant of Lewis Morris, one of the signers of the Declaration of Independence, and after him Mr. Rutherfurd was named.

At the age of fifteen he entered the Sophomore class at Williams College, and was graduated in due course. At College he showed his love for investigation, and was made assistant to the Professor of Chemistry and Physics. He aided in the lecture preparations and experiments. Here he gave evidence of his taste for scientific work and of his mechanical skill. After graduation he studied law with the Hon. William H. Seward, at Auburn, N. Y., and was admitted to the bar in 1837. Mr. Rutherfurd's associates in the practice of law were the distinguished men, Peter A. Jay, and, after Jay's death, the Hon. Hamilton Fish.

During the practice of his profession he gave much of his leisure time to studies and experiments in chemistry and mechanics bearing on astronomy. In the early part of his professional career he married Miss Margaret Stuyvesant Chanler, a niece of Peter G. Stuyvesant. His wife's fortune added to his own made it agree-

---

[*] Communicated by the author.

[†] I am indebted for many items of information in this brief sketch to Mr. Rutherfurd's son, Rutherfurd Stuyvesant, Esq., of New York City, who at my request sent me a copy of some notes written out by his father a few years ago after urgent and repeated solicitation on the part of the son. A portion of these notes was used in preparing the article on Mr. Rutherfurd in Appleton's Cyclopædia for 1888.

able and possible for him in 1849 to abandon the law, and thereafter he devoted his leisure to science, principally in the direction of astronomical photography and spectrum analysis.

In 1849 he travelled in Europe and studied with the Italian optician Amici. He remained abroad some time travelling and studying. On his return to New York City he erected in his garden, at the back of his house at the corner of Second Avenue and Eleventh Street, a small but excellent Observatory. The building was arranged to contain transit instrument, clock and equatorial telescope. It was a very modest building but destined to be the witness of great deeds.

Near by, in the fine dwelling house, were a commodious study and a work shop fitted with turning lathes and tools of all kinds necessary for his work. The splendid work of Bunsen and Kirchhoff was then attracting great attention, and Mr. Rutherfurd devoted most of his time to spectroscopic investigations. One result was that in January 1863 he published in Silliman's Journal* a paper on the spectra of stars, moon, and planets. In this paper he gave diagrams of the lines and a description of the instruments employed. This paper was the first published work on star spectra. In this important communication the first attempt was made to classify the stars according to their spectra. He wrote in this paper, "The star spectra present such varieties that it is difficult to point out any modes of classification. For the present, I divide them into three groups: first, those having many lines. and bands, and mostly resembling the Sun, viz., Capella, β Geminorum, α Orionis, etc. These are all reddish or golden stars. The second group, of which Sirius is the type, presents spectra wholly unlike that of the Sun, and are white stars. The third group comprising α Virginis, Rigel, etc., are also white stars, but show no lines; perhaps they contain no mineral substance or are incandescent without flame."

The spectroscope of that day was a rude instrument, not well understood; and its results, of course, do not compare in definition and accuracy with spectroscopes of more recent times, but Mr. Rutherfurd's results were most suggestive and valuable.

In the course of his observations upon the stellar spectra he discovered the use of the star spectroscope to show the exact state of the color correction in an object glass, particularly for the rays used in photography. Patiently and skillfully he followed up this trail, and in 1864, after many experiments in other directions, but always aiming at the same end, he succeeded

---

* *American Journal of Science* Vol. XXXV, p. 71.

in devising and constructing, with the aid of Mr. Fitz, an object-glass 11¼ inches in diameter and about fifteen feet focal length. This lens was corrected for photography alone and was useless for vision. A very brief account of this glass and of the prior experiments was published by Mr. Rutherfurd in the *American Journal of Science* for May, 1865.

The 11¼-inch glass was a great success and was used constantly in making negatives of Sun, Moon, and star groups. All of the superb photographs of the Moon taken before 1868 were made with this lens. Mr. Rutherfurd considered the negative made on the night of March 6th, 1865, as especially good. His photographs of the Moon were the finest ever made up to that time and have only been equalled in very recent years. The copies, which were scattered with a generous hand, attracted great attention and inspired deserved admiration. Of course Mr. Rutherfurd used wet plates, and in making moon photographs he quickly discovered that the brighter portions of the moon must have shorter exposures than the ragged edge; so he always gave his plates a skillfully graduated exposure, which is evident in the beautiful definition throughout the whole surface of his moon photographs.

In 1868 he finished his 13-inch object glass. The 11¼-inch was taken by Dr. Gould in 1870 to South America. Unfortunately it was cracked in transit. Dr. Gould put the pieces together and made some photographs with it of the southern heavens. He afterwards obtained another lens. The new 13-inch had a focal length of a little over fifteen feet. This glass was an ordinary achromatic lens and was connected with a third lens of flint glass which made the proper correction for photography, and shortened the focal length to 13 feet. This correcting lens could be fixed outside of the ordinary seeing glass, in a few minutes, by three set screws. All of the photographs taken after 1868 were made with this new instrument. Mr. Rutherfurd's photographs of the Sun were quite as remarkable as those of the moon. The series taken in 1870 showed beautifully the details of spots, the faculæ, and the mottled surface of the photosphere, and exhibited clearly the rotation of the Sun and the changes in the forms and groupings of the spots. Mr. Rutherfurd was not content with merely taking the photographs: he contrived and constructed a measuring micrometer for his plates. This was arranged to measure position-angle and distance from a central star. In the micrometer used previously to 1872, he employed screws only, but, on finding that the screw was unreliable for long distances, be it cut ever so nicely by his own apparatus, as it needed constant investigation for errors of wear, etc., he in 1872 arranged his measuring machine with a glass *scale*, so that thereafter he depended on the screw for very small distance measures only between the divisions of the scale. This instrument will be found illustrated and described in Appleton's Cyclopædia. Doubts having been expressed in Germany as to the stability of the collodion film he published in 1872,* a series of measurements which demonstrated conclusively the fixity of the film when used upon a plate treated with dilute albumen. In 1864, Mr. Rutherfurd presented to our National Academy of Sciences a photograph of the solar spectrum obtained by using bisulphide of carbon prisms. He explained how he secured the needed uniform density of the liquid, and proved how essential this precaution was. The number of lines in the spectrum photograph was more than three times the number within the same limits on the chart of Bunsen and Kirchoff.

During 1870, Mr. Rutherfurd constructed a ruling engine described and figured in Appleton's Cyclopædia under the article "Spectrum." With this beautiful apparatus he produced superb interference gratings on glass and on speculum metal. Some of the ruled plates had 17,000 lines to the inch; they were superior to all others down to the time when Professor Rowland perfected his machine.

Mr. Rutherfurd spent a great deal of time studying the cutting operation of diamonds, and in perfecting the micrometer screw for his ruling engine. The engine was run by a miniature turbine wheel and was kept at work during the still hours of the night. Many of these ruled plates were distributed with a generous hand among the scientific men of the world.

The *American Journal of Science* for March, 1865, contains an article by Mr. Rutherfurd describing and illustrating his method for the adjustment of a battery of prisms to the position of least deviation. This method was extremely convenient. He produced a photograph of the solar spectrum with his grating (17,000 lines to the inch) which was for a long time unequalled.

Mr. Rutherfurd in 1876 gave an account of an instrument in which the divided circle was of glass. He showed that a far greater accuracy could be obtained with his glass circle than with a metallic one of the same diameter, at that time. This circle was broken during its use and Mr. Rutherfurd did not make a second one.

---

* *American Journal of Science*, December, 1872.

President Grant in 1873 appointed Mr. Rutherfurd one of the scientific commission to attend the Vienna Exposition, but he was obliged to decline the honor on account of business engagements in America. In 1885 he was named by the President of the United States one of the delegates to the International Meridian Conference which met in Washington in October, 1885. He took a very active and honorable part in that conference, and was able to bring about an agreement when none seemed possible. He framed and presented the resolutions which finally expressed the conclusions of the conference. The French Academy invited him to become a member of the International Conference on Astronomical Photography held in Paris in 1887. Our National Academy of Sciences named him as its representative to the same conference. Unfortunately failing health compelled him to decline these high and merited honors. He was frequently consulted by the United States and foreign goverment officials in relation to questions of photography especially referring to eclipses of the sun, and transits of Venus. For more than twenty-five years he was a most influential member of the Board of Trustees of Columbia College, taking active part in the formation of the School of Mines and in building up the scientific work of that institution. He resigned in 1884 because he was unwilling to be absent from the monthly meetings of the Board so much of the time as his health compelled. "No man's judgment was clearer, or better informed, no man's interest keener in all that pertained to the advancement and elevation of the college, no man was a better or more judicious friend of the professors and no man's resignation as trustee could, I believe, have been more reluctantly accepted."*

Mr. Rutherfurd was one of the original members named in the Act of Congress creating this National Academy of Sciences. For services rendered the cause of Astronomy he was made an associate of the Royal Astronomical Society of London. His work was recognized at home and abroad by many other honors conferred, such as diplomas (he was made an LL. D. at the centennial celebration of Columbia College in 1887), memberships, orders and medals; he received the Count Rumford medal.

Mr. Rutherfurd took a leading part in assisting President Barnard to form, with the aid of the late Professors Peck and Trowbridge, a department of Geodesy and Practical Astronomy at Columbia College in 1881. When the Trustees built the fine library building an Observatory was placed on the top of the

---

* Letter of Professor J. H. Van Amringe to the writer August 11, 1892.

edifice, and accomodations were prepared for equatorial, transit, and other instruments. In December 1883 Mr. Rutherfurd made an unconditional gift to the Observatory of his 13-inch telescope with its photographic correcting lens, his transit instrument, Dent clock, measuring micrometer, barometer and other apparatus. He was aware of the importance to science of a complete reduction of his measures on the star plates. Early in his work Dr. B. A. Gould reduced the measures made on the Pleiades and Præsepe plates taken with the 11¼-inch glass and measured with the first micrometer machine which was not provided with a *scale*.

As the scientific world is aware these results were given to the National Academy of Sciences in August, 1866, and April, 1870. In these reductions Dr. Gould showed clearly the great accuracy and value of the measures. The only publication made at the time was in the *Astronomische Nachrichten* where Dr. Gould gave the resultant distances and position angles from Alcyone for the brightest ten stars of the Pleiades group, and called attention to their close accordance with Bessel's earlier values deduced from his observations with the Königsberg heliometer. No further publication was made as Dr. Gould has explained (before the National Academy of Sciences at the New York meeting in November, 1891), because in May, 1870, he departed for South America expecting to be gone three years only, whereas his stay was prolonged to fifteen years. Moreover as Mr. Rutherfurd had in 1866 orally explained his methods to the National Academy, it was expected that he would write out a full account of his work which should antedate the full publication of the measures reduced by Dr. Gould. This Mr. Rutherfurd failed to do. Poor health and a very strong indisposition to "rush into print" (as he expressed it to me) prevented him. On Dr. Gould's return he had the original memoirs printed by the National Academy and thus twenty-two years after they were read these important communications were given to the world. During the intervening years Mr. Rutherfurd endeavored, he told me, to find some one to take up the reduction of the measures, but seemed unable to do so. His frequent and long absences from home prevented him from looking after the matter properly, and his sensitive nature would not allow him to ask anyone to attend to the work for him. It was during these years that I frequently urged him to present to Columbia College Observatory his negatives and measures, but he thought he would prefer to keep his work and arrange the reductions himself. He was exceedingly modest about his estimate of his work on the star groups, speaking of recent improvements that had been made and saying that perhaps after all there was no demand for the reductions. Finally, however, he gave up the idea of himself directing the reductions of the measures and was persuaded that astronomers were anxious to have the work reduced. Professor E. C. Pickering's influence was weighty at this time. He offered to Columbia College $500 of the Bruce fund to publish the reductions. President Low laid this offer before Mr. Rutherfurd and he at once replied that the donation was generous but unnecessary, and that he would place in my hands the matter of the reductions and supply the needed funds.

So on November 13th, 1890, Mr. Rutherfurd gave all his negatives of sun, moon and star groups to Columbia College. With these negatives came twenty folio volumes of about two hundred pages each containing the measures of many of the plates. This valuable contribution has been placed in a fire proof vault at the College. I have given in the Annals of the New York Academy of Sciences (Vol. VI, June, 1891,) a complete list of these negatives. This catalogue shows

175	plates of the	Sun	taken between	1860-74
174	" " "	Solar Spectrum	" "	1860-74
435	" " "	Moon	" "	1858-77
664	" " "	Star groups	" "	1858-77

Some of the principal star plates may be mentioned:

33	plates of	44 Bootis	taken between	1868-75
12	" "	B A. C. 8083	" "	1873-74
27	" "	η Cassiopeæ	" "	1870-73
58	" "	μ "	" "	1868-73
15	" "	β Cygni	" "	1875-76
24	" "	21 "	" "	1875-76
22	" "	61 "	" "	1871-76
19	" "	7 "	" "	1875-76
27	" "	Perseus Clusters	" "	1865-74
54	" "	Pleiades	" "	1865-74
23	" "	Præsepe	" "	1865-77
23	" "	1830 Groombridge	" "	1872-77

Many of the plates are still unmeasured.

When the collection was turned over to my care it was arranged to push forward the reductions as rapidly as possible. Mr. Jacoby of the College Observatory entered on the work at once and the results are shown in the first publication "The Rutherfurd Photographic Measures of the Group of the Pleiades." The measures reduced in this paper were made with the micrometer machine supplied with the glass scale, on plates taken with the 13-inch glass.

These reductions show conclusively that the results of Rutherfurd's measures of the Pleiades group must hereafter be taken into account with the Bessel and Elkin heliometer measures, for a study of proper motions and to form a definitive catalogue of the Pleiades. In a recent review of Mr. Jacoby's reductions Dr. Elkin states * that he shortly proposes to make a revision of the Yale Pleiades work and when that is done "the accuracy of the photographic results will be still more apparent." These results show with what ability and thoughtful care for every detail of measurement Mr. Rutherfurd directed the work of photography and of measurement; they also show that he was correct in his judgment when he stated "that the photographic method is at least equal in accuracy to that of the heliometer or filar micrometer, and far more convenient." When Mr. Rutherfurd was on his deathbed a bound copy of these reductions was placed in his hands. He was able to show his pleasure and great gratification only by the expression of his face. In the previous fall, however, he had seen most of the finished manuscript.

Mr. Jacoby has completed his reductions of the measures of the "Stars about β Cygni," and the publication will be sent out very soon. Other measures will be reduced as rapidly as possible. Rutherfurd Stuyvesant, Esq., has taken great interest in putting his father's work into available shape, and through Mr. Stuyvesant's aid the Columbla College Observatory hopes to place before the world the reductions of all the star measures. It may thereafter be desirable to measure the plates now unmeasured and to proceed to their reduction.

Dr. Gould, in an appreciative notice of Mr. Rutherfurd, has written:

"Mr. Rutherfurd was of an exceptionally amiable and generous disposition, helpful to others and tolerant of their feelings. His intellectual diffidence and almost shrinking modesty were as notable as were his boldness of invention, ingenuity of device and persistence in following up his ideas, under trying circumstances. The moral effect of his example among his co-workers, was quite as beneficent as the scientific stimulus exerted by the results he obtained and partially published. To these qualities he added a calm and unprejudiced judgment, an admirable power of statement, and every instinct of a gentlemen."†

A friend of Mr. Rutherfurd of thirty years' standing tells us in the *Photographic Times* that "The rigor of our northern winters

---

* *Publications of the Astronomical Society of the Pacific*, Vol. IV, No. 24.

† *Astronomical Journal*, June, 1892.

led him to spend the colder parts of the last twenty years in more southern latitudes: sometimes in the south of France but more recently amid the orange groves and tropical surroundings of Florida. While on his journey south in the autumn of last year, he contracted a severe cold, through some defect or oversight in the heating apparatus of his sleeping car, and he never fully recovered from its effects. While prostrated and weakened by this attack, the sudden death of a daughter in his northern home, produced a depression of vitality, which was lasting. In the early spring he returned to New York with his oldest son, who had passed the winter with him, and at whose residence he remained a few days. Not recovering his strength and seeming to realize that the end was near, he expressed a desire to reach his country home; the old homestead which he and his ancestors had occupied more than 150 years. Soon after reaching 'Tranquillity,' a home most appropriately named, the symptoms of failing strength became more marked, until a blood clot formed on the brain, which, although it rendered him speechless during the last few days, yet did not destroy consciousness, until the end, which came peacefully and without apparent pain" on May 30th, 1892.

COLUMBIA COLLEGE OBSERVATORY, August 25th, 1892.

DISCOVERY OF COMET BROOKS 1892.

WILLIAM R. BROOKS.

While engaged in searching the eastern heavens on the morning of August 28th, at 13 hours, I discovered a new comet, in the constellation Auriga.

The approximate position was R. A. 5 hours, 59 minutes, declination north 31° 52′. Motion was very soon detected, which was easterly. The comet was so near the path of Denning's comet, the ephemeris of which I did not have for a later date than August 5, that at first a little uncertainty was felt about its identity. But it was soon ascertained that Denning's comet passed the place of my new object a month before, and was really several degrees distant. Moreover, my comet was much the brighter of the two.

A second observation was obtained the next morning as follows: Aug. 29th, 14 hours, R. A. $6^h\ 2^m + 31° 48'$. This gave a daily motion of east 3 minutes south 4′.

This morning the following place was read from the circles: Sept. 2d, 15 hours R. A. $6^h\ 11^m\ 50^s + 31° 26'$.

The comet is an easy object in the 10-inch refractor, and a short faint tail is perceptible.

SMITH OBSERVATORY, Geneva, N. Y., Sept. 3, 1892.

-PHYSICS.

COM a

I have obta
nine mornings April
servations with
the comet's low
interesting chan
shown in the obs in
given below. Acc
vations of April 1
then consisted of co
form quite unique an
There are no indicatio
familiar bands were se
to fall within the usua
must have taken place
noted that the comet was
The observations were n
inch equatorial. A very d
Brashear was used with ma
for the several nights are gi
tions.

April 5*d* 17ʰ. The continuous
C to G. Its east edge was sh
diffused. Later it was seen that
sides of the comet's nucleus tow
tively. The less refrangible edge
bands were very sharply defined, a
minated by a very bright line which
narrowed. The wave-lengths of th
relative motion of the comet and obse

5630 ± 2 5170.3 ± 0.3

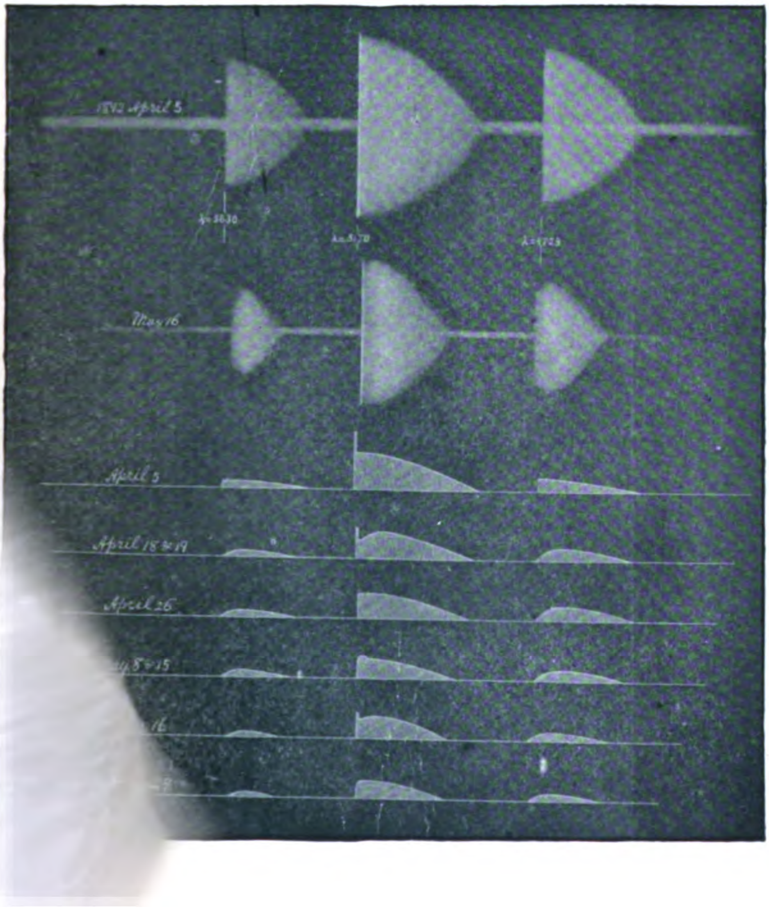
Slit width for first and third bands 0.0
0.003 inch. The intensities of the ban
ratios 1 : 6 : 2.

April 6*d* 17ʰ. The comet was observed w
tached to the 12-inch equatorial. The spec
the same as on the previous morning. Whil

---

* Communicated by the author.

PLATE XXXVI.



The Spectrum of Comet *a* 1892 (Swift).

ASTRO-PHYSICS.

THE SPECTRUM OF COMET *a* 1892 (SWIFT).*

W. W. CAMPBELL.

I have obtained observations of the spectrum of this comet on nine mornings subsequent to and including April 5. Earlier observations with the great telescope were practically prevented by the comet's low altitude and unfavorable weather. A number of interesting changes in the spectrum were noticed, which are shown in the observed wave-lengths and in the intensity curves given below. According to Konkoly's recently published observations of April 1 and 2 (*Astr. Nach.* No. 3087) the spectrum then consisted of continuous spectrum and five bright lines; a form quite unique and different from that seen by me at any time. There are no indications in his note that any traces of the three familiar bands were seen, save that the five bright lines referred to fall within the usual limits of the bands. A decided change must have taken place between April 2 and 5. It should be noted that the comet was at perihelion April 6.

The observations were made with the spectroscope of the 36-inch equatorial. A very dense and excellent 60° flint prism by Brashear was used with magnifying power 13.3. The slit widths for the several nights are given in connection with the observations.

April 5*d* 17^h. The continuous spectrum was visible from about C to G. Its east edge was sharply defined, its west edge quite diffused. Later it was seen that these edges corresponded to the sides of the comet's nucleus towards and from the Sun, respectively. The less refrangible edges of the three characteristic bands were very sharply defined, and the middle band was terminated by a very bright line which narrowed when the slit was narrowed. The wave-lengths of these edges, corrected for the relative motion of the comet and observer were

$$5630 \pm 2 \qquad 5170.3 \pm 0.3 \qquad 4723 \pm 1.$$

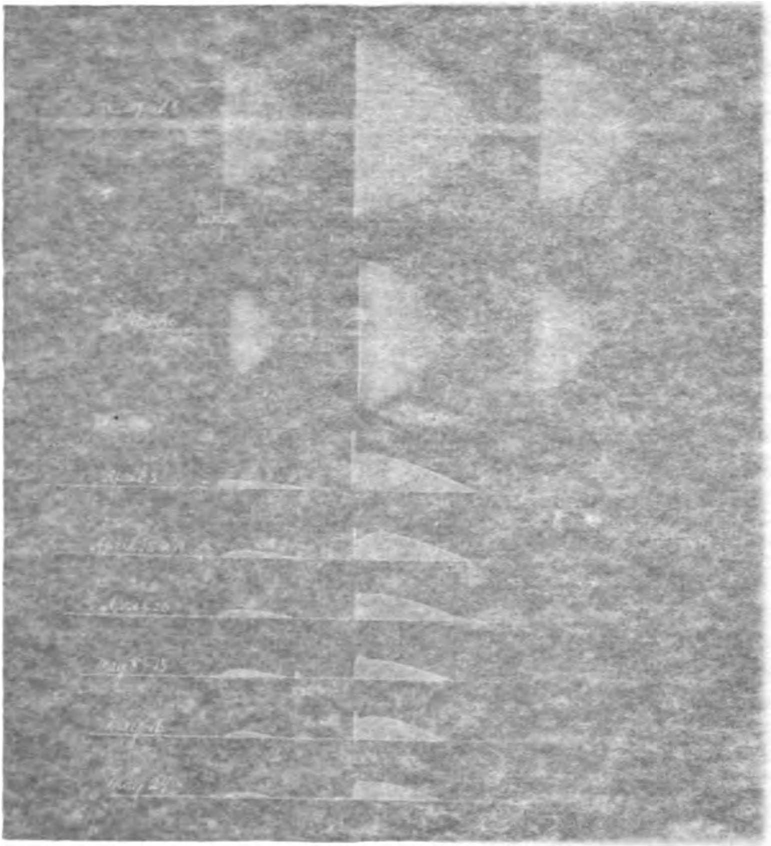
Slit width for first and third bands 0.006 inch; for middle band 0.003 inch. The intensities of the bands were about in the ratios 1 : 6 : 2.

April 6*d* 17^h. The comet was observed with a spectroscope attached to the 12-inch equatorial. The spectrum appeared to be the same as on the previous morning. While the spectrum was

---

* Communicated by the author.

PLATE XIV.



The Spectrum of Comet *a* 1892.

ASTRO-PHYSICS.

THE SPECTRUM OF COMET *a* 1892 (SWIFT).*

W. W. CAMPBELL.

I have [illegible] observations of the spectrum of this comet on nine mornings subsequent to and including April 5. Earlier observations with the great telescope were practically prevented by the comet's low altitude and unfavorable weather. A number of interesting changes in the spectrum were noticed, which are shown in the observed wave-lengths and in the intensity curves given below. According to Konkoly's recently published observations of March 1 and 2 (*Astr. Nach.* No. 3087) the spectrum then consisted of continuous spectrum and five bright lines, a form quite unique and different from that seen by me at any time. There are no indications in his note that any traces of the three familiar bands were seen, save that the five bright lines referred to fall within the usual limits of the bands. A decided change must have taken place between April 2 and 5. It should be noted that the comet was at perihelion April 6.

The observations were made with the spectroscope of the 36-inch equatorial. A very dense and excellent 60° flint prism by Brashear was used with magnifying power 13.3. The slit widths for the several nights are given in connection with the observations.

April 5*d* 17h. The continuous spectrum was visible from about C to G. Its east edge was sharply defined, its west edge quite diffused. Later it was seen that these edges corresponded to the sides of the comet's nucleus towards and from the Sun, respectively. The less refrangible edges of the three characteristic bands were very sharply defined, and the middle band was terminated by a very bright line which narrowed when the slit was narrowed. The wave-lengths of these edges, corrected for the relative motion of the comet and observer were

5630 ± 2 5170.2 ± 0.3 4723 ± 1.

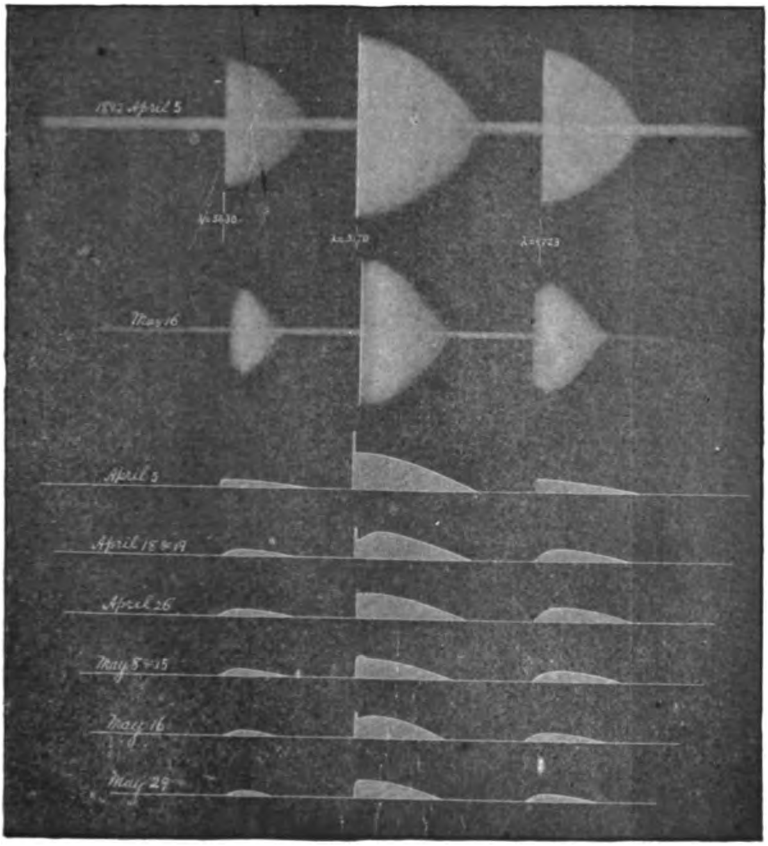
Slit width for first and third bands 0.006 inch; for middle band 0.003 inch. The intensities of the bands were about in the ratios 1 : 6 : 2.

April 6*d* 17h. The comet was observed with a spectroscope attached to the 12-inch equatorial. The spectrum appeared to be the same as on the previous morning. While the spectrum was

---

* Communicated by the author.

PLATE XXXVI.



The Spectrum of Comet *a* 1892 (Swift).

brighter with the 12-inch than with the 36-inch, yet it could not be observed nearly so well, on account of the smaller scale.

April 18*d* 16ʰ. The first and third bands were not sharply terminated, and there was insufficient time to measure their wave-lengths. The wave-length of the bright line which terminated the middle band, with slit width 0.003 inch was

5163.1 ± 0.4.

April 19*d* 16ʰ. The intensity curve appeared to be the same as on April 18, and the wave-length of the bright line, with slit width 0.003, was

5165.3 ± 0.2.

April 26*d* 16ʰ. The bright line had disappeared. The wave-length of the less refrangible edge of the middle band, with slit width 0.003 inch, was

5156.7 ± 0.4.

May 8*d* 15ʰ. Only two measures were obtained before it clouded over. The wave-length obtained with slit 0.003 inch was

5156.7.

May 15*d* 14ʰ. Only one measure obtained when further observations were prevented by dense fog on the object-glass. The resulting wave-length with slit 0.004 inch wide, was

5157.3.

May 16*d* 15ʰ. The wave-lengths of the edges of the bands were

5603 ± 2.7   5157.7 ± 0.3   4733 ± 1.8.

The wave-lengths of the most intense parts of the bands were

5552, 5107, 4697.

The slit width was 0.003 inch.

May 29*d* 14ʰ. The wave-length of the edge of the middle band, with slit width 0.003 inch, was

5154.5 ± 0.2.

June 13*d* 13ʰ. The spectrum was rendered excessively faint by fog on the object-glass and the observation is entitled to small weight. The wave-length of the middle band, with slit 0.005 inch wide, was

5149.3 ± 1.4

These fairly accurate measures and the accompanying intensity curves make it certain that important changes occurred at the less refrangible edge of the middle band. Probably three bright lines were formed at 5170, 5164 and 5157, and disappeared in that order; so that the wave-length of the edge diminished as the comet's distance from the Sun increased. Those at 5164 and

5157 were certainly not identical; and it is improbable that those at 5170 and 5164 were identical, though the former was observed on only one night.*

By arranging the published observations of other comet spectra in the order of their dates and with reference to the times of perihelion passage, I had hoped to detect evidences of similar changes. But the large probable errors of many of the observed wave-lengths, the great differences between the results obtained by different observers, on the same night, and the entire absence of intensity curves, made it impossible to secure such evidence. In many cases the published wave-length depends upon observations made on several evenings. If it is granted that the spectrum undergoes change, it is evident that the results obtained at different times should not in general be combined, and that an accurate intensity curve is practically as valuable as an accurate measure.

ON THE SPECTRA AND PROPER MOTIONS OF STARS.†

W. H. S. MONCK.

I have more than once called the attention of the readers of ASTRONOMY AND ASTRO-PHYSICS to the greater average proper motions of Solar stars than those of the Sirian type, and I intimated my own opinion that this difference arose from the greater nearness of the Solar stars. Solar stars, in my opinion, in consequence of their small relative brightness (or intrinsic brilliancy) become invisible at distances where the corresponding Sirian stars, though not perhaps of greater mass, can be clearly detected. It was, however, possible that the greater proper motions of the Solar stars arose from their moving through space with greater velocity, and it therefore became important to ascertain as far as possible whether the spectroscope revealed any difference in their actual velocities. We have now a table of the spectroscopic velocities of 51 stars determined by Vogel which may be relied on as fairly accurate. The following is the result distinguishing Sirian from Solar stars:

---

* By comparing the observed wave-lengths in the vicinity of = λ 5156 with the corresponding intensity curves, it will be seen that the results are greater or less according as the edges are more or less sharply defined.

† Communicated by the author.

Sirian Stars.	Type.	Velocity. miles per second.
α Andromedæ	A	+ 2.8
β Persei	A	− 1.0
γ Orionis	B	+ 5.7
β Tauri	A	+ 5.0
δ Orionis	B	+ 0.6
ε Orionis	A	+ 16.5
ζ Orionis	A	+ 9.3
β Aurigæ	A	− 17.5
γ Geminorum	A	− 10.3
Sirius	A ?	− 9.8
Castor	A	− 18.4
Regulus	A	− 5.7
β Ursæ Majoris	A	− 18.2
δ Leonis	A	− 8.9
β Leonis	A	− 7.6
γ Ursæ Majoris	A	− 16.5
ε Ursæ Majoris	A	− 18.8
Spica	A	− 9.2
ζ Ursæ Majoris	A	− 19.4
η Ursæ Majoris	A	− 16.3
β Libræ	A	− 6.0
α Coronæ Borealis	A	+ 19.9
α Ophiuchi	A	+ 11.9
Vega	A	− 9.5
Altair	A	− 22.9
α Cygni	A	− 5.0
α Pegasi	A	+ 0.8

Solar Stars.	Type.	Velocity. miles per second.
β Cassiopeiæ	F	+ 3.2
α Cassiopeiæ	K	− 9.5
β Andromedæ	K ?	+ 7.0
Polaris	F ?	− 16.1
γ Andromedæ	K	− 8.0
α Arietis	K	− 9.2
α Persei	F	− 6.4
Aldebaran	K	+ 30.2
Capella	F	+ 15.2
Rigel	F	+ 10.2
Procyon	F	+ 5.7
Pollux	K ?	+ 0.7
γ Leonis	K	− 24.0
α Ursæ Majoris	K	− 7.2
Arcturus	K	− 4.8
ε Bootis	G ?	− 10.1
α Serpentis	K ?	+ 14.0
β Herculis	K	− 22.0
ε Pegasi	K	+ 5.0
β Ursæ Minoris	L ?	+ 8.9

Disregarding signs and taking the arithmetical mean, the average velocity of the Sirian stars is 10.8 miles per second and of the Solar stars 10.9 miles per second. Vogel gives the average (including four stars with other spectra) as 10.4 miles per second.

Admitting that this result is not conclusive, I think, when taken in conjunction with the greater surface-brightness (this term is preferable to mass-brightness) of the Sirian binary stars whose orbits have been computed, we have strong reasons for concluding that Sirian stars are on the average much more distant than Solar stars of the same magnitude, and that the reason why Sirian stars appear to be more numerous than the Solars is that they are visible at distances where the corresponding Solars are invisible with the same instruments. This conclusion may modify our opinions as to the structure of the universe. For instance, the theory sometimes adopted that the Galaxy consists chiefly of Sirian stars would be completely overthrown if we suppose that Sirian stars are on the average visible at double the distance of Solar stars.

If the stars were motionless the average velocity of 10 miles per second would mean that this was the average velocity with which the Sun approached or receded from a point in the sky taken at random, and although the stars are no doubt moving, the result may, in this respect, prove not far from the truth. Referring the Sun's motion in space to three axes of co-ordinates at right angles to each other, we see that to give an average velocity of 10 miles per second to or from a given point, the velocity of the Sun's motion in space must be $\sqrt[2]{3} \times 10$ miles per second or between 17 and 18 miles per second. An examination of Catalogues of Proper Motion has led me to think that the Sun moves with at least this average velocity, and that consequently its speed is not likely to be less than 18 miles per second. If we knew the exact direction of its motion the corrected results of Vogel's observations would be very interesting. At present there is rather too much uncertainty for this.

THE PHOTO-ELECTRIC CELLS.*

G. M. MINCHIN.

The cells which are employed for obtaining electromotive force from the light of the stars and planets are known as *seleno-aluminium* cells. They are constructed in the following way. Take a small flat strip of aluminium about a quarter of an inch long and one-sixteenth of an inch broad; let this be heated on a clean iron plate placed over a Bunsen flame, and while it is hot let a very small bubble of melted selenium be rapidly and uniformly spread by means of a hot glass rod over about one-third of the length of the aluminium strip, the selenium forming a very thin layer. When this layer is spread, the little plate must be rapidly removed from the hot iron plate and thus cooled, while the Bunsen flame is, at the same time, removed from under the iron plate. The latter plate having become cooler, replace the aluminium strip on it, and then gradually heat up the iron plate from beneath by means of the Bunsen flame. As a result of this gradual heating, the aspect of the selenium layer on the aluminium changes; this layer changes from black to grey in appearance, and in the latter state it is sensitive to light. But to give the layer its maximum sensitiveness, several re-meltings may be necessary, until a grey surface of a somewhat brownish tinge, quite devoid of glossy streaks, is produced. Nothing but an actual sight of the process of making a sensitive plate can give the reader a correct notion of the proper kind of surface. Assuming

---

* Communicated by the author.

this surface produced by the gradual process of heating above referred to, the Bunsen flame is removed, and the seleno-aluminium plate is allowed to cool on the iron plate. When it has cooled (after about ten minutes) it is taken and joined to a very fine platinum wire which is inserted through a fine hole previously bored through the uncoated portion of the aluminium plate: this platinum wire is tightly pinched to the plate so as to make a good electrical contact.

So far for the sensitive plate. The cell into which it is to be inserted is a very fine glass tube about 1½ inches long, into which a platinum wire pinched to a clean plate of aluminium has been sealed: the size of this latter plate is immaterial—it may be a mere speck of the metal at the end of the platinum wire; it is the inactive plate of the cell. Into this glass tube, thus closed at one end, is inserted (by means of a pipette with a capillary stem) a quantity of pure acetone sufficient to occupy about one-quarter of the length of the tube; and then the sensitive plate is inserted until its sensitive extremity is very nearly in contact with the inactive plate, the whole of the sensitised part of the plate being covered by the acetone.

The platinum wire of the sensitive plate which now projects through the open end of the cell must be sealed into the tube, the end of the tube being, of course, completely closed by the sealing. Much practice is here necessary to prevent the vapor of the acetone from bursting the heated end of the tube; but the process becomes easy enough with practice.

The cell is now made, and if its poles are connected with those of an electrometer, and light is allowed to fall on the sensitive plate, an electromotive force will be indicated.

Shortly after the cell has been made, it is wonderfully quick in its response to changes of the incident light—almost instantaneous, in fact; but after about 24 hours, it becomes slower in its response. The cause of this is not yet quite known; but it has been found that a constant régime can be produced and kept up for months by—

(*a*) using perfectly pure acetone,

(*b*) using perfectly pure selenium,

(*c*) turning the cell upside down when it is not required for use, and thoroughly shaking the liquid away from the plates.

The complete and permanent elimination of sluggishness from the cell is under consideration at present.

As regards the *magnitude* of the electromotive forces produced, it may be said that ordinary diffused daylight falling on the sensitive plate will give an E. M. F. of about ½ volt, which is surprisingly great. A candle at a distance of 7 feet will give about $\frac{1}{30}$ volt.

Light of all refrangibilities from red to violet is effective—and this fact distinguishes this cell from every other known photo-electric cell—the maximum effect being produced by the yellow rays; but there is not very much difference between the effects of the various parts of the spectrum.

By putting a number of these cells in series, the effect is multiplied by the number employed; thus 10 cells in series will give 10 times the E. M. F. of one cell.

Hence for stellar observations the cells should be made as small as possible, and cells much smaller than the typical one above described have been made.

Does anything depend on the *size* of the sensitive plate? It would appear that nothing depends on the size, and that therefore a mere pin point of sensitive surface is as effective as a square centimètre. Perhaps this is so; but it has been found that the maximum E. M. F. is never given when the sensitive surface is as small as a large pin head. For stellar observations this is most unfortunate; but it is highly probable that the result is due to the large size and capacity of the electrometers at present at our disposal. There is good reason to think that, with an extremely small electrometer, the pin-head plates will give as good results as the larger ones. Certainly with a common quadrant electrometer a sensitive surface 6 millimètres long and 2 milemètres wide gives as good a result as a surface 10 times as large. For the light of the Moon there is no difficulty in making batteries of photo-cells containing 10 or 20 cells.

With Mr. Monck's refracting telescope, the image of Mars would take, perhaps, *three* cells, and an unmistakable E. M. F. should be produced. Jupiter would take more; but it would be difficult to cover *completely* the sensitive surfaces of *two* cells with the light of Vega. (The *whole* of the sensitive surface of every kind of photo-cell must be covered by the incident light to obtain the full effect).

The best existing form of electrometer is Clifton's form of Thomson's Quadrant. Some very slight improvements in this instrument would render it fairly fit for photo-electric observations in an Observatory. When working well (well insulated, and preserved from draughts of air) it will give about 200 half millimèters deflection on a scale distant 1 mètre from the mirror for 1 volt. Hence a candle at 7 feet from one photo-cell has been found to give about 7 divisions deflection. Thus it is very easy to get results from moonlight; and, with a clear sky and the absence of air currents, the light of a planet should be easily measurable.

For a given source of light, the E. M. F. developed in a photocell varies inversely as the distance of the light from the cell.

Instead of an electrometer, a high resistance reflecting galvanometer could be used with photo-cells; but the former instrument is far preferable, because it is not advisable to allow currents to circulate in the cell. A galvanometer and a condenser (the latter charged by the cell while light falls on it, and then suddenly discharged through the galvanometer) give enormous deflections with moonlight; but this method is objectionable.

So far as is known at present, these cells will stand any amount of exposure to light without deterioration—provided that they are always employed with an electrometer, *i. e.*, open-circuited.

Mr. Monck and Professor Dixon have, I believe, succeeded in obtaining results from the light of Mars under most unfavorable atmospheric conditions. I remained in Dublin for a week in the beginning of August to try the cells with the stars; but during this time not a single opportunity occurred, the sky being heavily clouded every night.

When a photo-battery has been used with a strong light, such as that of the Moon, the deflection on the electrometer scale takes some time to disappear when the light has been shut off. This deflection can, however, be very quickly got rid of without injury to the battery by an instantaneous connection of the battery with a Daniell cell whose zinc pole is for the moment connected with the sensitive pole of the battery, the copper being connected with the insensitive pole and with earth.

Royal Engineering College,
Cooper's Hill, England.

ON THE SPECTRUM OF LIQUID OXYGEN, AND ON THE REFRACTIVE INDICES OF LIQUID OXYGEN, NITROUS OXIDE, AND ETHYLENE.*

PROFESSORS LIVEING AND DEWAR.

In September, 1888, were described in this Magazine (p. 286) the absorption-spectrum of oxygen gas in various states of com-

---

* From the *Philosophical Magazine* for August, 1892.

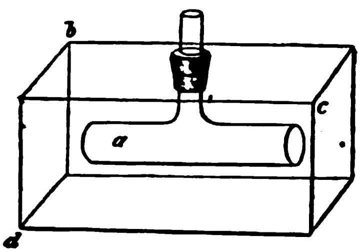
pression. At lower pressures the absorptions known in the solar spectrum as A and B were most conspicuous, and as the pressure increased the other bands described by Janssen came out with increasing intensity. The former appear to be due to the molecules of oxygen, and increase in intensity directly with the mass of the oxygen producing them; while the latter appear to arise from the mutual action of the molecules on one another, since their intensity is dependent on the density as well as the mass of the oxygen producing them.

With the small dispersion employed in these observations the absorptions A and B were not resolved into lines as in the solar spectrum, but they had otherwise the same general characters: A consisted of two bands, and both A and B were sharply defined on the more refrangible edge and gradually faded out on the less refrangible side. Considering how much more diffuse the lines forming these groups in the solar spectrum become as the Sun gets nearer the horizon (see McClean's photographs), it is probable that, under the circumstances of our experiments, they would not have been resolvable into lines even with higher dispersion.

Subsequently, in a paper read at the Royal Society (*Proc. Roy. Soc.*, vol. XLVI, p. 222), we described our observations on the absorption of a thickness of 12 millim. of liquid oxygen. We noticed, as Olszewski had done, the strongest three of the diffuse bands seen in the spectrum of the compressed gas, but could not detect A. The mass of oxygen in 12 millim. of the liquid was not enough to make A visible.

We have since made observations with larger quantities of liquid oxygen. For this purpose we have used a glass tube of the form shown at *a* in the annexed figure, about ¾ inch in diameter and 3 inches in length. This tube had the ends blown as flat and clear as possible, and it was enclosed in a box with glass sides *b c d*, and the air in the box well dried, in order to prevent the deposition of hoar-frost on the tube. The liquid oxygen was poured into the tube at the pressure of the atmosphere, and at first, of course, boiled violently, until the tube was reduced to the temperature of boiling oxygen, —181°, after which the liquid boiled slowly and quietly. Through the length of the tube (that is, a thickness of about 3 inches of liquid oxygen) we viewed the hot pole of an electric arc with a spectroscope having two calcite prisms of 30° and one of 60°. As reference-rays we used the red potassium-lines, of which the positions with reference to A and B were well determined by Kirchhoff, and confirmed by our own observations. These lines were easily obtained by dropping a little of a potassium salt into the arc.

The diffuse bands previously seen both in the gas and liquid were all of exceptional strength, but we did not notice any addition to their number except a faint band just above G. In place of A we observed a band, but different from A in the following remarkable particulars. Instead of having a sharp edge on the more refrangible side and fading gradually towards the less refrangible side, its position appeared to be reversed; the sharp edge was on the less refrangible side, and it faded away gradually on the more refrangible side. Moreover its sharp, less refrangible edge did not coincide with the sharp edge of A, but reached very nearly to the more refrangible of the two potassium-lines, that is, had a wave-length of nearly 7660. At the same time the band extended beyond the sharp edge of A on the more refrangible side. There was no indication that it was resolvable into lines, or even into two bands. Turning to the place of B in the spectrum we were not able, with that thickness of oxygen, to detect any band in that place. Olszewski (Wied. *Ann.* XLII, p. 663), with a thickness of 30 millim. of liquid oxygen, observed a somewhat faint band corresponding to A, which with a Rutherford prism was not resolvable into lines, but he has not noticed the reversed position of the band.



Using a similar tube for the liquid oxygen, but six inches long, the band at A came out very much stronger and extended much further on the more refrangible diffuse side, but was not conspicuously expanded on the other side, and did not hide the potassium-line. At the same time a fainter band appeared at the place of B. This had precisely the same character as that of A; that is, it had its sharp edge on the less refrangible side and faded gradually on the more refrangible side. Its sharp edge also did not coincide with the sharp edge of B, but reached nearly to the red potassium-line λ 6913. By estimation, using the potassium-lines for comparison, we put the wave-length of the less refrangible edge at about λ 6905, while its diffuse side was visible to about λ 6870, that is, barely to the place of the strong edge of B.

It is plain that these two bands are related to each other in the same way as the solar groups A and B are related, and we cannot avoid the conclusion that they represent A and B, but modified by the change of the absorbent from the gaseous to the liquid state.

If, as there is good reason to think, A and B are the absorptions of free molecules of oxygen, the persistence of these absorptions in the liquid seems to show that the molecules in the liquid are the same as in the gas. At the same time the changes they undergo ought to throw some light on the nature of the change in passing from the gaseous to the liquid state, as well as on the causes which produce the sequences of rays which are called channelled spectra.

We have noticed, as Olszewski also has noticed, that liquid oxygen is distinctly blue. This is, of course, directly connected with its strong absorptions in the orange and yellow. On looking at a mass of liquid oxygen through a direct-vision spectroscope in any direction the scattered light shows the strong bands plainly. Indeed they remain visible when the oxygen has evaporated to the last drop, and they increase in intensity as the liquid is cooled, so that when the pressure on the liquid is reduced and the oxygen cooled by its own evaporation to —200° they become exceedingly black. Olszewski states that this blue color is not, so far as he could make out, due to ozone, and we are of the same opinion. Ozone dissolves easily in liquid oxygen and imparts to it an indigo-blue color. Such a solution when poured into a saucer of rock-salt assumes the spheroidal state, and as the oxygen evaporates becomes more concentrated, and finally explodes with considerable violence. In the dilute solution we could not detect any absorptions due to the ozone. We attempted to obtain a larger quantity of liquid ozone, or of a concentrated solution, for the observation of its spectrum. Oxygen ozonized in a tube cooled by solid carbonic acid gave small beautiful cobalt-blue drops of liquid, but when a few of these drops collected together in a tube immersed in liquid oxygen to cool it to — 181°, they exploded and blew the whole apparatus to pieces, comminuting the tube to fine powder. This instability of ozone, equally at very low and at high temperatures, is a significant fact in regard to the form of chemical energy. It seems probable that it is connected with the great absorbent power of ozone. The radiant energy absorbed must give rise to molecular movements which may, we conceive, set up disintegration.

The determination of the refractive index of liquid oxygen, at its boiling point of — 182° C., presented more difficulty than would have been anticipated. The necessity for enclosing the vessel containing the liquid in an outer case to prevent the deposit of a layer of hoar-frost which would scatter all the rays falling on it, rendered manipulation difficult; and hollow prisms with cemented sides cracked with the extreme cold. It was only after repeated attempts, involving the expenditure of a whole litre of liquid oxygen on each experiment, that we succeeded in getting an approximate measure of the refractive index for the D line of sodium. The mean of several observations gave the minimum deviation with a prism of 59° 15′ to be 15° 11′ 30″, and thence $\mu = 1.2236$. The density of liquid oxygen at its boiling point of — 182° C. is 1.124, and this gives for the refraction-constant, $\frac{\mu - 1}{d} = 1.989$, and for the refraction-equivalent 3.182. This corresponds closely with the refraction-equivalent deduced by Landolt from the refractive indices of a number of organic compounds. Also it differs little from the refraction-equivalent for gaseous oxygen, which is 3.0316. This is quite consistent with the supposition that the molecules of oxygen in the liquid state are the same as in the gaseous.

If we take the formula $\frac{\mu^2 - 1}{(\mu^2 + 2) d}$ for the refraction-constant we find the value of it for liquid oxygen to be .1265, and the corresponding refraction-equivalent 2.024. These are exactly the means of the values found by Mascart and Lorenz for gaseous oxygen. The inherent difficulties of manipulation, and the fact that the sides of the hollow prism invariably became coated with a solid deposit, perhaps solid nitrogen, which obscured the image of the source of light, have hitherto prevented our determining the refractive indices for rays other than D.*

The determination of the refractive indices for liquid nitrous oxide did not present so great difficulties. The minimum deviations for the rays C, D, F, G, and for the lithium ray λ 6705.5, and the indium ray λ 4509.6, were found to be, respectively, 22° 53′, 23°, 23° 18′, 23° 33′, 22° 52′, and 23° 28′. The corresponding values for μ are 1.329, 1.3305, 1.3345, 1.3378, 1.3257 and 1.3368.

---

* This will be prosecuted further, however. The refractive index of oxygen has an important bearing on the electro-magnetic theory of light, considering that we are dealing with a magnetic liquid. The polarizing angle corresponding to the index of refraction found above for liquid oxygen is 50° 45′, and one of us has found that when liquid oxygen is cooled to — 200° by its own evaporation at reduced pressure so as to present a steady surface, and the image of a candle is viewed by reflection at that surface the light is very completely polarized when the incidence is at that angle.

The specific gravity of liquid nitrous oxide at its boiling point of — 90° C. was found, by weighing 100 cubic centim. of the liquid, to be 1.255.

This gives, for the D ray, $\frac{\mu - 1}{d} = 0.2634$ and for the molecular refraction 11.587. Or, if we take the other formula, $\frac{\mu^2 - 1}{(\mu^2 + 2)d} = .163$ and the corresponding molecular refraction 7.163. Subtracting the refraction-equivalent for oxygen we get for the molecular refraction of nitrogen 8.405 or 5.139 according to the formula used. Mascart's determination of the index of refraction of gaseous nitrous oxide for the D ray was 1.000516 and the corresponding molecular refraction 11.531, or 7.69, according to the formula used, and in this case the older formula for the refraction-equivalent satisfies the condition of continuity between the gaseous and liquid states better than the newer.

It was more difficult to obtain the refractive indices for liquid ethylene on account of its irregular boiling. Liquid oxygen and nitrous oxide boil steadily, but ethylene in sudden bursts of large volumes of vapor. The minimum deviation for the D ray was found to be 25° 29′, approximately. This gives $\mu = 1.3632$, and, since the density of the liquid at its boiling-point of — 100° C. is 0.58, $\frac{\mu - 1}{d} = 0.627$ and $\frac{\mu^2 - 1}{(\mu^2 + 2)d} = 0.384$. The corresponding numbers for gaseous ethylene, according to Mascart, are 0.578 and 0.385. The agreement for the second formula is close, but we doubt if much stress can be laid on this, inasmuch as we know that the liquid ethylene contained a small quantity of ether.

RESUME OF SOLAR OBSERVATIONS MADE DURING THE FIRST QUARTER OF 1892.*

P. TACCHINI.

The number of days of observation has been 82, *i. e.*, 21 in April, 31 in May and 30 in June. The following are the results:

	Relative Frequency		Relative Size		Number of groups per day.
1892.	of spots.	of days without spots.	of spots.	of faculæ.	
April	24.67	0.00	70.81	51.19	5.57
May	24.27	0.00	119.47	62.50	5.74
June	25.0	0.00	111.20	106.83	6.20

We thus find an augmentation in the phenomena of Sun-spots, and also in the faculæ.

---

[*] Communicated by the author.

For the prominences we have obtained the following results:

1892.	No. of days of observation.	Prominences		
		Mean Number.	Mean Height.	Mean Extent.
			″	°
April	19	7.84	38.7	2.0
May	27	7.70	38.2	1.9
June	30	10.63	37.5	1.7

The prominences have been more numerous than in the preceding quarter, and this agrees with the spots, for the secondary maximum occurred also in the same month of June. We have thus entered upon the truly maximum period of the solar activity.

R. Osservatorio del Collegio Romano,
Rome, 15 July, 1892.

DISTRIBUTION IN LATITUDE OF SOLAR PHENOMENA OBSERVED DURING THE SECOND QUARTER OF 1892.*

P. TACCHINI.

The following results were determined for each zone of 10°, in both hemispheres of the Sun:

1892.	Prominences.		Faculae.		Spots.		Eruptions	
90° + 80°	0.000	0.471						
80 + 70	0.013							
70 + 60	0.106							
60 + 50	0.065							
50 + 40	0.053		0.004	0.473				
40 + 30	0.073		0.033		0.011	0.512		
30 + 20	0.084		0.111		0.085			
20 + 10	0.039		0.202		0.308		0.667	0.667
10 . 0	0.038		0.123		0.106		0.000	
0 − 10	0.033	0.529	0.074	0.527	0.000	0.490	0.000	0.333
− 10 − 20	0.062		0.156		0.234		0.111	
− 20 − 30	0.085		0.206		0.202		0.111	
− 30 − 40	0.106		0.091		0.054		0.111	
− 40 − 50	0.091		0.000					
− 50 − 60	0.115							
− 60 − 70	0.037							
− 70 − 80	0.000							
− 80 − 90	0.000							

The prominences and faculæ have been a little more frequent in the southern hemisphere, while the spots and eruptions show a maximum in the same zone (+ 10° + 20°) north of the equator. The maximum for prominences occurs farther from the equator than was the case during the preceding quarter, but prominences

---

* Communicated by the author.

are still lacking in the vicinity of the poles. In examining Professor Hale's beautiful photographs of faculae on the solar disc I foresee that he will arrive at the same conclusion that has resulted from my own observations, *i. e.*, that the phenomena which are in closest accord with the prominences are the faculæ, while spots and eruptions are always confined to low latitudes.

R. OSSERVATORIO DEL COLLEGIO ROMANO,
Rome, 27 August, 1892.

NEW RESULTS ON HYDROGEN, OBTAINED BY SPECTROSCOPIC STUDY OF THE SUN.—COMPARISON WITH THE NEW STAR IN AURIGA.[*]

H. DESLANDRES.

The complete spectrum of hydrogen was observed for the first time in white stars by Dr. Huggins, who succeeded in adding ten new ultra-violet lines to the four lines previously known in the visible region. This result was afterwards confirmed by Lockyer, Vogel and Cornu, who found in laboratory experiments on incandescent hydrogen successively one, four and nine of these new lines.

A short time later M. Balmer pointed out a simple function of successive whole numbers which exactly represents this series of fourteen lines, which is comparable to a series of harmonic tones. This remarkable function, which also applies to the greater part of the metals, is the following:

$$N = A - \frac{B}{n^2};$$

N being the number of vibrations, A and B two constants, and n a whole number varying between 3 and 16.

The series of harmonics of hydrogen, which in the state of dark lines characterizes the white stars, can with difficulty be obtained only as a faint and incomplete series in the laboratory. But I have recently obtained it in the Sun, brilliant, very intense, unbroken, and with five additional new lines, under such conditions as allow the precise measure of the vibration numbers.

These upper harmonics of hydrogen do not show themselves, as is well known, in the disc of the Sun, which is a yellow star, but they appear distinctly in the most brilliant parts of its atmosphere, as I have already pointed out (see *Comptes rendus*, Aug. 1891, Feb. and March, 1892). On the fourth of May last I pho-

---

[*] Comptes rendus (Paris), 25 July, 1892.

tographed* the region of the spectrum between λ 400 and λ 360 of a remarkably brilliant prominence, which was characterized by the richest and most complete radiation so far observed in this region. In fact, the negative which I have the honor to present to the Academy, exhibits, in addition to a large number of metallic lines enumerated at the bottom of the page,† the ten ultra-violet hydrogen lines of Dr. Huggins, and five new lines in addition, which follow the preceding ones with such regularity that one is led to assign these also to hydrogen. Moreover these bright lines are projected on the spectrum of the diffuse light of the sky, or of the Sun, which is at present more exactly known than any other spectrum. I have thus been able to measure with precision their vibration numbers as referred to Professor Rowland's fundamental lines. The table below allows a comparison of the vibration numbers thus measured by me, the vibration numbers obtained in the laboratory by Mr. Ames, and the numbers calculated by Balmer's formula with the constant determined by Ames on the visible lines:‡

$$N = 274.1831 - \left(\frac{4}{n^2}\right).$$

	Whole Numbers in the formula. *n*	Huggins' notation.	Vibration numbers obtained by me.	Vibration numbers obtained by Ames.	Vibration numbers calculated.
Observed in the Stars	12	Hε	266.565	266 575	266.566
	13	Hζ	267.685	267.715	267.694
	14	Hη	268.585	268.615	268.586
	15	Hθ	269.310	269.330	269.309
	16	Hι	269.890		269.898
Observed in the Sun.	17		270.385		270 387
	18		270.795		270.797
	19		271.140		271.142
	20		271.460		271.448
	21		271.700		271.694

It is seen, on the one hand, that, for the lines already known, the difference between the observed and calculated values is less for our measures than for those of Mr. Ames, our measures having been made under more favorable conditions; and on the other hand, that the new lines correspond exactly with the five succeeding terms of Balmer's formula. Consequently these lines

---

* This photograph was obtained with the aid of my assistant, M. Mittau.

† The principal lines (not corrected for refraction) are: λ 396.66, λ 394.41 of aluminium; λ 383.84, λ 383.25, λ 382.95 of magnesium, which are reversed; λ 385 65, λ 382.05, λ 381.60, λ 374.84, λ 374.58, λ 373.73, λ 372.01, λ 370.59 of iron; and also the lines λ 392.81, λ 392.30, λ 390.56, λ 388.64, λ 382.80, λ 382.60, λ 382.46, λ 381.98, λ 376.14, λ 375.93, λ 368.35, λ 368.52 which have not yet been assigned to any known element.

‡ These vibration numbers are corrected for atmospheric refraction.

belong to hydrogen, and we see it once more verified that this very remarkable formula represents the hydrogen vibrations better as the observations gain in extent and precision.

Our theoretical knowledge of hydrogen, which has been increased by the study of the stars, is thus completed by the study of the Sun, which is, it is true, the most intense source of light we can employ.

COMPARISON WITH THE TEMPORARY STAR IN AURIGA.

But this exceptional prominence is still of further interest on account of the comparison it allows with the temporary star in Auriga. In fact, the spectrum of this star, in the region included by the photograph, is identical in composition with that of the prominence; and this result strongly supports the explanation given by Dr. Huggins, who attributes the temporary brilliancy of the star to enormous prominences produced by the approach of two neighboring bodies.

The spectrum of the star is formed of lines grouped in pairs, a bright line being accompanied by a dark line, both bright and dark lines showing reversals, with a constant displacement of the reversed lines. Now the bright lines of calcium at the base of the prominence are also reversed. Moreover, when the prominences, instead of being on the limb, are projected on the disc of the Sun, appearing then among the faculæ, the dark lines of calcium always show a very distinct double reversal*, similar to that of the new star.

But the similarity is still more striking when we examine, no longer a particular point on the Sun, but the whole of the Sun, as in the case of the stars, by allowing light from all points to pass into the apparatus simultaneously; the double reversal of the faculæ is still present,—†although less intense—if the Sun is rich in faculæ; it is proportional to their brilliancy and extent. Moreover, when the faculæ, which are considered as grouped in the same region, are approaching or receding from the Earth on account of the solar rotation, the reversed lines are displaced with reference to the whole spectrum. Thus, and this fact is worth pointing out, the Sun sometimes exhibits one of the most singular phenomena of the new star.

These bright lines of reversal represent the whole of the elevated incandescent gaseous masses of the atmosphere, and their

---

* I was the first to point out this property of the faculæ, which Mr. Hale has confirmed in parallel investigations.

† It may be masked by prominences on the limb, when they are very brilliant. It may be obtained when the Sun is invisible, with the light of the clouds.

displacements with reference to the other lines are due to the rotation of the star. As they are found in the Sun it is natural to look for them in the stars; and certainly, with the large telescopes at present employed, the brightest stars can be analyzed almost as well as the Sun. The study of these reversals will furnish valuable data on the nature and rotation of the atmospheres of stars, and will permit problems to be attacked, which have up to the present seemed quite beyond our reach.

OBSERVATOIRE DE PARIS.

RECENT OBSERVATIONS OF NOVA AURIGÆ.[*]

W. W. CAMPBELL.

The new star in Auriga was clearly seen with the 36-inch telescope on April 24, when it was of the sixteenth magnitude or fainter. It was occasionally glimpsed late in the evening of April 26, when its altitude was small. Further observations were prevented by a three weeks' storm, at the close of which the star was too low in the west to be observed. The rapid decline in brightness made it probable that it would soon disappear from sight. But it was again observed by Professors Holden and Schaeberle and myself on August 17, when its magnitude was estimated at 10.5. All the observers agreed that its appearance was different from that of other stars of the same magnitude, in that its disk was larger and its light duller. However, the moon was only a few degrees east of the star and the bright sky interfered with further observations on that point. A direct vision spectroscope of very small dispersion showed its spectrum to consist of three bright lines and a faint continuous spectrum. The instrument did not permit of measures being made to determine the wave-lengths, and the telescope was not available again for spectroscopy for several days.

On August 19 (15 hours), with a more powerful spectroscope attached to the 12-inch telescope, the brightest line previously observed was resolved into three lines. These were at once recognized to be the three characteristic nebular lines, and thus the nebulous character of the object was established. By bringing the lines into contact with a bar in the focus of the eyepiece and turning to β Tauri and Venus the wave-lengths were estimated to be 501, 496 and 486. The faint continuous spectrum

---

[*] Communicated by the author.

was just visible. The magnitude of Nova was noted as midway between that of Pickering's comparison star *s* and the $9^m.5$ star DM. + 30°.920: that is, about $9^m.9$. Mr. Townley estimated it at $0^m.2$ brighter. No appreciable change in brightness has yet been observed.

The same morning Professor Barnard, using the 36-inch telescope, observed the Nova as a nebula 3″ in diameter, with a tenth magnitude star in its centre.

Further study of the spectrum with the large spectroscope has shown eleven bright lines and a continuous spectrum corresponding to a star of the eleventh magnitude or fainter. The positions of nine of these lines have been quite accurately determined; one at λ 5268 was measured only once; and another estimated at λ 557 could not be measured with the large spectroscope, though it was twice clearly seen with a small spectroscope using weak dispersion. Two others in the green and a line near C were suspected on different occasions, but they could not be located surely. The continuous spectrum presents the appearance of containing a large number of bright lines, just beyond the power of the telescope to define.

Below is a table of the wave-lengths of the lines. They are reduced to the Sun. The difficulty with which the several lines were measured permitted the relative intensities to be estimated very accurately. The lines at λ 4466 and λ 4336 are not visible to me, and their intensities were estimated from the photograph by comparison with the line λ 4360. The unmarked wave-lengths were obtained with the dense 60° flint prism and the 10½-inch observing telescope, using a magnifying power of 13.3. In obtaining those marked with an asterisk (*) the prism was replaced by a second order grating of 14,438 lines to the inch. In obtaining those marked thus (†) a first order grating was used. The one marked thus (‡) was obtained with a thallium compound prism. Those marked thus (§) were obtained photographically, using the 60° prism and replacing the micrometer by a camera.

[illegible]

the H[illegible]

[illegible] night [illegible] 52 [illegible]

[illegible] the [illegible]

[illegible] know[illegible]

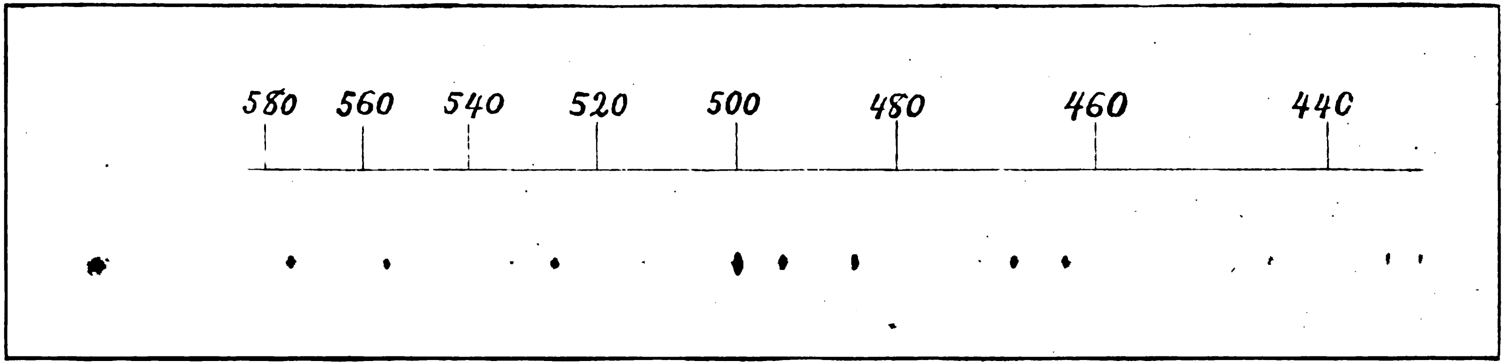
the pos[illegible] 57[illegible]

1634 is [illegible] in s[illegible]

examin[illegible] of [illegible]

[illegible] there [illegible]

PLATE XXXVII.

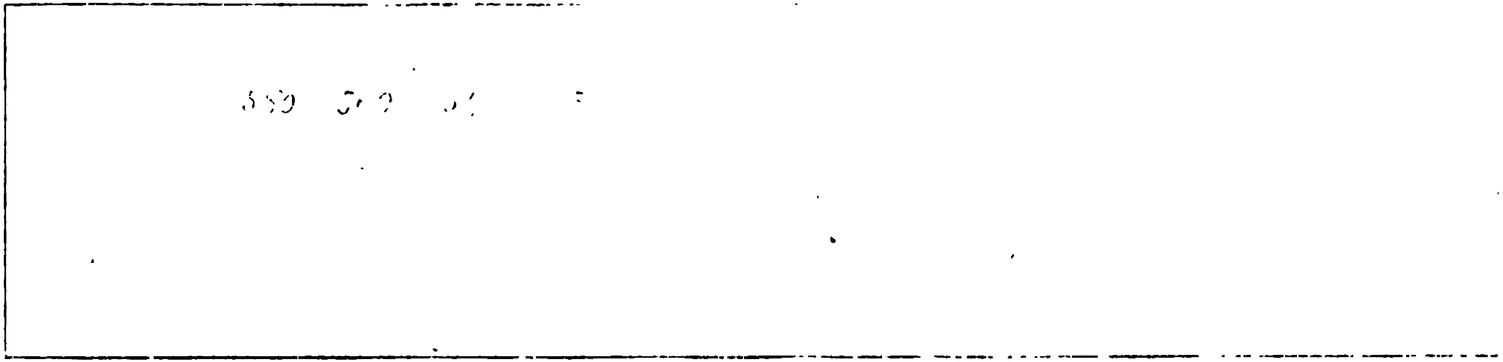


Spectrum of Nova Aurigæ.

[illegible] line [illegible] ment of the [illegible] to that of the [illegible] doubtedly correspond [illegible] 2 [illegible] and shows the [illegible] corresponds to the line λ [illegible] of the [illegible] erly displaced [illegible] positions in the [illegible] 7[illegible]2 were measured [illegible] and [illegible] respectively. [illegible] λ 5[illegible] and [illegible] λ 727 and λ 5[illegible] seen in the Orion [illegible] planetary nebulæ. So far as I know [illegible] been observed in the positions λ 57[illegible] though the line λ 463·4 is present in [illegible] Possibly a careful examination of [illegible] reveal some or all of them. There is [illegible] the [illegible] region.

---

* Professor Keeler's [illegible]



Spectrum of Nova Aurigae.

Astronomy and Astro-Physics, No. 108.

Intensity.	Aug. 20	Aug 21	Aug. 22	Aug. 23	Aug. 30	Sept. 3	Sept. 4	Sept. 6	Sept. 7
1	5746	5751	5750	5752	......	......	......	......	......
0.2	......	......	......	......	[557]	......	......	......	......
0.3	......	5268	......	......	......	......	......	......	......
10	5003.6	5003.7	5003.7	*5003.1	5002.9	5002.4	†5001.97	§5001.9	†5001.83
......	......	......	......	......	‡5002.3	......	*5001.80	§5002.4	*5002.00
......	......	......	......	......	*5002.24	......	§5001.9	......	§5002
3	4954	4953	4954	......	......	......	§4953.3	§4953.3	§4953
......	......	......	......	......	......	......	......	§4952.1	......
1	4856	4858.4	4858.3	......	4857.3	4856.8	§4856.7	§4856.7	......
0.4	4677	4684	4685	......	......	......	......	§4678	4680
......	......	......	......	......	......	......	......	......	§4685
0.7	4628	4633	4631	......	......	......	......	......	4628
......	......	......	......	......	......	......	......	......	§4634
0.1	......	......	......	......	......	......	......	......	§4466
0.8	436	4357.1	4358.9	4358.0	......	4358.9	......	......	§4360
0.1	......	......	......	....	......	......	......	......	§4335.9

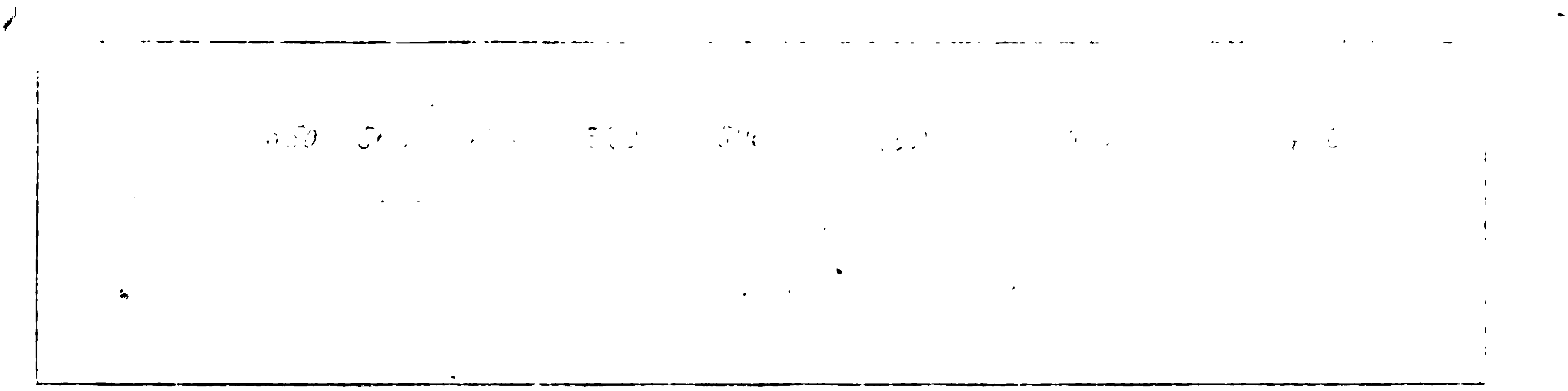
[In the photograph of Sept. 7, the lines between λ 5002 and λ 4466 are slightly out of focus, and the results are of small weight.]

The spectrum resembles that of the planetary nebulæ. The lines at λ 5002, λ 4953 and λ 4857 are undoubtedly the three nebular lines, displaced toward the violet about five tenth-metres.* The nebula is therefore approaching us with a velocity of at least 175 miles per second. The presence of a prominent line at λ 4358 and the fact that no line is visible in the position of Hγ led me to infer that the Hγ line is absent. But a photograph of the Hγ region obtained this morning with a two hours' exposure shows not only the very bright line λ 4360 but also the bright Hγ line at λ 4335.9 and a trace of a line at λ 4466. The displacement of the Hγ line is thus shown to be similar and equal to that of the three nebular lines. The line λ 4466 undoubtedly corresponds to the line λ 4471 in the planetary nebula Σ 6, and shows the proper displacement. The line λ 4681 corresponds to the line λ 4685 in some of the planetary nebulæ and is properly displaced. Its positions in the spectra of N. G. C. 7027 and 7662 were measured last night and found to be λ 4685 and λ 4684 respectively. The lines λ 5268 and λ [557] are possibly the lines λ 527 and λ 554 seen in the Orion Nebula and some of the planetary nebulæ. So far as I know nebular lines have never been observed in the positions λ 5755, λ 4635 and λ 4364, though the line λ 463-4 is present in some of the bright line stars. Possibly a careful examination of the planetary nebulæ would reveal some or all of them. There is no visible trace of a line in the D_3 region.

---

* Professor Keeler's adopted wave-length of the first nebular line is 5007.05.

PLATE XXXVII



Spectrum of Nova Aurigæ.

ASTRONOMY AND ASTRO-PHYSICS, No. 105.

Intensity	Aug. 20	Aug. 21	Aug. 22	Aug. 23	[illegible]	[illegible]	[illegible]	Sept. 6	Sept. 7
[illegible]	[illegible]	[illegible]	5750	5753	[557]	5002.4	5001.97	5001.9	5001.33
[illegible]	[illegible]	[illegible]	5003.7	5003.1	5002.9	[illegible]	5001.80	5002.4	5002.00
[illegible]	[illegible]	[illegible]	[illegible]	4358.0	5003.3	[illegible]	5001.9	4953.3	5003
[illegible]	[illegible]	[illegible]	[illegible]		5002.24	4358.9	4953.3	4953.1	4953.3
[illegible]	[illegible]	4357.1	4358.9		4857.3		4856.7	4856.7	[illegible]

[In the photograph of Sept. 7, the lines between λ 5002 and λ 4466 are slightly out of focus, and the results are of small weight.]

The spectrum resembles that of the planetary nebulæ. The lines at λ 5002, λ 4953 and λ 4857 are undoubtedly the three nebular lines, displaced toward the violet about five tenth-metres.* The nebula is therefore approaching us with a velocity of at least 175 miles per second. The presence of a prominent line at λ 4358 and the fact that no line is visible in the position of Hγ led me to infer that the Hγ line is absent. But a photograph of the Hγ region obtained this morning with a two hours' exposure shows not only the very bright line λ 4360 but also the bright Hγ line at λ 4335.9 and a trace of a line at λ 4466. The displacement of the Hγ line is thus shown to be similar and equal to that of the three nebular lines. The line λ 4466 undoubtedly corresponds to the line λ 4471 in the planetary nebulæ and Σ 6, and shows the proper displacement. The line λ 4681 corresponds to the line λ 4685 in some of the planetary nebulæ and is properly displaced. Its positions in the spectra of N. G. C. 7027 and 7662 were measured last night and found to be λ 4685 and λ 4684 respectively. The lines λ 5268 and λ [557] are possibly the lines λ 527 and λ 554 seen in the Orion Nebula and some of the planetary nebulæ. So far as I know nebular lines have never been observed in the positions λ 5755, λ 4635 and λ 4364, though the line λ 4634 is present in some of the bright line stars. Possibly a careful examination of the planetary nebulæ would reveal some or all of them. There is no visible trace of a line in the D_3 region.

---

* Professor Keeler's adopted wave-length of the first nebular line is 5007.05.

The line λ 5002 has been more refrangible than the lead line λ 5005.63 on every night. But on Aug. 30 the distance between them seemed greater than usual. To confirm this point the difference of wave-length was measured successively with the 60° prism, the compound prism and the second order grating. The displacement of the line λ 4858, which had just previously been measured, shows a similar and equal variation. If the variation is real and progressive, the later measures do not confirm it as strongly as could be wished. But the perfectly independent measures on the two lines most carefully compared leave little doubt that some change has occurred. The difficulties in the way of deciding the question arise not from the faintness of the lines, but from their great breadth. They are more diffuse than those of any of the planetary nebulæ which I have observed. With the grating the line λ 5002 is at least eight tenth-metres broad, with diffuse edges, and a brighter central region about four tenth-metres broad. On Aug. 30 the line was suspected to be double, and the grating measures of that night refer to a point midway between the two condensations. On Sept. 7 the measures refer to a point of maximum brightness slightly less refrangible than the centre of the line. The other lines are too faint to be observed with the grating and narrow slit.

In order to test the adjustments of the spectroscope, the positions of the lines in the planetary nebula Σ 6 were measured on several nights, using the 60° prism. The three nebular lines and the Hγ line occupied their normal positions, within the errors of observation. On Aug. 23 the position of the first nebular line in Σ 6 was measured with the second order grating and found to be λ 5006.93 (corresponding to a velocity of approach of 4.5 miles per second). The mean of Professor Keeler's observations on thirteen nights is λ 5006.89 (corresponding to a velocity of approach of 6.0 ± 1.2 miles). Turning to Nova without changing any of the adjustments the wave-length of the corresponding line was measured and found to be 5003.1 Similarly, on Sept. 4, the position of the first nebular line in nebula N. G. C. 7027 was found to be 5007.18 (corresponding to a velocity of recession of 4.8 miles per second). From four nights' observations Professor Keeler obtained a velocity of recession of 6.3 ± 1.2 miles. Turning to Nova, the wave-length of the first nebular line was found to be 5001.9.

The relation of this spectrum to the early one of February and March is not apparent. The lines λ 4858 and λ 4336 coincide almost exactly with the sharp edges of the original bright F and

Hγ lines. If we also except the line λ 4630, then the remaining lines fall upon comparatively thin (dark) regions of the original spectrum. All of the lines now present, however, could have been present in the early spectrum when it was observed here and have escaped detection. The brighter continuous spectrum would mask them effectually in visual observations and also in the photographic, even if the exposures had been long enough to record them. The line λ 4630 falls upon a broad bright line of the original spectrum.

Visual observations on three nights in February and traces of a line on two photographs fix the position of a faint line at λ 4969. At first there seemed very little reason for suspecting it to be the second nebular line. But after reducing the photographic observations, and considering it in connection with a faint line at λ 5885 (D_3?) observed March 13, with all or a portion of the very bright line λ 5016, and with the less refrangible components of F and Hγ shown on the photographs at λ 4871 and λ 4348, there was seen to be a possibility that these were nebular lines, displaced about ten tenth-metres toward the red. It is important to note that in the original spectrum there were also prominent lines at λ 5577, λ 5281, λ 4481, and later at λ 5761: and the *only* prominent lines in those regions. The *relative* positions of these lines agree remarkably well with those of the present lines (excepting the lines λ 4630 and λ 4360). But the two sets of lines could be related to each other only by an enormous change in the velocity of the light source (about 500 miles per second). On the hypothesis of two bodies and a period of several months, this would be possible only with a very excentric orbit, the major axis and periastron probably directed towards the solar system, and the proper relation existing between the masses of the two bodies. The evidences of increasing velocity of approach in the recent measures support the hypothesis. But the evidence of fairly *constant* velocity during February and March is opposed to it. If the hypothesis is tenable future observations will show increased velocities. If further observations show no increase of velocity the hypothesis is probably untenable. As stated above, it apparently does not explain the presence of the lines λ 4630 and λ 4360.

Mr. S. D. Townley, Fellow in Astronomy, kindly assisted in making and reducing the observations.

MT. HAMILTON, 1892, Sept. 8.

OBSERVATIONS ON THE THERMAL ABSORPTION IN THE SOLAR ATMOSPHERE, MADE AT POTSDAM.*

EDWIN B. FROST.

I. OBSERVATIONS ON THE PHOTOSPHERE.

The absorptive properties of the solar atmosphere have received the attention of several observers since Bouguer's original attempt to measure the different intensity of the light at different distances from the center of the Sun's disk. The absorption of the "photographic" rays of short wave-length was carefully investigated by Vogel in 1872 (Berichte der K. Sächs. Ges. d. Wiss. 1872 Juli).

Secchi, Liais and Pickering made extended series of photometric observations in the years 1852-74 on the diminution of intensity for the rays of medium wave-length from the center toward the edge of the disk, but the most complete investigation was made by Vogel† in 1876 with the use of his modification of the Glan spectral-photometer, whereby exact values of the absorption were obtained for six different portions of the Spectrum between $\lambda = 405$ and 658 $\mu\mu$.

By means of the thermopile the absorption for the heat rays has been studied by Secchi, Langley, Cruls and others. The results are subject to very considerable discordances. As Professor Vogel has not been able to carry out his plan of undertaking this investigation, he suggested that I should begin it and this paper may in a sense be regarded as a continuation of his spectral-photometric determination extended to the rays of greater wave-length.

Owing to the very numerous and unavoidable sources of error in such observations, due chiefly to our atmosphere, it seemed to be decidedly advantageous not to employ too delicate apparatus, and therefore, instead of using Langley's bolometer or Boy's radiomicrometer,—instruments whose extraordinary delicacy made it probable that these extraneous sources of error might largely mask the sought-for effect—I resolved also to employ the thermopile.

---

* From *Astronomische Nachrichten*, 3105-3106, with corrections and additions by the author.

† Spectralphotometrische Untersuchungen (Monatsberichte der Kgl. Acad. der Wissenschaften zu Berlin, März 1877). A valuable re-reduction and discussion of these observations is given by Professor Seeliger in his paper "Ueber die Extinction des Lichtes in der Atmosphäre" (Sitzungsberichte der math.-phys. Classe der Kgl. bayer. Acad. der Wiss. 1891 Bd. XXI, Heft III).

As, however, most of the thermopiles to be had of manufacturers are extremely short and do not allow of certainty that the back junctions do not receive heat by conduction from the exposed surface and do not permit that the back junctions may be kept at a constant temperature, I decided to construct the apparatus myself, a task which the admirable resources of this Observatory greatly lightened.

The original plan of observation was quite analogous to that with the spectral-photometer.

Twin thermopiles of considerable length with their back junctions at the same temperature were to be joined in circuit against each other and to be simultaneously exposed, the one directly to the Sun's rays, while the other, placed in the optical axis of the telescope, received the radiation from any given portion of the real projected solar image. Although this plan of observation had to be subsequently modified yet the construction of the apparatus was not altered.

A long time was spent in the attempt to make thermopiles oı antimony and bismuth which should have a length of not less than 20 cm. and a sufficiently small diameter. The brittleness of these metals made it, however, practically impossible to fulfil these requirements and I was finally obliged to adopt iron and German silver for the purpose. These metals were procured in the form of wires of 0.3 mm. diameter with silk insulation; these were cut off in lengths of 25 cm., and two piles of 6 pairs each, as exactly similar as possible, were constructed and the exposed surfaces were brought into a plane occupying a space of about 4 sq. mm. A brass tube of 9 mm. diameter and 49 cm. length was then passed lengthwise through a tin cylinder of 9 cm. diameter and 16 cm. length, and the two ends were bent up at right angles so that the tube had a U shape. The back junctions of the two thermopiles, after having been carefully insulated and imbedded in sealing wax, were inserted into the two ends of the brass tube, the proportions being such that the front faces of the piles projected just out of the tube while the back junctions were in contact at the middle of the tube. The cylinder being now filled with water, (one liter), one could be assured that the two back junctions were at the same temperature, that no appreciable amount of heat could be transferred by conduction from the exposed faces, and that accidental thermo-effects in the metals of the thermopiles were practically impossible.

The upper ends of the brass tube pass into small wooden caps which are so hollowed out that the exposed faces lie at their center, and over these were slipped pieces of polished brass tube 2 cm. long and 1 cm. diameter, blackened on the inside, and carrying on their upper ends cardboard diaphragms with an aperture of 5 mm. Other diaphragms of smaller aperture were inserted midway between these and the thermopile surfaces during some of the observations.

The whole of the apparatus up to the last mentioned brass caps was now protected against external radiation by being enclosed in a sort of cardboard box covered with tinfoil and then attached to a metal frame, constructed for a similar purpose previously, which was firmly clamped to the Grubb refractor of 20cm. aperture. This frame carried a pasteboard screen of 30cm. diameter, through the center of which the inner thermopile projected, and upon which were ruled off rectangular co-ordinates so that the distance of the point of the Sun's surface under examination from the center of the disk could be at a glance read off on the four radii. These were oriented to the apparent parallel to the daily motion except where it is noted that they were set for the Sun's true poles and equator.

The first method of procedure,—that of throwing different portions of the projected image upon the inner thermopile, while the outer (lying in the same plane but at a distance of 25 cm.) was simultaneously exposed to the direct rays,—had to be given up after a series of experiments because of the disproportionately greater intensity of the latter. By placing a thin silk gauze in the path of the direct rays and at a distance of several feet from the thermopile it was possible to secure the desired equality of intensity, as well as by inserting a shunt in the circuit against the outer pile, but both of the methods involved new and uncertain sources of error, and accordingly the plan of observation was modified, the inner pile being alone exposed. The outer pile was hereafter kept uniformly shaded from direct solar radiation, but served the important purpose of balancing all extraneous disturbing effects, such as air currents, reflected radiations, change of temperature of the water, etc.

It may be here remarked that the apparatus was as a rule brought to the dome a considerable time before the commencement of the observations in order that it might obtain the temperature of the air by the telescope. The exposure was made by rotating a shutter which was placed so far away from the thermopiles as to have no radiating effect itself; the objective was moreover kept closed as much as possible, being regulated by a convenient arrangement at the eye end. After some experiments it was found that 30^s was the most advantageous time of exposure and it was uniformly so given, a clock in the dome with a loud tick furnishing the time. All the connecting wires at the telescope were well insulated and further enclosed in rubber tubing, which in turn was shielded from direct radiation by being covered with tinfoil. Exposed connections were protected by cotton batten.

The galvanometer, Siemens & Halske No. 1256, was of the astatic, dead beat type, and the deflection was observed by telescope and scale at a distance of generally 3 meters. The four coils were coupled in series. During the first of the observations, until Oct. 2, the galvanometer was set up on a bracket in the wall of the passage to the west dome, at a distance of about 5 meters from the telescope. It was soon found that the large amount of iron in the neighborhood exerted a very disturbing effect on the magnets, the zero point being constantly changed when the dome was moved, and it therefore became necessary to transfer the galvanometer to the physical laboratory, where a solid pillar gave a more steady support and where the neighboring iron masses were constant. This made a very long circuit unavoidable, but it was fortunately so situated as to be little exposed to changes of temperature.

The procedure of observation was this: First the assistant at the galvanometer gave the signal that the needle had come to rest, then a signal for attention would be returned, and 3^s before the exposure a second signal to make the reading was given, and then the shutter was opened with the clock beat. The galvanometer gave a steady throw during the 30^s and could be very exactly read off; it would have been possible to estimate the tenths of a mm. but it seemed best to only read the whole mm.

With a dead beat galvanometer of this sort the "first throw" cannot be accurately observed and so that method was not used.

It was always an important point that the needle should come to rest before making another exposure; very naturally it would not as a rule come quite back to the original zero-point and there was therefore a tendency for the zero-point to rise; in the small limits within which this occurred it could not be considered as introducing an error. With the distance of scale from mirror which was employed the heat was of course to be considered as directly proportional to the deflection.

The correction for torsion of the suspension thread was determined by turning the needle once around by means of a magnet and then observing the deflection from its normal position. The torsion's factor varied according to circumstances from $\frac{1}{40}$ to $\frac{1}{100}$; the instrument being altered during the winter by increasing the length of the suspension. The data of the electrical circuit are: Resistance of the thermopiles each 8, of the galvanometer 10 ohms; of the rest of the circuit at first one ohm, and subsequently 7 ohms, making the totals in the two cases 27 and 33 ohms, certainly not the most advantageous combination, but under the circumstances necessary. The sensitiveness of the galvanometer was such that a deflection of one division of the scale was produced by a current of approximately 0.00000001 ampere (one hundredth of one millionth).

The detailed observations follow. They were made between 11 and 1 o'clock and only under the best atmospheric conditions, though they were occasionally interrupted by haziness or clouds. The low altitude of the Sun made observations impossible during the winter months.

The interval between successive exposures, determined by the time required for the needle to come fully to rest after a deflection, was usually about five minutes. The galvanometer readings were very carefully made by the clerk of the Observatory, Herrn Kettler. The quality of the exposure was always recorded at the telescope, and no observations have been here included by which inaccuracy as to the duration, position on the surface or atmospheric conditions were noted.

The first column contains the distance ρ, and direction (*N*, *E*, *S*, *W*, oriented to the parallel of declination), of the point observed from the center of the disk, the radius being taken as 100, and *M* denoting the center. The second and third columns give the corrected deflection in units of the scale and the ratio of this deflection (and consequently of the intensity) to that adopted for the center and designated by M_0 in the column of remarks; M_0 is the mean of the successive values for *M*, unless the notes ascribed less weight to one of the values. The difference in the absolute values on different days is due to the different diameters of the image employed and to the varying ratio of the temperature of the air (and water) to that of the Sun.

ρ	Defl.	$I : I_0$	Remarks.
			1891, Sept. 12
M	168		$M_0 = 168$
97 W	80	47.6	
50 W	149	88.7	
60 W	148	88.1	
74 W	142	84.5	
71 N	151	89.9	
87 N	128	76.2	
M	168		

ρ	Defl.	$I:I_0$	Remarks.
			Sept. 14 (I)
M	166		$M_0 = 165$
M	167		
74 W	140	84.8	
97 W	85	51.5	
87 W	117	70.9	
94 W	106	64.2	
50 W	160	97.0	
M	163		

ρ	Defl.	$I:I_0$	Remarks.
			Sept. 14 (II)
M	173		$M_0 = 173$
94 W	110	63.6	
97 W	87	50.3	
87 W	128	74.0	
M	172		
25 W	171	97.7	$M_0 = 175$
50 W	164	93.7	
74 W	139	79.4	
87 W	132	75.4	
94 W	112	64.0	
97 W	98	56.0	
M	178		
			Sept. 23
M	149		
94 W	98	66.2	$M_0 = 148$
94 S	92	62.6	
94 N	100	67.6	
M	147		
			Sept. 24
92 N	139	65.3	$M_0 = 213$
M	205		
92 E	149	70.0	
92 W	142	66.7	
92 S	135	63.4	
M	220		
			Sept. 25.
66 W	127	57.2	$M_0 = 222$
69 E	126	56.8	
96 S	126	56.8	
96 N	130	58.6	
M	224		
96 S	155	55.4	$M_0 = 280$
96 N	168	60.0	(Occasional Clouds)
M	290		
96 W	176	62.9	
96 E	162	57.9	
M	270		
			Sept. 30
87 W	111	79.3	$M_0 = 840$
87 W	106	75.7	
M	142		
94 S	87	62.1	
" N	88	62.9	
" E	88	62.9	
" W	87	62.1	
M	135		Slight haze
M	134		
			Oct. 1
M	110		
97 W	60	54.1	$M_0 = 111$
97 E	58	52.3	
96 S	63	56.8	
M	111		
97 N	62	55.9	
25 W	111	100.0	
25 E	107	96.4	
50 E	105	94.6	
87 E	81	73.0	
M	112		
87 W	78	70.3	

ρ	Defl.	$I:I_0$	Remarks.
			Oct. 2
94 W	50	67.6	$M_0 = 74$
71 W	66	89.2	
60 W	68	91.9	
40 W	80	100.4	
97 W	43	54.0	$M_0 = 79.7$
M	81		
40 W	79	99.1	
97 W	43	53.9	
" N	46	57.7	
" S	43	53.9	
" E	44	55.2	
M	80		
M	78		
			Oct. 5
M	154		
76 N	131	86.8	$M_0 = 151$
" S	130	86.1	
" W	127	84.1	To-day oriented to the Sun's Pole.
" E	128	84.8	
M	147		
M	164		
96 N	88	56.4	$M_0 = 156$
" E	85	54.5	
" S	85	54.5	
" W	86	55.1	
M	154		
M	150		
			1892.
			March 30
M	117		
40 W	112	96.6	$M_0 = 116$
40 W	107	92.3	
76 W	86	74.1	
76 W	90	77.6	
M	115		
50 W	99	91.7	$M_0 = 108$
50 W	101	93.5	
76 W	82	75.9	
M	102		
			March 31
M	125		
50 W	114	91.2	$M_0 = 125$
75 W	99	79.2	
75 E	98	78.4	
			Clouds
50 E	107	90.7	$M_0 = 118$
94 E	72	61.0	
95 E	95	80.5	
M	118		
			April 5
50 W	121	94.5	$M_0 = 128$
M	129		
50 E	121	94.5	
75 E	103	80.5	
97 E	71	55.5	
M	127		
97 W	63	51.6	$M_0 = 122$
M	122		
M	122		
97 W	63	51.6	

ρ	Defl.	$I:I_0$	Remarks.
			May 9
M	166		
50 E	148	89.2	$M_0 = 166$
87 W	109	65.7	
M	166		
87 E	118	71.1	
75 W	129	80.6	$M_0 = 160$
" E	136	85.0	
" N	136	85.0	
" S	134	83.8	
" S	128	80.0	
M	148		
M	139		
87 N	101	73.7	$M_0 = 137$
87 S	87	63.5	(Oriented to the Sun's Pole)
97 S	69	50.4	
96 N	77	56.2	
M	132		

ρ	Defl.	$I:I_0$	Remarks.
			May 9
87 N	91	69.0	$M_0 = 132$
" S	92	69.7	
" S	93	70.5	
" N	95	72.0	
M	132		
			May 12
M	141		
50 E	137	97.2	$M_0 = 141$
25 E	136	96.5	
25 N	130	98.5	$M_0 = 137$
50 N	126	95.5	
M	132		
25 S	134	100.2	$M_0 = 132$
50 S	124	93.9	
M	130	69.7	
87 S	92	73.5	
N	97		
87 N	97	73.5	To Sun's Pole
S	94	71.2	
S	89	67.4	
M	133		

The results of these observations are combined as follows:

ρ	97	96	94	92	87	76	75	74	71	60	50	40	25
No. of obs.	16	14	12	4	21	7	9	3	2	2	14	4	6
Mean $I:I_0$	53.2	57.1	63.9	66.4	71.7	81.3	81.4	82.9	89.5	90.0	93.3	97.1	98.8
Probable Error	± 0.44	0.40	0.42	—	0.53	1.35	0.55	—	—	—	0.47	—	0.43
P. E. of single obs.	± 1.8	1.5	1.5	—	2.4	3.6	1.7	—	—	—	1.8	—	1.1
Curve — Obs.	+1.7	+0.5	−2.1	−1.2	0	−0.4	+0.2	−0.6	−5.5	−0.2	+0.3	−0.8	+0.1

Through these values (given in the third line) a smooth curve has been drawn, abscissas representing the distance from the center of the disc (ρ) and ordinates expressing the amount of heat transmitted, that at the center being taken as 100. The last line, Curve minus Observation, shows how well the curve satisfies the observations.

From the curve I now take the following values, given in the column headed O.

ρ	θ	O	C	C−O
0	0°	100.0	100.0	0.0
10	5.7	99.9	99.8	− 0.1
20	11.5	99.4	99.3	− 0.1
30	17.5	98.4	98.4	0.0
40	23.6	96.3	97.1	+ 0.8
50	30.0	93.6	95.1	+ 1.5
60	36.9	89.8	92.2	+ 2.4
70	44.4	84.6	87.8	+ 3.2
80	53.1	77.9	80.6	+ 2.7
90	64.2	68.0	65.6	− 2.4
100	90.0	(39)	—	—

$$\nu = 0.1412 \qquad e^{-\tau} = I_0 = 0.72.$$

In comparing now the above results with the Theory of Absorption we proceed from the standpoint that the Sun, deprived of its atmosphere, would appear as a flat uniformly illuminated disc, as has been experimentally shown to be the case for glowing balls of metal. The formula which La Place gave in Méc. Célest. Book K, corrected to accord with this more modern view, becomes $I = e^{-f\sec\theta}$ where I represents the amount of light transmitted through the Sun's atmosphere, e the base of natural logarithms, f the coefficient of absorption, and θ the angle at the Sun's center between the line to the observer and the radius to the point observed, ρ being the sine of θ. At the center of the disc where $\theta = 0$ the intensity is $I_0 = e^{-f}$. The above measurements are therefore a determination of the ratio $\frac{I}{I_0} = \frac{e^{-f\sec\theta}}{e^{-f}}$; this formula may be more conveniently expressed in the form

$$\log\frac{I}{I_0} = -\nu\frac{1-\cos\theta}{\cos\theta}$$

where $\nu = f \times$ Mod.

Using this formula I have computed ν for each of the given values of ρ and have then determined the most probable value of ν by the method of least squares, and finally have substituted this value of ν in the formula, and thus calculated the values of $I : I_0$ given in the fourth column of the table under the heading C. The column C — O shows the comparison of the theory with the observations. The differences are similar to those in the spectral-photometric observations, especially for green rays, attaining a maximum for about $\rho = 70$; their amount is greater here, as was to be expected, owing to the numerous unavoidable sources of error in such heat measurements; yet the departure of the observed curve from that derived from the theory seems to be real, and would indicate the insufficiency of the formula to absolutely represent the observations.

This divergence could be doubtless much diminished by the introduction of another constant in the formula, as Professor Seeliger has done for the green, blue, dark blue and violet rays, but did not find necessary for the red and yellow rays. I have not been disposed to do so for the present measurements, since the amount of the differences C — O are really very small, and the coincidence thereby gained would be rather illusory. The physical interpretation of the additional constant is moreover somewhat uncertain.

I may say here that my attempts to find a certain amount of radiation from the absorbing layer itself have led to negative results.

A comparison of the above results with the spectral-photometric observations is now of interest:

$\lambda =$	662 $\mu\mu$	......	579	513	470	443	409	......
ρ	Red	Heat	Yellow	Green	Blue	Dark-blue	Violet	Photographic
10	99.9	99.9	99.8	99.7	99.7	99.7	99.6	99.6
20	99.5	99.4	99.2	98.7	98.8	98.7	98.5	98.4
30	98.9	98.4	98.2	96.9	97.2	96.8	96.3	96.7
40	98.0	96.3	96.7	94.3	94.7	94.1	93.4	93.7
50	96.7	93.6	94.5	90.7	91.3	90.2	88.7	89.7
60	94.8	89.8	90.9	86.2	87.0	84.9	82.4	83.3
70	91.0	84.6	84.5	80.0	80.8	77.8	74.4	73.7
80	84.3	77.9	74.6	70.9	71.7	67.0	63.7	59.6
90	71.0	68.0	59.0	56.6	57.6	50.2	47.7	39.3
*(100	30.0	39	25.0	16.0	16.0	14.0	13.0	13.5)

The heat curve thus lies, as might have been expected from the known position in the spectrum of the maximum of intensity for thermal rays, between those for red and yellow, only falling under the latter for the three middle values of ρ.

As the original publication of this extremely interesting research of Vogel's is inaccessible to many readers, a short account of the methods employed may not be out of place.

The form of spectral-photometer, as devised by Dr. Glan and modified by Dr. Vogel, consists of a compound spectroscope of the Bunsen type, with its slit divided into two halves by a small strip crossing it at the middle. Between the collimator lens and the prism are inserted first a doubly-refracting Wollaston prism and then a Nicol's prism which may be rotated on a graduated circle. The doubly-refracting prism furnishes four images of the slit, two of which are gotten rid of by the insertion of a movable diaphragm in the focus of the observing telescope. The two remaining images of the slit, *i. e.*, spectra lying in contact one above the other, are polarized at right angles to each other, and consequently by rotating the Nicol they may be quite accurately made of equal intensity, since the brightness of the one increases while that of the other decreases. The adjustable diaphragm enables narrow and equal portions of the spectra to be compared. If now the light of the object be thrown upon one half of the slit, while the other half is illuminated by a standard source of light, we shall be able to compare the intensities of the two sources in different portions of the spectrum. In this case Vogel used the direct light of the Sun, thrown on one-half of the slit by a mirror and reflecting prism, as a standard source.

The primary image of the Sun from the 9-in. Berlin refractor was now projected upon the half-slit, and different portions of the image were brought upon it by means of the slow motion in declination.

---

*The values for $\rho = 100$ are, of course, quite uncertain, having been obtained by extrapolation.

In this way a series of comparisons was made between the intensity for the different colors at the center of the disc and at different points along the radius, and finally the results were combined in a curve.

The absorption for the photographically active rays was studied by Dr. Vogel (1872) on negatives of the Sun, the "density" of which at different points was measured by comparison with certain photographically prepared scales.

A long and careful series of measurements with the thermopile was made by Professor Langley in 1873-4. The investigation does not appear unfortunately to have ever been published in full; it is referred to in his paper "The Solar Atmosphere, an introduction to an account of Researches made at the Allegheny Observatory" (Am. Jour. X 1875), and in Comptes rendus, T. 80 and 81 (1875); in the latter he gives the amounts of the transmitted heat for four points of the disk. They are as follows:

				P. E. of single obs.	
ρ	No. obs.	Intensity ($I : I_0$)	Langley—F.	Langley.	Frost.
50	72	95.0 ± 0.35	+ 1.4	± 3.0	± 1.8
75	98	85.9 ± 0.17	+ 4.3	1.7	1.7
96	33	61.9 ± 0.39	+ 4.2	2.2	1.5
98	124	50.1 ± 0.23	− 1.6	2.6	—

The discrepancies here are so much larger than the errors of observation indicated by the probable errors that they can be explained only by systematic errors on the part of one or both observers, or by an actual change in the transmission curve for the Sun. Considering the character of such observations, the former supposition seems the more probable, and the true values perhaps lie between these, although I am unable to account for any systematic errors in my observations which should tend to give too small results. Professor Vogel has given (Spect. phot. Untersuch.) a series of values taken from a curve which he constructed from Secchi's and a few of his own observations with the thermopile; he calls attention to their uncertainty. Cruls and Lacaille published in Comptes rendus, T. 88, 1879, the results of their thermopile measurements between Jan. 9 and 24, 1878.

They found the heat radiated from the Southern hemisphere of the Sun to be only three-fourths of that from the Northern.

		Cruls		
ρ	Vogel & Secchi	N	S	VS—F.
10	100	—	—	0
20	99	97.5	80.0	0
30	99	91.7	63 9	+ 1
40	98	88.8	60.7	+ 2
50	97	82.3	57.6	+ 3
60	94	77.4	55.1	+ 4
70	89	67.7	52.1	+ 4
80	82	64.2	47.6	+ 4
90	69	50.5	39.9	+ 1
100	(40)	—	—	

These observations at Rio Janeiro, of which the details are not published, are not reconcilable with those of the other observers.

It is an interesting point to see whether the observations indicate a difference in the thermal conditions for the poles and equator and for the Northern and Southern hemispheres. Secchi announced that the Northern radiated the more and that the regions above the 30th parallel on the Sun radiated 6 per cent less than at the equator; this amount however, lies inside the range of errors of his observations. Langley found that the absorption was precisely the same along the four radii *N*, *S*, *E* and *W*. Accordingly I oriented the co-ordinate axes on the projecting screen parallel to the daily motion, for the obvious convenience in using the slow motions of the instrument; on three days, in order to test this point, I adjusted to the Sun's pole and equator. The resulting average difference in the transmission for two corresponding positions $N - S$ was less than one and one-half per cent, that for the Northern hemisphere being the greater; if all the observations be used (whether oriented parallel to the Earth's or Sun's equator) the average difference becomes $+ 1.9$; the values for corresponding points on the *E*, *S* and *W* radii differ on the average by less than one-half of one per cent. We may therefore conclude that the heat transmitted from the neighborhood of the Sun's poles is at present practically the same as that from a point on the equator equally distant from the center of the disc, and that the difference between the Northern and Southern hemispheres, if real, is exceedingly small.

As above stated, the computations gave the most probable value of $\nu = 0.1412$, whence the coefficient of transmission of the solar atmosphere, which is the intensity for $\theta = 0$ expressed as a fraction of the intensity ($= 1$) if there were no absorption, becomes 0.72, or in other words only 28 per cent of the heat radiation emitted from the Sun and passing along its radius is absorbed in its atmosphere. The spectral-photometric observations gave for this coefficient for the red rays ($\lambda = 662\ \mu\mu$) 0.77 and for the yellow rays ($\lambda = 579$) 0.66.

We pass to the consideration of the question: how much more heat should we receive from the Sun if its atmosphere were removed? This might be determined by integrating the expression already given for the intensity at any point of the surface, $I = e^{-f \sec \theta}$, which as we have seen nearly represents the observations. It is, however, more convenient to divide the Sun's disc into concentric zones of 0.05 of the radius in width, and to multiply the area of each zone by the intensity at its middle point taken directly from the curve of observations, and then sum up these products. According to our original assumption that the Sun, deprived of its atmosphere, would send out its radiations to us equally from all portions of its disc, we should have (the radiation at the center, and the radius being each called unity) for the expression for the total heat radiation $I \pi R^2 = \pi = 3.14$.

The above process of summation, however, gives 2.56; moreover we have found that but 0.72 of the emitted heat is transmitted at the center; accordingly, were its atmosphere removed, the amount of heat received by us from the Sun would become $\frac{3.14}{2.56} \times \frac{1}{0.72} = 1.70$ times greater.

Professor Vogel found by this method for the red rays 1.54 and for the violet rays 2.67, as the factors by which these luminous radiations would be increased in the absence of a solar atmosphere. Secchi's results (computed after the uncorrected formula of Laplace): 8 for this last mentioned factor and 0.32 for the coefficient of transmission, may be mentioned for their historical interest. Langley has given no precise statement of his results, remarking that "not greatly less or more than one-half of the whole luminous heat rays" are transmitted through the solar atmosphere, so that this factor would be about 2 according to his observations.

II. OBSERVATIONS ON SUN-SPOTS.

The apparatus remained unchanged for measurements of the thermal condition of Sun-spots. Had this been the chief object of this investigation certain alterations would have been made in the arrangement of apparatus. The much greater magnification which had to be employed for spots necessarily reduced the deflections of the galvanometer and this, as well as other obvious reasons, made the measurements much less accurate than those above given. As, however, both kinds of observations were frequently made on the same day, practical considerations decided me to leave the thermopiles and galvanometer unchanged.

In order to give a clear idea of the character of the observations I add the full details.

The first column explains itself. Professor Spoerer has kindly furnished me the heliographic latitudes and longitudes of the spots, as well as the values of ρ found in the second column. n and p refer to nucleus and photosphere, the point of the latter which was observed being always taken as near the spot as possible and so chosen as to be at the same distance from the center of the disc. The deflection, corrected for torsion, is given in the third column, and the fourth contains the percentage of the thermal radiation from the nucleus of the spot to that from the neighboring photosphere, the mean value of which, p_0, is given in the first column.

In cases where a pause occurred during the observations this percentage is taken as the ratio of two successive measurements of n and p, and is indicated by brackets. Finally the mean value of the percentage or relative intensity i, is given in the first column followed by its value, i', when reduced to the center of the disc by means of the curve of absorption.

DETAILED OBSERVATIONS.

	ρ		Defl.	i
1891 Sept. 12	80	p	140	
Spot *a*. $\beta = +14^\circ$ $\lambda = 130^\circ$		n	123	88
$i = 88$ $i' = 69$				
	48	n	115	72
Sept. 14 (I)		p	167	
Spot *a*. $p_0 = 160$		p	157	
		n	118	74
$i = 73$ $i' = 69$		p	157	
		n	119	74
Sept. 14 (II)	48	n	29	66
Spot *a*. $p_0 = 44$		p	46	
		p	41	
$i = 70$ $i' = 66$		n	32	73
		p	44	
Sept. 24	97	n^*	41	111
Spot *b*. $\beta = +23^\circ$ $\lambda = 305^\circ$		p	37	
		p	30	103
$i^* = 107$ $i' = 59$		n	31	
Sept. 24	92	n	40	114
Spot *c*. $\beta = -23^\circ$ $\lambda = 86^\circ$		p	34	
$p_0 = 35$		p	36	
$i = 116$ $i' = 75$		n	41	117
Sept. 25	97	p	27	
Spot *c*. $p_0 = 26$		n^*	25	96
		n	27	104
		p	25	
$i^* = 96$ $i' = 53$		p	26	
		n	23	88
The same.		p	9	
Highest power eye-piece.		n	7	117
$p_0 = 6$		p	5	
		n	7	117
$i = 117$ $i' = 64$		p	5	
Mean of both $i = 106$ $i' = 58$				
Sept. 25				
Spot *b*. Western Nucleus.	91	p	39	
$p_0 = 37$		n	26	70
		n	27	73
		p	36	
$i = 75$ $i' =$		p	36	
		n	30	81

	ρ	Defl.	i
Oct. 2			
Spot *d*. $\beta = +27°$ $\lambda = 249°$	58 *p*	24	
$p_0 = 24$	*n*	21	89
	n	18	76
	p	24	
$i = 82$ $i' = 74$	*p*	23	
	n	19	80
Oct. 5			
Spot *e*. $\beta = -16°$ $\lambda = 198°$	70 *p*	26	
Western Nucleus. $p_0 = 26$	*n*	21	81
	n	19	73
$i = 77$ $i' = 65$	*p*	26	
Oct. 5			
Spot *d*. $p_0 = 27$	37 *n*	23	85
	p	27	
	p	27	
	n	22	81
$i = 81$ $i' = 79$	*n*	21	78
	p	27	
Oct. 7			
Spot *d*.	60 *p*	26	88
	n	23	
	p	24	79
	n	19	
$i = 85$ $i' = 77$	*p*	54	87
	n	47	
Oct. 9			
Spot *e*. $p_0 = 49$	45 *n*	42	86
	p	50	
	p	48	
	n	36	73
$p_0 = 42$	*p*	43	
	n	33	79
$i = 80$ $i' = 76$	*n*	35	83
	p	41	
Oct. 10			
Spot *f*. $\beta = +13°$ $\lambda = 130°$	68 *p*	39	
*contains a "Bridge"	*n**	33	85
$p_0 = 39$	*n*	33	85
	p	38	
$i^* = 85$ $i' = 73$	*p*	39	
	n	33	85
Oct. 10			
Spot *e*.	57 *n*	32	85
contains a "Bridge"	*p*	38	
$p_0 = 38$	*p*	37	
$i = 81$ $i' = 74$	*n*	29	77
Oct. 10			
Spot *g*. $\beta = -15°$ $\lambda = 209°$	67 *n*	27	84
Western Nucleus.	*n*	24	76
	p	32	
$p_0 = 31{\cdot}7$	*p*	31	
	n	26	82
$i = 83$ $i' = 72$	*n*	28	88
	p	32	

	ρ	Defl.	i
Oct. 16			
Spot *f.* (bridged)	60 *p*	43	
$p_0 = 44$	*n*	37	85
	n	37	85
$i = 85$ $i' = 77$	*p*	44	
1892 March 21			
Spot *b.* $\beta = +10^\circ$ $\lambda = 169^\circ$	29 *p*	58	
	n	48	73
$p_0 = 66$	*p*	70	
	n	49	74
$i = 74$ $i' = 73$	*p*	69	
	n	49	74
March 22			
Spot *b.* N. W. Nucleus.	34 *p*	62	
	n	35	60
	n	42	72
$p_0 = 59$	*p*	56	
	p	57	
	n	49	83
	n	47	80
$i = 74$ $i' = 73$	*p*	62	
	n	43	73
	p	57	
March 22			
Penumbra of Spot *b.*	34 *pen*	46	77
$p_0 = 60$	*pen*	47	78
	p	61	
$i = 78$ $i' = 76$	*p*	59	

* The star indicates that a portion of the penumbra was probably included with the nucleus.

A rather surprising result of these observations was that spots are occasionally relatively warmer than the surrounding photosphere.

Unless the air was very steady, it was difficult to be absolutely sure that no portion of the penumbra was included with the nucleus; were it the case, however, it would scarcely account for a radiation exceeding that of the neighboring photosphere unless it be a real condition. I am therefore forced to conclude that the observations represent the true state of affairs. The question at once arises whether these differences of temperature depend upon the distance of the spot from the center of the disc, and a reference to the observations shows that the two spots with the highest relative temperature were very near the Sun's edge. The weather has unfortunately not permitted following a spot from day to day as it approached the edge, and days clear enough for observations have been scarce. While it would be absurd to attempt to draw too general conclusions from the few measurements made here, yet it is of interest to see if the spots are subject to the same law of absorption as the photosphere, since we may perhaps hereby gain some idea of their position (depth) in reference to the photosphere.

Accordingly I give the following comparison of the results for different days, the radiation of the nucleus being respectively referred to that of the surrounding photosphere (i), and to that of the center of the disc (i').

	a			*b*			*c*			*d*	
ρ	i	i'	ρ	i	i'	ρ	i	i'	ρ	i	i'
80	88	69	97	107	59	92	116	75	58	82	74
48	72	68	91	75	50	97	106	58	37	81	79
									60	85	77
	e			*f*			*g*			*h*	
70	77	65	68	85	73	67	83	72	29	74	73
45	80	76	60	85	77				34	74	73
57	81	74									

The values of i represent the temperature ratio of spots to neighboring photosphere if the absorption is the same for both, those of i', on the contrary, if the spots suffer no absorption (more than at the center of the disc, *i. e.*, no absorption which is a function of ρ). While now the observations are unfortunately not sufficient in number to allow of more than stating what they suggest, I am inclined to think that the true condition lies between the values of i and i', but more nearly the latter, since the values of i' coincide somewhat better among themselves and for different spots than those of i; since the values of i' do not show the falling off in intensity as the spot nears the limb (except for spot *c*, which was poorly determined on the second day), which would be expected if the same amount of absorption took place for spots and photosphere, and finally since otherwise we should be obliged to believe that spots near the limb not infrequently reach a higher temperature than the surrounding photosphere. If these data were sufficient to absolutely establish that the spots are subject to a considerably less absorption than the neighboring photosphere, then it would seem most readily accounted for by considering them to lie in a higher stratum than the photosphere. In C. R. Tome 80, p. 848 (1875) Langley remarks as follows: “· · · Avec de plus grandes images et un appareil perfectionné, je trouvai que, dans un anneau complet de la surface solaire, la photosphère encore brilliante donnait près du bord absolutement moins de chaleur que le noyau des taches. Il me fallut beaucoup de temps pour établir ce fait d'une manière incontestable, car cet intéressant phéonmène ne peut être bien observé qu'a moins de ½ minute d'arc du limbe, et des précautions particulières devaient être prises pour empêcher qu'aucune vacillation de l'image n'affectât les mesures.”

According to my observations the thermal radiation from the nucleus of an average spot is about the same as that from an equal area on the Sun's surface at a distance of nine tenths of the radius ($\rho = 88$) from the center of the disk.

The only exact measurements of the thermal conditions of Sun-spots known to me and available for comparison were made by Langley in 1874-5 (*Monthly Notices* XXXVII p. 5). They are unfortunately not published in full. The method was similar to that employed here except that but one thermopile was used.

He states " . . . The quotient expresses the value of the umbral radiations, in parts of those of the adjacent photosphere. The decrement of heat, as we approach the limb, is, though not exactly, yet so very nearly, in the same ratio for photosphere and spots, that no correction is needed on this account for the present observations. 36 measurements on umbræ, and 32 on penumbrae were obtained in the autumn of 1874 and the spring of 1875. . . . The result is, that taking the mean thermal photospheric radiation in the spot's vicinity as unity, the mean umbral radiation is 0.54 ± 0.005, the mean penumbral 0.85 ± 0.01. These probable errors include all the discrepancies due to the greater or less approach to the limb in the spots measured, or due to absolute differences in their radiation, as well as the errors of observation."

The greatest and least values, among the 36 which are there given, are 0.63 and 0.43. Whether the separate measurements are of different spots on different days or include the single determinations for the same spot on one day or more is not stated. The observations must have been therefore made on spots which were not very far from the central portions of the disc, for otherwise they would be rather contradictory to those above quoted from Comptes rendus.

Although it seems to me that the individual character of Sun-spots is often so different as to make it scarcely allowable to combine them together in taking a mean value, yet for the sake of comparison I give the mean value for the above 17 day-values, reduced to the center of the disc, viz. 0.70 ± 0.01 ; referred to the surrounding photosphere this becomes 0.85 ± 0.02; 52 single measurements on the above given eight spots are included in these values.

Professor Langley's instrumental equipment was considerably better than that used here, and I have no doubt that his measurements on spots are superior to mine.

Furthermore, as already stated in the notes, there was sometimes danger that a small portion of the penumbra was included with the nucleus, so that there would be a tendency for my measurements to be too large. I cannot believe, however, that the large difference 0.16, or 25 per cent of the whole quantity measured, can be thus accounted for.

It may be remarked that Prof. Langley's observations were made about three years after a solar maximum while these of mine at about two years after a minimum.

In our present state of knowledge of this subject it is impossible to assert that the thermal conditions of spots (and perhaps of the photosphere and atmosphere) are invariable during the eleven-year period of solar activity, and it is to be hoped that the importance of systematic observations on this subject may be more fully recognized by observers having favorable climates and adequate instruments.

In conclusion I must express my deep indebtedness to Professor Vogel for the resources he has so freely placed at my disposal and for the interested encouragement with which he has followed my work.

Potsdam, 1892, June.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subects properly included in ASTRO-PHYSICS, should be addressed to George E. Hale, Kenwood Observatory, of the University of Chicago, U. S. A. Authors of papers are requested to refer to page 752 for information in regard to illustrations, reprint copies, etc.

A New Outburst of Nova Aurigæ.—The following circular from the Wolsingham Observatory was our first intimation of the Nova's reappearance: "Mr. H. Corder having informed me that the Nova Aurigæ has increased, it was examined here Aug. 21 and found to be 9.2, spectrum monochromatic. One intense line (500?). T. E. Espin." It is safe to say that this announcement caused considerable surprise wherever it was received. At the Lick Observatory in April, Mr. Burnham had watched the gradual decline in the star's brilliancy until it was too low in the west for further observation. At that time it was almost at the limit of vision with the great telescope, and it seemed probable that it would soon be lost to view. Of early morning observations since that time we have no information, and it seems probable that no one saw the star pass its minimum, and rise again into an easily visible object. In fact, the most generally accepted explanation of the Nova's first outburst is perhaps to some degree responsible for the subsequent lack of observations. For the two bodies were supposed to be moving in hyperbolic orbits after their close approach, and consequently no second meeting could ever occur. But not only does the new outburst of light make necessary a revision of our ideas as to the form of the orbits: still another difficulty arises from the discovery that we are no longer dealing with a star, but with a nebula. On another page will be found observations which show that the spectrum has undergone a complete change, and is now quite of the type characteristic of nebulæ. Moreover, the nebulosity surrounding the stellar nucleus is plainly visible to Mr. Barnard with the 36-inch Lick telescope, and he has found its diameter to be 3″. Whether it can be seen with a smaller instrument we do not yet know; we observed the Nova on the morning of Sept. 6 with Mr. Burnham, using the 12 inch refractor of the Kenwood Observatory, and though the star was well seen (estimated by Mr. Burnham as 10.4 mag.) the bright moonlight would have completely hid even a bright nebulosity. From Science Observer *Special Circular, No. 97* we learn that Dr. A. Krueger of Kiel found the magnitude to be 9.2 on August 21, and 9.3 on August 31, so the star seems to have been decreasing in brilliancy. It is stated in the same circular that observations of the Nova at the Harvard College Observatory show a quite constant brightness at about 10.5 magnitude. It is greatly to be hoped that the brightness will not much decrease until a sufficient number of visual and photographic observations are obtained to fully acquaint us with the character of the spectrum. Professor Campbell's determination of a steady increase in velocity is of great interest and value, and perhaps our collected data may ere long be complete enough to allow a solution of this remarkable stellar problem.

Exceptional Solar Disturbance.—Owing to the frequent disturbances in the electrical and magnetic conditions on the earth, an account of a marked disturbance near the Sun's eastern limb, [position angle 130 degrees], observed by me on the morning of Thursday, August fourth, might be of interest to some of your readers. The instruments used were the six-inch equatorial of the Lick Observatory and a spectroscope belonging to the Chabot Observatory. This latter was without micrometer, so all displacements were estimated and not measured. My attention was first attracted by a marked distortion of the C line, at about $8^h 36^m$ Pacific Standard Time. Between $8^h 10^m$ and $8^h 20^m$, I had been watching the same part of the Sun, but had seen nothing but two small prominences about 10° to 20° from the point which afterwards became the center of disturbance. From the time that it was first noticed until the observations were discontinued, the violence of the disturbance steadily decreased. The following reversals were noted with a narrow tangential slit. A line was reversed at about wave-length 7065, [probably Young's first chromosphere line]. 6678.1 was brightly reversed. The C line was very much distorted on both sides and looked very much as in the sketch (which accompanied the letter.)

The displacements at *a*, *b*, *c* and *d* were estimated proportionally to the relative positions of the neighboring lines and from these displacements the velocities at those points were found to be as follows; at *a*, 83 miles per sec., at *c*, 73 miles per sec., both towards the earth; and at *b*, 73 miles per sec., at *d*, 146 miles per sec., both away from the earth. D_1 and D_2 each showed a bright spot or nodule on each side of the line, probably corresponding to *c* and *d* of the figure; both lines were very brilliantly reversed low down in the prominence. D_3 was violently disturbed, showing nearly but not quite so much motion as C and looking very much the same as the C line. 5316.8 [1474 *K*] was brilliant near the base of the prominence. b_1, b_2 brilliant; b_3 very bright in spots. b_4 less bright than the other two magnesium lines. b_1 reversed to a considerable height and comparatively quiescent, F very brilliant and very much like the C line. $H\gamma$ brilliant and showing considerable motion towards the violet. By $9^h 40^m$ nearly all disturbance had ceased. I examined the eastern limb of the Sun for spots but could see none in the neighborhood of this disturbance. H. C. LORD.

Professor Schuster's Address before the British Association.—At the very successful meeting of the British Association, which was held in Edinburgh early in August, we believe that there were no papers specially dealing with astro-physical subjects. Professor Schuster's address as President of the Section of Mathematics and Physics contained, however, some suggestions of such interest and value that we give them in full below:

"Some of the results recently brought to light by investigations on the discharge of electricity have interesting cosmical applications. Thus it is found that such a discharge through any part of a vessel containing a gas converts the whole gas into a conductor.* The dissociation which we imagine to take place in a liquid before electrolytic conduction takes place must be artificially produced in a gas by the discharge itself. We may imitate in gases which have thus been rendered conductive many of the phenomena hitherto restricted to liquids; thus I hope to bring to the notice of this meeting cases of primary and secondary cells in which the electrolyte is a gas. There are other ways in which a gas can be put into that sensitive state in which we may treat it as a conductor, and we have every reason to suppose that the upper regions of our atmosphere are in this state. The principal part of the daily variation of the magnetic needle is due to causes lying outside the surface of the earth, and is in all probability only an electro-magnetic effect due to that bodily motion in our atmosphere which shows itself in the diurnal changes of the barometer. A favorite idea of the late Professor Balfour Stewart will thus probably be confirmed. The difference in the diurnal range between times of maximum and times of minimum Sun-spots is accounted for by the fact that the atmosphere is a better conductor at times of maximum Sun-spots.

The mention of Sun-spots raises a point not altogether new to this section. Careful observation of celestial phenomena may suggest to us the solution of many mysteries which are now puzzling us. Consider, for instance, how long it would have taken to prove the universal property of gravitational attraction if the record of planetary motion had not come to the philosopher's help. And surely the most casual observation of cosmical effects teaches us how much we have yet to learn.

The statement of a problem occasionally helps to clear it up, and I may be allowed, therefore, to put before you some questions, the solution of which seems not beyond the reach of our powers.

1. Is every large rotating mass a magnet? If it is, the Sun must be a powerful magnet. The comets' tails, which eclipse observations show stretching out from our Sun in all directions, probably consist of electric discharges. The effect of a magnet on the discharge is known, and careful investigations of the streamers of the solar corona ought to give an answer to the question which I have put.†

2. Is there sufficient matter in interplanetary space to make it a conductor of electricity? I believe the evidence to be in favor of that view. But the conductivity can only be small, for otherwise the earth would gradually set itself to revolve about its magnetic pole. Suppose the electric resistance of interplanetary space to be so great that no appreciable change in the earth's axis of rotation could have taken place within historical times, is it not possible that the currents induced in planetary space by the earth's revolution may, by their electro-

---

* An experiment by Hittorf (*Wied. Ann.* VII, p. 614) suggested the probability of this fact, which was proved independently by Arrhenius and myself.

† The efforts of Mr. Bigelow have a bearing on this point, also some remarks which I have made in a lecture before the Royal Institution (*Proc. Roy. Inst.* 1891), but nothing decisive can be asserted at present.

magnetic action, cause the secular variation of terrestrial magnetism? There seems to me to be here a definite question capable of a definite answer, and as far as I can judge without a strict mathematical investigation the answer is in the affirmative.

3. What is a Sun-spot? It is, I believe, generally assumed that it is analogous to one of our cyclones. The general appearance of a Sun-spot does not show any marked cyclonic motion, though what we see is really determined by the distribution of temperature and not by the lines of flow. But a number of cyclones clustering together like the Sun-spots in a group should move round each other in a definite way, and it seems to me that the close study of the relative positions of a group of spots should give decisive evidence for or against the cyclone theory.

4. If the spot is not due to cyclonic motion, is it not possible that electric discharges setting out from the Sun, and accelerating artificially evaporation at the Sun's surface, might cool those parts from which the discharge starts, and thus produce a Sun-spot? The effects of electric discharges on matters of solar physics have already been discussed by Dr. Huggins.

5. May not the periodicity of Sun-spots, and the connection between two such dissimilar phenomena as spots on the Sun and magnetic disturbances on the earth, be due to a periodically recurring increase in the electric conductivity of the parts of space surrounding the Sun? Such an increase of conductivity might be produced by meteoric matter circulating round the Sun.

6. What causes the anomalous law of rotation of the solar photosphere? It has long been known that groups of spots at the solar equator perform their revolution in a shorter time than those in a higher latitude; but spots are disturbances which may have their own proper motions. Duner[*] has shown, however, from the displacement of the Fraunhofer lines, that the whole of the layer which produces these lines follows the same anomalous law, the angular velocity at a latitude of 75° being 30 per cent less than near the equator.[†] As all causes acting within the Sun might cause the angular velocity of the Sun to be smaller at the equator than at other latitudes, but could not make it greater, the only explanation open to us is an outside effect either by an influx of meteoric matter, as suggested by Lord Kelvin, or in some other way. If we are to trust Dr. Wilsing's result that faculæ which have their seat below the photosphere revolve in all latitudes with the same velocity, which is that of the spot velocity in the equatorial region, we should have to find a cause for a retardation in higher latitudes rather than for an acceleration at the equator. The exceptional behavior of the solar surface seems to me to deserve very careful attention from solar physicists. Its explanation will probably carry with it that of many other phenomena.

A National Physical Laboratory.—In an able paper on this subject (see the *Pedagogical Seminary*, Vol. II, No. 1,) Dr. Arthur Webster of Clark University urges that the United States Government should follow the example set by Germany, and establish a National Physical Laboratory on a scale commensurate with the importance of such an institution. The subject is one which has already received considerable attention in England, where the situation is very similar to that existing in this country. Professor Oliver Lodge was one of the first to call attention to it there, and his suggestions at the Cardiff meeting of the British Association a year ago were followed up this year at Edinburgh by a general discus-

---

[*] Oefvers. af Kongl. Veterrk. Ak. Forhandl., 47, 1890.

[†] Although the importance of M. Duner's results would make an independent investigation desirable, the measurements of Mr. Crew, who by a much inferior method arrived at other results, cannot have much weight as compared with those of Duner.

sion, in which Professor von Helmholtz, the distinguished Director of the National Physical Laboratory of Germany, was a prominent participant. The speakers found no difficulty in adducing weighty reasons in favor of the proposed measure, though Professor Fitzgerald's expression of doubt as to whether the House of Commons is sufficiently educated to understand that the advance of scientific work is of national value made plain the serious difficulty of accomplishing the desired result. But while it might be impossible to convince the House of Commons or our own House of Representatives that a large appropriation would be many times returned in the nation's advance in pure science, it would seem that the technical side of the subject might be urged with a better hope of success. The need of Government standardization of electrical instruments becomes daily more apparent, and Professor Webster has forcibly presented this aspect of the question in the paper to which we have alluded. We heartily second the views he has expressed, and hope that American physicists may unite to present this important subject to Congress.

Progress in Solar Photography at the Kenwood Observatory.—The sudden outburst on the Sun photographed at the Kenwood Observatory of the University of Chicago on July 15 having emphasized the importance of securing a practically continuous record of the condition of the solar surface, Professor Hale has devised a new form of spectroheliograph for this purpose. The instrument is radically different in design from the one now in use, and the form of construction is greatly simplified. An automatic arrangement has been added, which will allow photographs of the Sun, showing spots, faculæ and prominences, to be taken at any desired interval throughout the day, the instrument requiring no attention after once being set in operation.

The Distribution of Sun-Spots in Solar Latitude.—In the July number of *Knowledge* Mr. E. W. Maunder has an interesting paper under the above title. By means of a series of novel diagrams he illustrates the gradual change in latitude from minimum to maximum spot-period, and concludes "that these various relations—the sudden appearance of the spots of a new cycle in high latitudes, the persistent decline in latitude of the general spotted area as the cycle progresses, and the drift in latitude of individual groups—seem to me absolutely fatal to the idea, once popular, that the secret of solar disturbances lies without the Sun; in the relative positions of the planets, for example, or in the fall of meteorites." This view receives a strong confirmation, as Mr. Maunder points out, in the fact that outbreaks often recur in the same regions after considerable intervals of time.

New Observatories.—From *l'Astronomie* for August we learn that M. Bischoffsheim, the founder of the Nice Observatory, is about to construct an Observatory on the summit of Mt. Monnier in the Maritime Alps. The elevation is 2800 meters, 9200 feet, considerably greater than that of Nice.

A new Observatory, d'Abbas-Touman, has been opened in Trans Caucasia, in latitude 41° 46′ north, longitude 40° 32′ east from Paris. It was founded by the Grand-Duke Georges Mikhaïlowitch and is at a considerable elevation. M. Glasenapp, Professor of Astronomy in the University of St. Petersburg, has been charged with the mounting of the instruments and has already installed a ten-inch refractor.

CURRENT CELESTIAL PHENOMENA.

PLANET NOTES FOR NOVEMBER.

H. C. WILSON.

Mercury will be at greatest elongation east from the Sun, 21° 52′, Nov. 23. It will then set about an hour later than the Sun. Its low altitude will be unfavorable to day observations of the planet.

Venus will be in good position for observation just before sunrise. She will be in conjuction with the Moon Nov. 15 at 4^h 07^m P. M. We had a splendid view of this planet on the morning of Sept. 5. The phase was slightly crescent and at the cusps there were two oval white patches which seemed to stand out like the polar caps of Mars. Near the center a large dusky shading had the appearance of a real marking on the planet.

Mars during November will be getting pretty well toward the west in the evening, but as his declination will increase rapidly his position will be better for observation than it is at present. The diameter of his disk will decrease during the month from 14″ to 10″. Mars will be in conjunction with the Moon Nov. 27 at 11 A. M.

The months of August and September of course have been the great months for observation of Mars, and elsewhere in this journal will be found much concerning it, but the position of the planet will be more favorable to northern observers a little later, so that we may expect still further results. Clouds prevented us from observing the occultation of Mars on the morning of Sept. 4.

Jupiter will be in his best position for observation during the month of November, crossing the meridian at a high altitude early in the night. There will be two occultations of Jupiter during this month, the conjunctions occurring Nov. 2 at 5 P. M. and Nov. 29 at midnight, central time. These will be visible as occultations only in equatorial and southern latitudes. As seen in our latitude the Moon will pass to the south of Jupiter in both instances.

The great red spot has about the same appearance as during last year and is equally conspicuous. It came to the central meridian of the planet at the predicted time Sept. 14, so that the ephemeris which we give of its meridian passages may be considered correct.

One of the most important astronomical discoveries of this century has just been made by Mr. E. E. Barnard with the 36-in. equatorial of Lick Observatory, the discovery of a fifth satellite of Jupiter. Probably no planet has been examined more frequently and more thoroughly with telescopes of all kinds and sizes than has Jupiter. Yet no satellites have been added to the four which were discovered by Galileo with the first telescope in January 1610. The new satellite is of the 13th magnitude so that it can be seen only with large telescopes and with great difficulty because of the glare of the planet. Its greatest distance from the limb of the planet is about equal to the planet's diameter.

Saturn is a morning planet visible for about three hours before sunrise.

Uranus will be at conjunction with the Sun Oct. 29, and will be hidden by the solar rays during November.

Neptune is in good position for observation after midnight. He comes to opposition on the first day of December.

Date. 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Nov. 5	15 51.4	− 22 09	8 20 A. M.	12 49.6 P. M.	5 19 P. M.
15	16 50.9	− 25 02	8 55 "	1 09.6 "	5 25 "
25	17 40.5	− 25 39	9 08 "	1 19.8 "	5 32 "
			VENUS.		
Nov. 5	12 12.5	+ 0 21	3 06 A. M.	9 11.2 A. M.	3 16 P. M.
15	12 56.7	− 4 03	3 28 "	9 15.9 "	3 03 "
25	13 41.8	− 8 26	3 52 "	9 21.7 "	2 52 "
			MARS.		
Nov. 5	22 04.1	− 14 01	1 54 P. M.	7 01.2 P. M.	12 08 A. M.
15	22 25.2	− 11 36	1 26 "	6 42.9 "	12 00 mdn
25	22 47.1	− 9 02	12 58 "	6 25.4 "	11 53 P. M.
			JUPITER.		
Nov. 5	1 04.5	+ 5 11	3 31 P. M.	10 01.1 P. M.	4 25 A. M.
15	1 01.0	+ 4 52	2 56 "	9 18.2 "	3 41 "
25	0 58.6	+ 4 40	2 15 "	8 36.7 "	2 58 "
			SATURN.		
Nov. 5	12 32.9	− 1 10	3 34 A. M.	9 32.8 A. M.	3 32 P. M.
15	12 36.7	− 1 33	3 00 "	8 57.3 "	2 55 "
25	12 40.3	− 1 54	2 28 "	8 21.4 "	2 20 "
			URANUS.		
Nov. 5	14 18.5	− 13 23	6 08 A. M.	11 18.1 A. M.	4 28 P. M.
15	14 20.9	− 13 35	5 31 "	10 40.2 "	3 49 "
25	14 23.2	− 13 47	4 56 "	10 03.3 "	3 11 "
			NEPTUNE.		
Nov. 5	4 36.9	+ 20 28	6 03 P. M.	1 32.9 A. M.	9 03 A. M.
15	4 35.8	+ 20 25	5 23 "	12 52.5 "	8 22 "
25	4 34.6	+ 20 23	4 43 "	12 12.0 "	7 41 "
			THE SUN.		
Nov. 5	14 45.4	− 15 59	6 44 A. M.	11 43.7 A. M.	4 43 P. M.
15	15 26.0	− 18 45	6 58 "	11 44.9 "	4 32 "
25	16 08.0	− 20 57	7 09 "	11 47.4 "	4 24 "

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A. .... $0^h\ 52^m\ 32^s$
Decl .... + 81° 17′
Period .... $2d\ 11^h\ 50^m$

Nov. 4	6 P. M.
9	5 "
14	5 "
17	4 A. M.
22	4 "
27	4 "

ALGOL.

R. A. .... $3^h\ 01^m\ 01^s$
Decl .... + 40° 32′
Period .... $2d\ 20^h\ 49^m$

Nov. 3	6 P. M.
15	5 A. M.
18	2 "

ALGOL CONT.

Nov. 20	11 P. M.
23	8 "
26	4 "

R. CANIS MAJORIS.

R. A. .... $7^h\ 14^m\ 30^s$
Decl .... − 16° 11′
Period .... $1d\ 03^h\ 16^m$

Nov. 1	9 P. M.
3	1 A. M.
4	4 "
9	8 P. M.
10	11 "
12	2 A. M.
13	5 "
18	10 P. M.

R. CANIS MAJ., CONT.

Nov. 20	1 A. M.
21	4 "
26	9 P. M.
27	12 midn.
29	3 A. M.
30	6 "

Y CYGNI.

R. A. .... $20^h\ 47^m\ 40^s$
Decl .... + 34° 15′
Period .... $1d\ 11^h\ 56^m$

Nov. 1	11 P. M.
7	11 "
13	11 "
19	10 "
25	10 "

Phases and Aspects of the Moon.

		d	h m
Full Moon	Nov.	4	9 49 A. M.
Perigee	"	4	9 54 "
Last Quarter	"	11	4 02 P. M.
Apogee	"	17	11 06 "
New Moon	"	19	7 19 A. M.
First Quarter	"	27	10 28 "

Jupiter's Satellites.

Nov. 1	12	14	A. M.	II	Sh. In.
	12	47	"	I	Tr. Eg.
	1	18	"	I	Sh. Eg.
	1	44	"	II	Tr. Eg.
	2	45	"	II	Sh. Eg.
2	5	02	P. M.	I	Tr. In.
	5	34	"	I	Sh. In.
	5	42	"	II	Oc. Dis.
	7	15	"	I	Tr. Eg.
	7	39	"	III	Oc. Dis.
	7	48	"	I	Sh. Eg.
	9	14	"	II	Ec. Re.
	9	42	"	III	Oc. Re.
	9	54	"	III	Ec. Dis.
	11	55	"	III	Ec. Re
7	3	09	A. M.	I	Oc. Dis.
8	12	29	"	I	Tr. In.
	13	01	"	I	Sh. In.
	1	35	"	II	Tr. In.
	2	33	"	I	Tr. Eg.
	2	53	"	II	Sh. In.
	3	14	"	I	Sh. Eg.
	9	35	P. M.	I	Oc. Dis.
9	12	28	A. M.	I	Ec. Re.
	6	47	P. M.	I	Tr. In.
	7	29	"	I	Sh. In.
	7	58	"	II	Oc. Dis.
	9	00	"	I	Tr. Eg.
	9	42	"	I	Sh. Eg.
	10	59	"	III	Oc. Dis.
	11	49	"	II	Ec. Re.
10	1	08	"	III	Oc. Re.
	1	56	"	III	Ec. Dis.
	6	57	P. M.	I	Ec. Re.
11	4	11	"	I	Sh. Eg.
	4	13	"	II	Sh. In.
	5	14	"	II	Tr. Eg.
	6	43	"	II	Sh. Eg.
13	6	12	"	III	Sh. Eg.
15	2	58	A. M.	I	Sh. In.
	11	22	P. M.	I	Oc. Dis.
16	2	23	A. M.	I	Ec. Re.
	8	33	P. M.	I	Tr. In.
	9	24	"	I	Sh. In.
	10	16	"	II	Oc. Dis.
	10	46	"	I	Tr. Eg.
	11	37	"	I	Sh. Eg.
17	2	23	A. M.	III	Oc. Dis.
	2	25	"	II	Ec. Re.
	5	49	P. M.	I	Oc. Dis.
	8	52	"	I	Ec. Re.
18	5	05	"	II	Tr. In.
	5	12	"	I	Tr. Eg.
	6	06	"	I	Sh. Eg.
	6	52	"	II	Sh. In.
	7	35	"	II	Tr. Eg.
	9	22	"	II	Sh. Eg.
20	4	14	"	III	Tr. In.
	6	28	"	III	Tr. Eg.
	8	01	"	III	Sh. In.
	10	13	"	III	Sh. Eg.
23	1	10	A. M.	I	Oc. Dis.
	10	20	P. M.	I	Tr. In.
	11	19	"	I	Sh. In.
24	12	33	A. M.	I	Tr. Eg.
	12	36	"	II	Oc. Dis.
	1	32	"	I	Sh. Eg.
	7	35	P. M.	I	Oc. Dis.
	10	48	"	I	Ec. Re.
25	4	47	"	I	Tr. In.
	5	48	"	I	Sh. In.
	7	00	"	I	Tr. Eg.
	7	28	"	II	Tr. In.
	8	01	"	I	Sh. Eg.
	9	31	"	II	Sh. In.
	9	59	"	II	Tr. Eg.
26	12	01	A. M.	II	Sh. Eg.
	5	17	P M.	I	Ec. Re.
27	6	18	"	II	Ec. Re.
	7	45	"	III	Tr. In.
	10	02	"	III	Tr. Eg.
28	12	03	A. M.	III	Sh. In.

Approximate Central Times when the Great Red Spot will pass the Center of Jupiter's Disk.

	h	m	
Oct. 16	6	44	P. M.
18	12	30	A. M.
18	6	22	P. M.
19	4	13	"
20	2	08	A. M.
20	10	00	P. M.
21	5	51	"
22	3	46	A. M.
22	11	37	P. M.
23	7	29	"
24	5	24	A. M.
25	1	16	"
25	9	07	P. M.
26	4	58	"
27	2	54	A. M.
27	10	45	P. M.
28	6	36	"
30	12	23	A. M.
30	8	13	P. M.
Oct. 31	4	05	P. M.
Nov. 1	2	01	A. M.
1	9	52	P. M.
2	5	44	"
3	11	30	"
4	7	22	"
6	1	09	A. M.
6	9	00	P. M.
7	4	51	"
8	2	47	A. M.
8	10	38	P. M.
9	6	29	"
11	12	16	A. M.
11	8	8	P. M.
13	1	55	A. M.
13	9	46	P. M.
14	7	42	A. M.
14	5	37	P. M.
Nov. 15	11	24	P. M.
16	7	15	"
18	1	2	A. M.
18	8	54	P. M.
19	6	50	A. M.
19	4	45	P. M.
20	10	32	"
21	6	24	"
23	12	11	A. M.
23	8	2	P. M.
25	1	49	A. M.
25	9	41	P. M.
26	7	36	A. M.
26	5	32	P. M.
27	11	19	"
28	7	10	"
30	12	58	A. M.
30	8	40	P. M.

Configuration of Jupiter's Satellites at 10:30 p. m. Central Time

Nov.		Nov.		Nov.	
1	4 3 2 ○ ●	11	1 2 ○ 4 3	21	3 ○ 1 2 4
2	4 1 ○ 2 ●	12	2 4 ○ 1 3	22	3 2 1 ○ 4
3	○ 4 1 2 3	13	4 1 3 ○ 2	23	3 2 ○ 1 4
4	1 2 ○ 3 4	14	4 3 ○ 1 2	24	○ 3 2 4●
5	2 ○ 1 3 4	15	4 3 2 1 ○	25	♃ 1 ○ 3 4
6	3 1 ○ 2 4	16	♃ 4 3 2 ○	26	2 ○ 1 3 4
7	3 ○ 1 2 4	17	4 ○ 1 3 2	27	♃ 1 ○ 2 4
8	3 2 1 ○ 4	18	4 1 2 ○ 3	28	3 4 ○ 1 2
9	1 3 ○ 4 ●	19	2 4 ○ 1 3	29	3 4 2 1 ○
10	○ 1 2 4 3	20	1 3 ○ 2 4	30	4 3 2 ○ 1

Occultations Visible at Washington.

Date 1892.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	IMMERSION Angle f'm N pt. °	EMERSION Washington M. T. h m	EMERSION Angle f'm N pt °	Duration. h m
Nov. 2	96 Piscium........	7	14 47	121	15 18	183	0 31
11	42 Leonis..........	6	11 07	143	11 49	249	0 42
13	*b* Virginis..........	6	14 58	106	16 04	313	1 06
14	Saturn................		15 19	160	16 08	260	0 48
21	Σ Sagittarii.......	5	5 24	32	6 06	320	0 42
25	35 Capricorni....	6	5 31	59	6 52	239	0 21
27	ψ^2 Capricorni....	4	11 24	32	12 17	264	0 53
30	*o* Piscium..........	4	6 35	45	7 45	239	1 10

Occultation of Mars, Sept. 3, 1892.—This was observed at the Chamberlain Observatory by Mr. H. L. Shattuck, Mr. O. F. Shattuck and myself. Mr. H. L. Shattuck used a 2-inch telescope with a magnifying power of 30 diameters; Mr. O. F. Shattuck, a 5-inch with a power of 80, and I, a 6-inch with a power of 170.

The latitude and longitude are 39° 40′ 36″.4 and 6^h 59^m $47^s.63$ (from Greenwich). The local mean times of the phases are given below. At first contact, the telescope of O. F. S. was shaking so that he could not get distinct vision and estimated his time as 5 seconds slow. The atmospheric conditions were good.

	1st Contact. h m s	2nd Contact. h m s	3rd Contact. h m s	4th Contact. h m s
O. F. S.	10 45 40.4	10 46 29.1	12 2 10.8	12 2 53.8
H. L. S.		27.1	11.8	
H. A. H.	35.7	28.4	10.6	53.4

University Park, Colo. HERBERT A. HOWE.

Partial Eclipse of the Sun, Oct. 20.—We call attention again to this eclipse which was mentioned in our last number. The eclipse will be visible throughout almost the whole of North America. At Northfield the eclipse will begin at 10^h 32^m 53^s A. M. and end at 1^h 25^m 18^s P. M. central time. First contact will occur at a point 28.8° to the west, and last contact 97.6° to the east, of the north point of the solar disk. At the middle of the eclipse at Northfield about half the Sun's diameter will be covered by the moon. At Albany the eclipse will begin at 12^h 02^m 41^s and end at 3^h 03^m 39^s P. M. eastern time, the contacts occurring at points 34° west and 106° east from the north point of the Sun's disk.

New Minor Planet 1892 A (Wolf).—A new minor planet of the twelfth magnitude was discovered photographically by Wolf at Heidelberg. It was observed by Palisa at Vienna, Aug. 26, 10^h 52^m: R. A. 22^h 42^m 16^s; Decl. — 10° 22′. Daily motion — 44^s and — 3′.

COMET NOTES.

Comet *d* 1892 (Brooks).—A new comet was discovered by Mr. W. R. Brooks of Geneva, N. Y., on the night of Aug. 28 in R. A. 5^h 59^m; Decl. 31° 52′. The discovery was verified on the following night and announced by telegraph on the next day. The announcement was received at Northfield Aug. 31 and the position of the comet determined on that night. The following observations are now at hand:

No	Date	Gr. M. T. h m s	R. A. h m s	Decl. ° ′ ″	Observer	Place
1	Aug. 31	20 07 46	6 06 50.44	+31 40 38.9	Wilson	Northfield
2	Sept. 1	17 49 43	6 09 01.66	31 35 51.2	Wendell	Cambridge
3	1	19 47 26	6 09 15.83	31 35 19.0	Wilson	Northfield
4	2	19 42 44	6 11 42.48	31 29 39.6	Wendell	Cambridge
5	4	2 29 45	6 14 45.7	31 22 50	Barnard	Lick Obs.
6	4	21 37 43	6 16 56.70	31 17 08.8	Wilson	Northfield

Since the last date cloudy weather and moonlight have prevented observations so that no good elements of the orbit are yet possible. The following rough elements were computed by Mr. A. G. Sivaslian and myself, using for the first set my own observations alone. As these gave very unequal intervals of time the results were not satisfactory. When the *Science Observer Circular* No. 97 arrived containing Mr. Wendell's observations, we made a new computation using the observations numbered 1, 4 and 6 and obtained the second set of elements:

	I	II	
T	= 1892. Dec. 22.80	1892, Dec. 9.31 Gr. M. T.	
π	= 165° 28′	182° 11′	
ω	= 263 27	284 37	1892.0
☊	= 262 06	257 35	
i	= 27 00	31 57	
q	= 0.7962	0.4764	

These elements agree as well perhaps as could be expected, considering the shortness of the arc described by the comet, only a little over 1° of heliocentric longitude, with those found by Berberich from observations Sept. 1, 4 and 6.

T = 1892 Dec. 19.69 Gr. M. T.
ω = 269° 24′ ⎫
☊ = 261 03 ⎬ 1892.0
i = 27 57 ⎭
q = 0.6991

It will be seen that there is considerable uncertainty as to the comet's perihelion distance, and therefore as to its brightness and visibility during the coming months. From the following ephemeris computed by Mr. Sivaslian from elements II, it seems certain that the comet will be much brighter than it now is.

Ephemeris of Comet *d* 1892 (Brooks).

Gr. M. T.	R. A. h m	Decl. ° ′	log Δ	log r	Brightness
Oct. 2.5	7 40.8	+25 25	0.1303	0.1752	4.5
6.5	7 56.4	+23 46	0.0999	0.1556	5.7
10.5	8 13.2	+21 46	0.0688	0.1348	7.2
14.5	8 31 5	+19 24	0.0369	0.1126	9.2
18.5	8 51.3	+16 32	0.0055	0.0892	11.9
22.5	9 13.0	+13 08	9.9746	0.0640	15.4
26.5	9 36.7	+ 9 06	9.9460	0.0370	19.9
30.5	10 02.7	+ 4 33	9.9214	0.0082	25.4
Dec. 9.3	15 34.5	−31 25	0.0757	9.6780	57 2

Ephemeris of Comet 1892 (Winnecke).

(From *Astr. Nach.* No. 3112).

		App. R. A.			App. Decl.			log *r*	log *Δ*	Br.
		h	m	s	°	′	″			
1892 Oct.	1	1	30	09.0	− 30	30	54			
	2		28	12.8		21	08			
	3		26	19.2		10	57			
	4		24	28.4	30	00	21	0.2068	9.8395	0.807
	5		22	40.4	29	49	21			
	6		20	55.3		37	59			
	7		19	13.1		26	15			
	8		17	33.8		14	10	0.2176	9.8658	0.681
	9		15	57.5	29	01	46			
	10		14	24.1	28	49	03			
	11		12	53.7		36	03			
	12		11	26.3		22	46	0.2280	9.8922	0.574
	13		10	01.9	28	09	13			
	14		8	40.6	27	55	25			
	15		7	22.2		41	24			
	16		6	06.8		27	09	0.2382	9.9185	0.485
	17		4	54.4	27	12	42			
	18		3	44.9	26	58	04			
	19		2	38.4		43	15			
	20		1	34.9		28	16	0.2480	9.9448	0.411
	21	1	0	34.3	26	13	08			
	22	0	59	36.6	25	57	52			
	23		58	41.8		42	28			
	24		57	49.8		26	58	0.2576	9.9709	0.349
	25		57	00.6	25	11	20			
	26		56	14.2	24	55	38			
	27		55	30.6		39	50			
	28		54	49.6		23	58	0.2670	9.9967	0.297
	29		54	11.2	24	08	03			
	30		53	35.5	23	52	05			
	31		53	02.3		36	04			
Nov.	1		52	31.5		20	01	0.2760	0.0222	0.253
	2		52	03.3	23	03	56			
	3		51	37.4	22	47	50			
	4		51	13.9		31	43			
	5		50	52.7	22	15	36	0.2849	0.0472	0.216
	6		50	33.7	21	59	29			
	7		50	16.9		43	22			
	8		50	02.2		27	16			
	9		49	49.7	21	11	11	0.2935	0.0718	0.186
	10		49	39.2	20	55	07			
	11		49	30.8		39	04			
	12		49	24.4		23	03			
	13		49	19.9	20	07	06	0.3019	0.0960	0.160
	14		49	17.3	19	51	06			
	15	0	49	16.6	− 19	35	10			

Comet 1892 I.—Swift's comet is still an easy object in small telescopes. On the evening of Sept. 20 it was quite conspicuous in our 5-inch finder. It has a well defined nucleus and short broad tail. It is now in the southern part of the constellation Cassiopeia and moving slowly southwest.

In *Astr. Nach.* 3110 Mr. Berberich gives elliptic elements of this comet depending on observations of March 8, April 10, May 12 and July 12. The best parabola gave residuals of 28″ and 20″ in the latitudes of the middle places, while the ellipse gave very small residuals.

On the other hand, Miss F. Gertrude Wentworth (*Astr. Jour.* No. 273), using observations of several observers on the dates March 7, May 4 and June 29, finds parabolic elements completely representing the observations. The following ephemeris calculated by Miss Went[illegible]h is taken from *Astr. Jour.*, No. 274.

Ephemeris of Comet 1892 I (Swift.)

Gr. M. T.		App. R. A.			App. Decl.		log Δ	Brightness
		h	m	s	°	′		
Oct.	1.5	0	03	38.9	+47	21.8		
	2.5		2	36.4	47	05.9		
	3.5		1	35.5	46	49.8		
	4.5	0	00	36.3	46	33.5	0.3070	0.050
	5.5	23	59	38.9	46	17.1		
	6.5		58	43.2	46	00.4		
	7.5		57	49.3	45	43.6		
	8.5		56	56.7	45	26.7	0.3146	0.046
	9.5		56	05.2	45	09.6		
	10.5		55	15.4	44	52.2		
	11.5		54	27.0	44	34.7		
	12.5		53	40.7	44	17.1	0.3270	0.043
	13.5		52	56.3	43	59.5		
	14 5		52	13.7	43	41.8		
	15.5		51	32.8	43	24 0		
	16.5		50	54.0	43	06.1	0.3320	0.040
	17.5		50	17.0	42	48.2		
	18.5		49	42.0	42	30.2		
	19.5		49	09 0	42	12.2		
	20.5	23	48	38.1	41	54.7	0.3415	0.037

NEWS AND NOTES.

Foreign subscribers are reminded that money orders may be drawn on Northfield as its post office has recently been made a foreign money order office.

The Sidereal Messenger forms one series of this publication consisting of ten volumns covering a period from 1882 to the end of 1891. Astronomy and Astro-Physics began with January 1892. The volume for this year, the first in the new series, will contain about 1,000 pages with nearly fifty full page plate engravings.

The Planet Mars. We have given large space in this number, to recent studies of the planet Mars by some of the best astronomers in this country. Our readers will find it all most valuable matter, but wholly devoid of all that highly sensational and imaginative display of knowledge about the people of Mars which has appeared so constantly in the daily papers during the last sixty days.

Is Mars Inhabited?—Whether the planet is inhabited or not, seems to have been the all-absorbing question, everywhere in popular thought and expression. With the astronomer this query is almost the last thing about the planet that he would think of when he has an opportunity to study its surface markings at such a favorable opposition as that which has recently past. No astronomer claims to know whether the planet is inhabited or not. The chief thing that he is after is to see all he possibly can of detail markings on the planet's surface, measure and map as much as he can be sure of by repeated observation. This is painstaking, and very laborious work, courageously pursued every favorable night as long as the planet is within reach of the telescope. Under such circumstances the astronomer would not have much to say about the people of Mars, however pointedly he might be questioned. This brings to mind the report that has been circulated far and near, that we have said " Mars is undoubtedly inhabited " *We have never made any such statement.*

An Account of the Discovery of a Fifth Satellite to Jupiter.—I am glad to write some account of the discovery of the fifth satellite of Jupiter for ASTRONOMY AND ASTRO-PHYSICS, as telegraphically requested by the editor.

I have already sent to Dr. Gould for the *Astronomical Journal* all my micrometrical observations so far obtained of the satellite and a short account (which will be a historical record) of the conditions of the discovery. It is unnecessary for me to go into those same details here, as they will be found on record in the pages of the *Astronomical Journal.*

Friday being my night with the 36-inch telescope, after observing Mars and measuring the positions of his satellites, I began an examination of the region immediately about the planet Jupiter. At 12 o'clock as near as may be, to within a few minutes, I detected a tiny point of light close following the planet and near the 3rd satellite which was approaching transit. I immediately suspected it was an unknown satellite and at once began measuring its position-angle and distance from the 3rd satellite. On the spur of the moment, this seemed to be the only method of securing a position of the new object, for upon bringing the slightest trace of the planet in the field the little point of light was instantly lost.

I got two sets of distances and one set of position-angles, and then attempted to refer it to Jupiter but found that one of the wires of the micrometer was broken out and the other loose. Before anything could be done the object rapidly disappeared in the glare of Jupiter. From the fact that it was not left behind by the planet in its motion, I was convinced that the object was a satellite. A careful watch was kept at the preceding limb of the planet for the reappearance of the satellite, but up to daylight it could not be seen.

Though positive that a new satellite had been found, extreme caution suggested that it would be better to wait for a careful verification before making any announcement.

The following night with the 36-inch belonging to Professor Schaeberle, he kindly gave it up to me, and shortly before midnight the satellite was again detected rapidly leaving the planet on the following side. That morning I had put new wires in the micrometer, and now began a series of careful measures for position. As I have said, the satellite was so small that no trace of Jupiter could be admitted into the field for reference in the measures. It was necessary, therefore, to bisect the satellite, with the planet out of the field, and then by sliding the eye-piece bring the limb of Jupiter into view and bisect it. This method did not permit any measures from the polar limbs of Jupiter. Following the satellite thus, it was seen to recede from the planet to a distance of some 36″ from the limb when it gradually became stationary. Remaining so for a while it began once more to approach the planet and rapidly disappeared in the glow near the limb. The measures, repeated as rapidly as possible, thoroughly covered the elongation, and gave the means of approximating to its period.

The following morning a telegram was sent out announcing the discovery. Subsequent observations have thoroughly confirmed the discovery.

On account of its extreme closeness to the planet it is difficult to say just what its magnitude is. Taking everything into account, I have provisionally assigned it as thirteenth magnitude. I hope to be able to settle definitely this question by observing some little star near Jupiter and then afterwards determining its magnitude when the planet has left it. Until this is settled, any estimate of the actual size of the satellite must be the merest guess, but it will probably be found to not exceed 100 miles in diameter, and perhaps less than that.

After the first few observations I inserted a piece of smoked mica in the eye-piece, and using this as an occulting bar, the measures were made with ease and accuracy. Careful measures thus made from the polar limbs for the Jovicentric latitude of the satellite, show that its orbit lies sensibly in the plane of Jupiter's equator and that consequently the satellite is not a new addition to the Jovan family, since it would doubtless require ages for the orbit to be so adjusted if the object were a capture.

A sufficiently long interval has not yet elapsed to permit an accurate determination of the periodic time of the new satellite, but using three of the measured elongations and the known mass of Jupiter I have deduced the following approximations to the period, by the formula:

$$P = p\sqrt{\frac{m}{M}\frac{R^3}{r^3}}$$

where m and M are the masses of the Earth and Jupiter, and p and r the period and distance of our Moon, R in the three cases being derived from the direct measures and having the following values:

112,250 miles	Periodic Time = 11^h 47.6^m
112,750 "	11 52.3
112,400 "	11 49.0

Hence the mean of these—11^h 49.6^m—will not be far from the truth, as it seems to satisfy the mass of Jupiter.

It will be thus seen that this new satellite makes two revolutions in one day, and that its periodic time about the planet is less than two hours longer than the axial rotation of Jupiter. Excepting the inner satellite of Mars it is the most rapidly revolving satellite known. When sufficient observations have been obtained it will afford a new and independent determination of the mass of Jupiter. Of course from what I have said in reference to the difficulty of the new satellite, it will be apparent that the most powerful telescopes in the world, only, will show it.

E. E. BARNARD.

Mt. Hamilton 1892, Sept. 21.

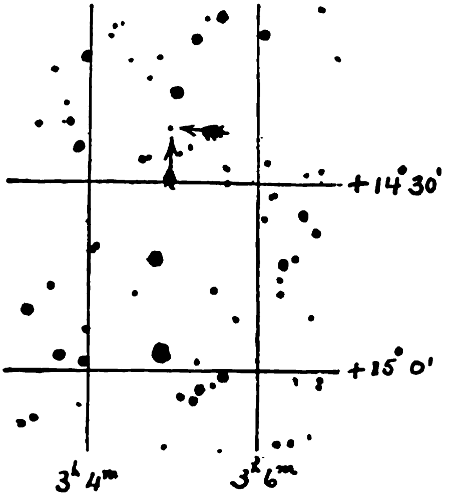
Nova Aurigæ.—Observations have been made of Nova Aurigæ at the Harvard College Observatory on every clear evening since its reappearance has been announced. In the spring it was last seen here on April 26, when it had the magnitude 14.5 Later observations were prevented by its low altitude in the evening twilight. Observations by Mr. O. C. Wendell with a photometer attached to the 15-inch equatorial on September 2, 6, 7, 8 and 9, gave the stellar magnitudes 10.62, 10.60, 10.57, 10.57 and 10.54. The change, if any, appears therefore to be very slight and to indicate an increase in light. These observations show that it is slightly brighter than the star following it at 3^s and $2'$ north, whose magnitude is found to be 10.94. A series of photographic charts, on the other hand, make it about half a magnitude fainter than this star, showing that its color is on the whole redder than that of the comparison star.

Its spectrum was last certainly photographed in the spring on March 24 when of the eleventh magnitude. On March 21, the hydrogen lines G, F, H, and h were shown in the order of brightness named. On September 2, two lines of nearly equal brightness were clearly shown in the photograph, one coinciding with the hydrogen line G, the other having a somewhat greater wave-length than F, and probably coinciding with the principal nebula line $\lambda = 500$. An interesting analogy is suggested in the observation of Lord Lindsay in 1877 that Nova Cygni then gave the spectrum of a planetary nebula (Observatory III, p. 185).

EDWARD C. PICKERING.

Harvard College Observatory, Cambridge, Mass., Sept. 12, 1892.

A New Variable Star in Aries.—With the aid of some photographic plates kindly lent to us by the Harvard College Observatory I have found a new variable star in the approximate position R. A. $3^h\ 49^m$; Decl. + 14° 22′ (1892).



NEW VARIABLE STAR IN ARIES.

On one of the two plates available the image corresponds to a star of about the 9.5 magnitude, while on the other plate the image if present, is fainter than the faintest images which can be recognized with certainty. Visual observations made with a six-inch telescope show a star of the eleventh magnitude in the proper position.

To make sure of the identity of the star I made an exposure of 60^m, with the Willard lens of the Crocker telescope, on Aug. 26. The photographic magnitude as shown on the resulting negative is about the same as the visual, viz., eleventh. On the following night viewed through the 36-inch telescope the spectrum was found to contain bright lines and bands. Last night Professor Campbell measured the positions of some four or five of these bright lines.

As the star is now very faint I have made the accompanying diagram (from a photograph taken Aug. 26) of the region, with the aid of which it will be easy to identify the star. The brightest star in the diagram is 8.7 magnitude; the faintest, about 11.5 magnitude.

J. M. SCHAEBERLE.

Nova Aurigæ a Nebula.—Mr. Campbell having announced that Nova Aurigæ was again bright, I have taken the first opportunity to examine it with the 36-inch, and this morning found the object to be really a small bright nebula with a 10th magnitude nucleus. The nebula is of that class which appear stellar with low powers or insufficient optical means. With the micrometer the nebulosity was found to be 3″ in diameter—a fainter nebulosity still surrounded this and was perhaps ½′ in diameter. The position of the Nova was carefully measured with reference to two small stars previously used by Mr. Burnham in his careful chart of the region about the Nova published in M. N., Vol. LII., No. 6.

Following are his measures and my own present ones:

	A and E.		
1892.14	323°.6	74″.24	*β* 3 *n*
1892.64	323 .3	74 .24	B 1 *n*
	A and F.		
1892.12	32°.4	85″.05	*β* 4 *n*
1892.64	32 .6	85 .03	B 1 *n*

These measures show conclusively that the Nova has not sensibly changed its position in six months. The nucleus is one-tenth or two-tenths magnitude less than the star F, though the nebula as a whole is brighter.

I am familiar with other nebulæ that are exactly similar to this object.

Mt. Hamilton, 1892, Aug. 20. E. E. BARNARD.

A New Variable Star.—At the request of Professor Holden, Director of the Lick Observatory, the discovery by Professor Schaeberle, of that Observatory, of a new variable star is announced in the present article. The discovery was made during the examination for another purpose of a series of photographs made at Harvard College Observatory with the eight-inch photographic telescope of that institution. Upon one of these plates, taken December 18, 1891, Professor Schaeberle noticed a star of the magnitude 9.5 which could not be certainly found on another plate taken January 24, 1891, and may consequently be assumed to have been at that time much fainter than the eleventh magnitude. Recent visual observations, made by Professor Schaeberle with a six-inch telescope, showed a star of about the eleventh magnitude in the place of the suspected variable, and these observations were confirmed by a photograph which he took with the Willard lens and an exposure of 60^m. On August 27, 1892, the spectrum of the star was examined with the 36-inch telescope of the Lick Observatory and found to contain bright lines.

From additional photographs of the same region, preserved at Harvard College Observatory, the following photographic magnitudes of the star have been obtained:

1890	Oct.	31	9.6	1891	Nov.	25	10.0
	Dec.	20	10.2		Dec.	16	10.4
	Dec.	29	11.0		Dec.	17	10.3
1891	March	14	<11.7	1892	Jan.	5	10.9
	Nov.	25	10.1				

These photographs, accordingly, confirm the fact of the variability of the star. Its position for 1900 is as follows: R. A. $3^h\ 5^m.5$; Decl. + 14° 24′.

EDWARD C. PICKERING,
Director of Harvard College Observatory.

Cambridge, U. S., Sept. 9, 1892.

PUBLISHER'S NOTICES.

The subscription price to ASTRONOMY AND ASTRO-PHYSICS in the United States and Canada is $4.00 per year, in advance. For foreign countries it is $4.40 per year which is the uniform price. Messrs. Wesley & Son, 28 Essex Street, Strand, London, are authorized to receive subscriptions. Payment should be made in postal notes or orders or bank drafts. Personal checks for subscribers in the United States may be used.

Currency should *always* be sent by registered letter.

Foreign post-office orders should *always* be drawn on the post-office at Northfield, Minnesota, U. S. A.

All communications pertaining to Astro-Physics or kindred branches of Physics should be sent to George E. Hale, Kenwood Astro-Physical Observatory Chicago, Ill.

All matter or correspondence relating to General Astronomy, remittances, subscriptions and advertising should be sent to Wm. W. Payne, Publisher of ASTRONOMY AND ASTRO-PHYSICS, Goodsell Observatory, of Carleton College, Northfield, Minn.

Manuscript for publication should be written on one side of the paper only and *special care should be taken to write proper names and all foreign names plainly*. All drawings for publication should be *smoothly* and *carefully* made, in *India ink* with lettering well done, because such figures are copied exactly by the process of engraving now used. If drawings are made about double the size intended for the printed page, better effect will be secured in engraving than if the copy is less in size. As a rule the publishers have had to re-draw the figures seen during the last year at considerable expense. We hope to avoid this in the future. It is requested that manuscript in French or German be type-written. If requested by the authors when articles are sent for publication, *twenty-five* reprint copies, in covers, will be furnished free of charge. A greater number of reprints of articles can be had if desired, at reasonable rates.

Rates for advertising and rates to news agents can be had on application to the publisher of this magazine.

Astronomy and Astro-Physics.

NEW SERIES No. 9. NOVEMBER, 1892. WHOLE No. 109

GENERAL ASTRONOMY.

THE PROBABLE ORIGIN OF METEORITES.*

GEORGE W. COAKLEY.†

In the problem discussed in this paper the term *meteorites* is used to denote only those solid masses of metals or minerals which have been ascertained to have fallen upon the Earth from some source beyond it. The term is used particularly to exclude the case of a *shooting-star*, or a shower of such stars, as the thirty-three year November shower, or the annual August shower, or any similar meteoric display.

In the popular mind, and even in the minds of many astronomers, no sufficient distinction is made between the nature, or the flight, of a solid meteoric mass, and that of a shooting-star or meteoric shower. The great November shower of meteors has been identified with the motion and path of a comet; so also has the annual August shower been identified with the motion and orbit of another comet. Other similar identifications have been made; and the conclusion has been securely reached that these meteoric displays are the consequence of the Earth's passing through the intersections of her orbit with those of some great comets, and that the fragments, into which these comets have been divided by some cause, traverse our atmosphere with immense velocities. So great is the velocity with which these numerous small pieces of a comet rush through our atmosphere, that they are instantly inflamed, giving us the magnificent display of a meteoric shower, or sometimes of a single shooting-star. Every astronomer who examines the evidence for this view of the meteoric showers must admit its truth. But some go farther and include the case of *meteorites*, or solid bodies falling upon the Earth, in the same cometary theory.

There are, however, several important facts which seem to separate entirely the case of these solid meteorites from that of

---

* Communicated by the author.

† Professor of Mathematics and Astronomy, University of the City of New York.

the shooting-star, or the meteoric shower. For, while the shooting-star, or one of those that constitute the shower, is never seen for more than half a second of time, or a second at most (except that it may leave an illuminated trail after it, of more permanent duration), the meteorite, on the contrary, when seen in its flight through the air, is visible sometimes for a minute or more. This is undoubtedly owing to its much slower velocity than that of the single or multiple shooting-star.

The late Professor J. Lawrence Smith, of Kentucky, was for many years one of the most persistent and painstaking students of all ascertainable facts with regard to meteorites, or meteoric stones. He collected the evidence of their phenomena, traced the appearances they presented to observers, and their whole history, and he procured and analyzed many specimens of them. Among his latest conclusions with regard to meteorites were, first, that they had, from all accounts, a much slower motion than that of the shooting-star, or *meteor proper*; and secondly, he announced the conclusion that they probably had a totally different origin from that of the shooting-stars, or meteoric showers. He also noticed their close resemblance, in chemical composition, to volcanic minerals.

Professor Ball, the Astronomer Royal of Ireland, in his interesting work, "The Story of the Heavens," says:

"We have shown that the well-known star-showers are all intimately connected with comets. In fact each star-shower revolves in the path pursued by a comet, and the shooting-star particles have, in all probability, been derived from the comet. Showers of shooting-stars and comets have, therefore, an intimate connection; but there is no ground for supposing that meteorites have any connection with comets,—the facts, indeed, all seem to me to point in the opposite direction."

"Meteorites have never been known to fall from the great star-showers. No particle of a meteorite was ever dropped from the *countless host* of the Leonids, or of the Perseids; the Lyraids never dropped a meteorite, nor did the Geminids, or the many other showers with which every astronomer is familiar. There is no reason to connect meteorites with these showers, and there is, accordingly, no reason to connect meteorites with comets. Indeed, the appearance of a comet, and the history of its movements and its changes, seem entirely at variance with the supposition that it is composed of materials resembling those in meteorites."

Professor Ball regards comets, as he elsewhere argues, as entirely of a gaseous nature, with nothing *solid* about them. He also points out the slow motion of meteorites, and argues that if they passed through our atmosphere with anything like the velocity which the shooting-star meteors are known to have (some twenty-six miles per second, as Professor Young states), the meteorites would be almost instantly vaporized and burned up, so that nothing but their constituent gases and ashes would reach the Earth. Still the motion is rapid enough to heat the meteorites so much as to form a fused crust around them to a small depth, and also to cause them frequently to explode into fragments with loud detonations, which have been heard to accompany their flight.

With regard to the nature and origin of meteorites, Professor Ball states the following "theory entertained by the Austrian mineralogist (Tschermak). He has made a study of the meteorites in the rich collection at Vienna, and he has come to the conclusion that the meteorites have had a volcanic source on some celestial body." Professor Ball then says, "Let us attempt to pursue this hypothesis and discuss the problem which may be thus stated: Assuming that meteorites have been ejected from volcanoes, on what body or bodies in the universe must these volcanoes be situated? This is really a question for astronomers and mathematicians. Once the mineralogist assures us that these bodies are volcanic, the question becomes one of calculation and of the balance of probabilities."

After trying the various planets of our solar system, including the asteroids and our Moon, he finds it difficult to place the volcanoes on any of them, with power to send us the meteorites. He therefore returns to the Earth, placing here the required volcanoes, but acknowledging frankly that none of our *present* volcanoes have the power to eject the meteorites with force enough to cause them to wander through the planetary regions, and to subsequently return to us, after many revolutions around the Sun. He thinks that in the old geologic times, some millions of years ago perhaps, the power of our volcanoes must have been sufficient to throw out these materials, and that they are now finding their way back to their old home.

The objections to Professor Ball's location of the volcanoes that send forth the projectiles to become meteorites, are, first, the enormous force required to perform this work. It is known that the velocity acquired by a body falling upon the Earth from an *infinite distance* is nearly seven miles per second, and that a force would be required that should impart this same velocity of seven miles per second to a projectile, to cause it to escape the Earth's power of attracting it back to its surface. The maximum velocity imparted to a cannon ball may be taken to be 2,000 feet per second. But the force to impart seven miles per second would be more than eighteen times as great as that required for the cannon ball. Could the Earth's volcanoes at any time have supplied so great a force? The required force would be even many times greater than that above stated; because the resistance of the Earth's atmosphere would, in addition, have to be overcome. This resistance tends to rapidly reduce the initial velocity imparted to the projectile, so that sufficient additional velocity beyond the seven miles per second must be supplied to overcome the resistance.

Secondly, if the required velocity were supplied from the Earth, the projectiles would become small planets revolving around the *Sun*, not around the Earth, since they would have to fly far beyond the moon, in order to be beyond the Earth's power of bringing them back to her surface in a short time; and besides they would retain the Earth's velocity of 18 miles per second in her annual orbit. The theory proposed in this paper, to account for the meteorites, is not the writer's own; it is not new. It prevailed during most of the last century, and was maintained by the greatest astronomers and mathematicians. It is simply that the volcanoes claimed as the origin of meteorites by the Austrian mineralogist, and laboriously sought after by Professor Ball, existed formerly in an active state on our Moon, and that they, and they alone, had the requisite power to throw these solid bodies beyond the reach of the Moon's prevailing attraction, and within the controlling attraction of the Earth.

About a century ago the problem of the origin of meteorites, or aerolites, was discussed by Laplace, Lagrange, Poisson, Legendre and other great mathematicians. They generally agreed that the most probable origin was the *formerly active* volcanoes of our moon.

This is what Laplace says in the fifth chapter of the second volume of his "Systeme du Monde," from which the writer translates freely (Sixth Paris edition):

"The attraction of gravity on the surface of the Moon being much less than on the surface of the Earth, and this satellite having no atmosphere which might oppose a sensible resistance to the motion of projectiles, we may conceive that a body thrown with a great force by the explosion of a lunar volcano, might reach, and pass beyond the *limit* where the Earth's attraction would begin to be superior to the Moon's attraction. It would suffice for this purpose, that the body's initial velocity in a vertical direction should be 2,500 meters per second," (about one and a half miles per second.) "Then instead of falling back upon the Moon, it would become a satellite of the Earth, and would describe around the Earth a more or less elongated orbit. The primitive impulse given to the body might be so directed that it would go straight to meet the Earth's atmosphere; or it might also be so directed that the body would not meet our atmosphere until after many, or even a *very great number of revolutions.* Because it is evident that the Sun's attraction, which changes in a very sensible manner the distances of the Moon and the Earth, ought to produce in the radius-vector of a satellite, moving in so very eccentric an orbit as that of the projected body, *variations* very much larger than those produced in the Moon's radius-vector. The disturbing action of the Sun might at length diminish the perigee distance of this new satellite to such a degree that the body could penetrate within our atmosphere. This body, in traversing the atmosphere with a great velocity would experience therefrom a very great resistance, and would at last be precipitated upon the Earth. The friction of the air against its surface would suffice to inflame it, and to cause it to detonate, if it contained materials suitable for these effects. It would then afford us all the phenomena which aerolites present.

If it were well proved that these bodies are not the products of our own volcanoes, nor of our atmosphere, and that it is necessary to seek their cause outside, in the celestial spaces, then the preceding hypothesis, which also explains the identity of composition observed in aerolites, by the identity of their origin, would not be destitute of probability."

This is Laplace's statement of the theory of meteorites, with the *lunar volcanoes* as their origin. It deserves careful comparison with Professor Ball's statement of their lunar origin, and with his reasons for rejecting that origin. They are principally two; first that there are now no active volcanoes on the Moon to send us meteorites at present. This argument applies as well to his theory of their terrestrial origin; for he admits that none of our present volcanoes could supply the requisite force. Secondly he can not admit that the Sun's disturbing force could bring the meteorites within our atmosphere, as Laplace shows it could. This argument also militates against his terrestrial origin of the meteorites, which would require perhaps an even greater perturbation to produce the required effect, since they would revolve around the Sun, and not around the Earth.

After the demonstrations of the great mathematicians no one thought of denying this lunar origin of aerolites, until it was found that the shooting-stars possessed a velocity of more than twenty miles per second. Then it was seen at once that the earth's attraction could never impart to *them* any similar velocity, since the greatest velocity that could be so imparted is a little less than seven miles per second. It follows at once that the shooting-star could not be projected from the moon, and be drawn to the Earth by the latter's attraction. For, in that case, the shooting-star's velocity could not exceed seven miles per second, instead of being more than twenty miles per second.

But the mistake was made of confounding the slowly moving aerolite, or meteorite, with the swiftly moving shooting-star, and thence concluding also that the meteorite could not come from the Moon. The conclusion was a *nonsequitur*, because the velocity really belonging to one class of these bodies, was wrongly attributed to the other very distinct class of the meteorites. It will be observed that Laplace speaks of the *limit of distance* from the Moon, at which the Earth's attraction *begins* to preponderate over that of the moon. Now it is a comparatively easy problem to determine how far from the Moon's center, in every direction, this *limit of distance* extends, and also to determine the *shape* of this limit. The condition for determining it is, evidently, that a body simply placed, without motion, any where on this limit, for any given position of the Earth and Moon, should be *equally attracted* towards the Earth and towards the Moon.

There is in the Astor Library, in New York, a small treatise by the great mathematician, Poisson, on the lunar origin of aerolites, or meteorites, in which he determines this *limit* to be the *surface of a sphere* surrounding the Moon on all sides. But the Moon's centre is not at the centre of this spherical limit. The centre of the sphere is on the prolongation of the line joining the centres of the Earth and Moon, beyond the Moon's surface by nearly her whole diameter.

If we denote by a, the mean distance betwen the centers of the Earth and Moon, where $a = 238.840$ miles, according to Professor Young, then the centre of Poisson's limiting sphere lies beyond the Moon's centre at the distance $\frac{a}{80} = 2{,}985.5$ miles provided the Moon's mass is $\frac{1}{81}$ of the Earth's mass. The radius of the sphere is $\frac{9a}{80} = 26{,}769.5$ miles; the distance of the sphere's point, nearest to both the Earth and Moon, is, on the line joining their centres, $\frac{a}{10} = 23{,}884$ miles from the Moon's centre; and the distance from the Moon's centre to the point farthest from both the Earth and Moon, on the prolongation of the line of centres, is $\frac{a}{8} = 29{,}855$ miles.

Any point *within* this sphere is more attracted by the Moon than by the Earth; every point *outside* this sphere is more attracted by the Earth than by the Moon. Only on its surface are the attractions of the two bodies equal.

The advantage of knowing this limiting sphere of equal attraction between the Earth and Moon is, that we are not obliged to determine the velocity with which the Moon must project a body in order to send it to an *infinite distance*; but only the smaller velocity with which the body must be projected to reach the surface of this sphere, or just to pass beyond it, so that the body will not return to the Moon.

The velocity with which a lunar volcano, nearest the Earth, must project a body, to just reach the nearest point of the sphere of equal attraction, at the distance from the Moon's centre equal to 23,884 miles, is found to be 1.443 miles per second. The velocity with which the body must be projected from a lunar volcano farthest from the Earth, on the opposite hemisphere of the Moon, to a distance from her centre equal to 29,855 miles, is found to be 1.450 miles per second. But while the projectile in the former case, thrown *towards* the Earth, is leaving the Moon's surface, and drawn back by her attraction, its flight is being *helped* by the Earth's attraction, which *alone* would impart to it a *final velocity* at the surface of the sphere, equal to 0.292 miles per second.

Hence the lunar volcano nearest the Earth needs only to impart the velocity $1.443 - 0.292 = 1.151$ miles per second in order to cause the projectile to reach the surface of equal attraction. This is only about three times the maximum velocity of 2,000 feet per second, of a cannon ball. In the opposite direction, however, when the projectile is launched from a volcano on the Moon's farthest hemisphere, if there be any there, with the velocity 1.450 miles per second, the Earth's attraction *helps the Moon* to bring it back with a total imparted velocity of 0.292 miles per second. Hence the volcano ought to impart a velocity of $1.450 + 0.292 = 1.742$ miles per second, in order that the body may just reach the sphere of equal attraction. This velocity is only about four and a half times the cannon ball's maximum velocity of 2,000 feet per second. However, it is not improbable that, in this last case, the Earth's attraction would help the Moon to bring back the projectile to her surface. Though it is probable that the Moon's farthest hemisphere has been subject to volcanic action, like the hemisphere nearest to us, yet we know nothing certain with regard to that distant hemisphere. We shall not count on it in any way in the theory of meteorites except that it is now certain that an initial velocity of from three to about four and a half times the maximum velocity of a cannon ball applied in a vertical direction to a projectile at any point of the Moon's surface would bring it to the surface of the sphere of equal attraction between the Earth and Moon.

Indeed we may leave out of account any lunar volcano situated more than 84° on a great circle across the Moon's disk from the point nearest the Earth. In this case every projectile from any volcano within these 84° will be more or less *assisted*, in its flight from the Moon's surface, by the Earth's attraction. The extreme velocity which the volcano alone must supply to the projectile will then be just about four times the cannon ball's maximum velocity; and the least velocity required from the volcano will be three times this maximum velocity of the cannon ball. Hence we have the fact that over a wide range of 168° on a great circle of the Moon's nearest hemisphere, in every direction from its visible centre, a lunar volcano needs only to impart these moderate velocities, of three or four times that of a cannon ball, to send a projectile to the surface of *the sphere of equal attraction* between the Earth and Moon.

Every astronomer knows that the Moon's nearest hemisphere is almost covered, in all directions, by the craters of extinct volcanoes, many of them far greater in extent than any on the Earth. It can hardly be doubted that the Earth's volcanoes are capable of imparting, in a vertical direction, a velocity three, four or five times that of the cannon ball's maximum. Hence these *larger lunar volcanoes* must be considered capable of exerting at least an equal force. The bodies projected from them would reach the surface of the sphere of equal attraction with various velocities, and from all directions within 84° of the Moon's visible centre, on a great circle across her disk. If the greater part of these projectiles had fallen back to the Moon the interior floor of her volcanic craters would present a very different appearance from that observed. They would be filled up with these irregular fragments, instead of presenting usually a deeply excavated and smooth surface, only broken occasionally by a few small volcanic cones, the effects probably of subsequent minor eruptions.

The Moon's volcanoes must have been active for many ages, though they have now been extinct perhaps for millions of years. The explosions, which may have sent forth the masses that have fallen on the Earth, should be considered as having taken place at various periods, after long intervals from the same volcano, and also at different times, and in various directions, from other volcanoes with a different situation on the Moon's surface. The projectiles should not be considered as all starting at once from all the volcanoes; but their ejections should be regarded as spread over long intervals of time, whether from the same or from different lunar volcanoes.

Let us consider more particularly the probable course of some one projectile, thrown from the visible centre of the moon's disk directly towards the Earth, and with just sufficient velocity to cause it to reach the nearest surface of the sphere of equal attraction. What would happen when the projectile reached this point? It certainly would not go back to the Moon, because the Earth's equal attraction would prevent such a result. Neither would it go directly to the Earth, because of the Moon's equal attraction. But the Moon has the same average velocity of about 18 miles per second around the Sun, which the Earth has in her annual orbit. Hence the projectile in consideration, having this same velocity of 18 miles per second, will go around the Sun in an annual orbit just as the Earth and the Moon do. Also the moon has a velocity of about 0.636 miles per second in her relative orbit about the Earth; and the projectile will also have this same velocity eastward, and will therefore revolve about the Earth just as the moon does, and nearly in the same time, and in the same plane. It will become a satellite of both the Sun and the Earth. The perturbations of its orbit about the Earth, by both the Sun and the moon, will be very great; but they may never cause it to fall on the Earth, as even Laplace supposes, because its orbit will be too nearly circular, or of *small eccentricity*. At any rate, if this projectile ever reached the Earth, it would have to be after a very prolonged period. In saying that such a projectile might come straight to the Earth, Lalace must have overlooked its orbital velocity about the Earth, derived from the Moon.

Suppose that another projectile from the visible centre of the Moon's disk were thrown with a slight excess of velocity above that requisite to bring it to the surface of equal attraction.

Then it would become a satellite of the Earth, as well as of the Sun, with an eccentricity of its orbit depending upon the amount of this excess of initial velocity. The apogee of its orbit about the Earth would be near the Moon, or rather near the *surface of equal attraction*, on the side towards the Earth; and its perigee would be diametrically opposite, on the other side of the Earth. As Laplace points out, the Sun's attraction would disturb the figure and dimensions of the projectile's orbit about the Earth, and might bring its perigee nearer the Earth by an amount depending upon the eccentricity of the orbit.

Another projectile from the same volcano, at a different time, might have a greater initial velocity, producing a still greater eccentricity of its orbit about the Earth, with a consequent yet greater disturbance of its perigee. In this way there might be very many projectiles from this one volcano, their ejections being spread over long periods of time, with all sorts of initial velocities within the requisite limits, producing orbits about the Earth with almost every degree of eccentricity, and consequent perturbations by the Sun. Suppose farther that similar projectiles have been thrown, at various times, while the lunar volcanoes were still active, by each of them, wherever placed on the nearest hemisphere of the Moon, and with every degree of initial velocity within the proper limits. The various *directions* as well as the *velocities* of these projectiles would ensure a great variety of eccentricities in their orbits about the Earth. They may continue to revolve around the Earth for many ages, even after the lunar volcanoes became extinct, before the Sun's attraction could bring their perigees so near the Earth as to cause them to penetrate our atmosphere. From the great number and variety of these orbits, the epochs, when their perigees should be so reduced by the Sun's action, might readily be *spread throughout the ages.* Portions of these projectiles may have been dropping upon the Earth for many ages past, and they may continue to do so, for many ages to come.

This theory of the Lunar Origin of Meteorites seems to be far more probable, than their derivations from comets, or from the meteoric ring-systems which have been identified with comets.

The equivalent of Poisson's proof of the *sphere of equal attraction* between the Earth and moon is as follows:

Let C_1 be the moon's centre, and C_2 be that of the Earth; and let their mean distance, $C_1C_2 = a$, the mass of the Earth being denoted by M, that of the moon by m. Then if P be the position of a body equally attracted by the Earth and the moon, a plane may be passed through P, and the line $C_1 C_2 = a$, joining the centres of the two bodies. Let the line of centres be taken as an axis of abscissas, the origin being at the Moon's centre, and the abscissas counted positive towards the Earth. A perpendicular from P to this axis will be the ordinate, and the distance from its foot to the moon's centre, the abscissa of the point P. Let $D_1 =$ the distance of the moon's centre from P, and $D_2 =$ the distance from the same point P to the Earth's centre. Then, evidently, $D_1^2 = y^2 + x^2$, $D_2^2 = y^2 + (a - x)^2$; hence

$$\frac{D_2^2}{D_1^2} = \frac{y^2 + (a - x)^2}{y^2 + x^2}, \qquad (1).$$

But the attraction of the Earth for a body at P is, disregarding its sign, $\frac{M}{D_2^2}$; and the attraction of the moon for the same body is $\frac{m}{D_1^2}$. By supposition these attractions are equal. Hence

$$\frac{m}{D_1^2} = \frac{M}{D_2^2}; \text{ or } \frac{D_2^2}{D_1^2} = \frac{M}{m} = 81, \qquad (2).$$

Comparing (1) and (2) gives

$$\frac{y^2 + x^2 - 2ax + a^2}{y^2 + x^2} = 81, \qquad (3).$$

$$\text{Hence, } y^2 + x^2 + \frac{2a}{80}x - \frac{a^2}{80} = 0, \qquad (4).$$

Equation (4) is evidently that of a circle, whose radius is $\frac{9a}{80}$, and its centre on the prolongation of the line joining the centres of the Earth and moon, at the distance from the latter's centre equal to $\frac{a}{80}$. By making the ordinate $y = 0$, the intersections of the circumference with the line of centres will be found to be $\frac{a}{10}$ from the Moon's centre towards the Earth, and $\frac{a}{8}$ in the opposite direction. Since the point P, may be in every possible plane around the line of centres, and in every such plane we have the same circle, hence this point will be on the surface of a sphere, of which each circle is a section by the plane containing P.

THE MOTION OF THE SOLAR SYSTEM.*

J. G. PORTER.

A new determination of the apex of the solar way, based on the Catalogue of Proper Motion Stars in Publication No. 12 of the Cincinnati Observatory, has just been completed. With the exception of the fundamental stars, the proper motions given in this Catalogue were all re-computed, and in the great majority of cases the available data were considerably improved by re-observation of the stars. The results may therefore be considered as on the whole the most reliable that have yet been published. Notwithstanding the exhaustive investigation recently made by Dr. Stumpe, (see *Astronomische Nachrichten* 2999-3000) it seemed worth while to repeat the computation for the Sun's motion, especially as the stars in the present list are more equably distributed than has generally been the case. The method employed was that given by Schönfeld in *Vierteljahrschrift der Astronomischen Gesellschaft*, XVII, p. 256, the equations of condition containing a term which depends on the supposed rotation of the stars in the plane of the Milky Way. This term, however, as in all previous investigations, appears to be insensible.

The stars were divided into four groups according to the amount of proper motion, and the resulting co-ordidates of the apex of the Sun's way as given by the different groups are as follows:

Proper Motion	No. of stars	R.A.	Decl.	$\frac{c}{\rho}$
'' ''		°	°	''
.15 to .30	576	281.9	+ 53.7	0.16
.30 to .60	533	280.7	+ 40.1	0.30
.60 to 1 20	142	285.2	+ 34.0	0.55
1.20 and over	70	277.0	+ 34.9	1.69

The last column gives the angular motion of the Sun as seen from the mean distance of the stars of each group respectively. Dr. Stumpe has already pointed out that the results plainly indicate that the amount of proper motion affords a more correct criterion of the distance of the stars than does their magnitude.

The most noticeable point in connection with the present investigation is the high declination given for the apex by the first group. I believe it is the most northerly declination which has ever been obtained; and yet the large number of stars and their wide distribution would seem to entitle the result to considerable

---

* Communicated by the author.

weight. The rather large difference in the direction of the Sun's motion as given by the first group and by the last two can be most readily explained by the supposition of a common drift for the nearer stars. It would be of great interest to compute the solar motion from stars with still less proper motion than those I have employed. I am glad to know that Professor Boss is now at work on such an investigation, and will doubtless before long be able to throw fresh light on this interesting question.

CINCINNATI OBSERVATORY, Oct. 3, 1892.

STARS HAVING PECULIAR SPECTRA.*

M. FLEMING.

A recent examination of photographs of stellar spectra lately received from the Peruvian station of the Harvard College Observatory and taken under the direction of Professor W. H. Pickering, has added five faint objects, in the constellation Argo, to the list of stars having spectra of the fifth type, and similar to the bright line stars in Cygnus. As forty of these objects have already been announced, this increases the known number to forty-five. The designation of the star, its approximate right ascension and declination for 1900 and its magnitude are given in the first four columns of the following table. The Galactic longitude and latitude are given in the fifth and sixth columns.

Designation.	R. A. 1900		Dec. 1900		Magn.	G. Long.		G. Lat.	
	h	m	°	′		°	′	°	′
——	10	7.6	−60	8	...	252	4	−3	30
A. G. C. 14691	10	40.3	−59	12	8½	255	48	−0	40
——	10	43.4	−58	41	...	255	20	−0	1
A. G. C. 14965	10	52.0	−59	51	8½	256	49	−0	38
——	10	55.8	−57	17	...	256	16	+1	56

In addition to the stars of the fifth type mentioned above, six new variables have been discovered from the photographs received from Peru and one from those taken in Cambridge during July. Their spectra are of the third type having also the hydrogen lines bright, as is the case in the spectrum of *o* Ceti and other variables of long period. A table of these is here given with further details regarding the measurements following it. The constellation is given in the first column and this is followed by the approximate right ascension and declination for 1900 of the variable. The next two columns give the greatest and least

---

* Communicated by Edward C. Pickering, Director of the Harvard College Observatory.

brightness as measured from the photographs. The date on which its spectrum was photographed is contained in the last column.

Constellation.	R. A. 1900		Dec. 1900		Gr. Br.	Lt. Br.	Date.
	h	m	°	′			
Horologium...............	2	49.7	— 50	21	6.2	9.7	Sept. 10, 1891
Octans.......................	5	56.8	— 86	26	7.4	< 11.3	Sept. 11, 1891
Bootis........................	14	22.3	+ 5	7	8.2	10.7	April 26, 1892
Libra..........................	15	18.5	— 22	34	8.4	< 11.0	July 25, 1891
Octans.......................	17	25.9	— 86	46	8.2	< 11.7	Aug. 31, 1891
Sagittarius................	19	49.7	— 29	26	7.5	< 12.6	Oct. 3, 1881
Tucana......................	23	52.2	— 65	56	10.2	< 12.6	Aug. 25, 1892

The variable star in Horologium in R. A. 2^h 49.7^m, Dec. — 50° 21′, was measured on photographs taken on Aug. 21, Aug. 25, Aug. 28, Sept. 7, Sept. 26, Nov. 3, 1889, Sept. 8, 1890, Sept. 10 and Sept. 11, 1891, and gave the magnitudes 9.6, 7.5, 7.6, 8.1, 9.3, 9.7, 7.7, 6.2 and 6.2 respectively.

The variable star in Bootis in R. A. 14^h 22.3^m, Dec. + 5° 7′, was measured on photographs taken on May 19, 1890, May 23, 1891, April 26, May 17, May 24, June 6, June 10, June 12, June 15, July 6 and July 21, 1892, and gave the magnitudes 8.8, 8.2, 8.2, 8.4, 8.4, 8.8, 9.1, 8.9, 9.1, 10.0, and 10. 7 respectively.

The variable star in Libra in R. A. 15^h 18.5^m, Dec. — 22° 34′, was measured on photographs taken on June 4, June 7, June 19, July 6, July 12, July 12, July 22, 1889, March 30, May 29, 1890, May 16, May 16, June 3, June 3, June 3, June 25, July 14, 1891, May 24, June 21, July 12, July 18 and July 25, 1892, and gave the magnitudes 9.0, 9.2, 8.6, 8.5, 8.6, 8.6, 8.6, 9.5, < 11.0, 8.5, 8.4, 8.8, 8.9, 8.8, 9.7, 10.4, 9.9, 8.6, 8.6, 8.4 and 8.5 respectively.

The variable star in Sagittarius in R. A. 19^h 49.7^m, Dec. — 29° 26′, was measured on photographs taken on June 10, June 20, July 8, July 21, Aug. 20, Aug. 22, Oct. 7, 1889, May 28, 1890, May 17, May 17, June 2, June 2, Aug. 11, Oct. 3, 1891, July 11, July 25, Aug. 16, Aug. 18 and Aug. 23, 1892, and gave the magnitudes 11.0, < 11.2, < 12.4, 12.4, 12.0, < 10.7, 11.1, 11.7, < 12.2, < 12.6, < 10.7, < 12.2, 11.0, 7.8, 10.8, 10.9, 8.0, 8.0, and 7.5 respectively.

The variable star in Tucana in R. A. 23^h 52.2^m, Dec. — 65° 56′, was measured on photographs taken on Aug. 13, Sept. 20, Oct. 8, Nov. 28, 1889, July 25, Sept. 10, 1890, June 30, Aug. 25, Aug. 25, Sept. 17, Sept. 17, Oct. 4, Oct. 4, Oct. 5 and Oct. 26, 1891 and gave the magnitudes 10.8, < 11.1, < 11.3, < 12.1, < 12.6, < 12.2, < 10.0, 10.6, 10.3, 10.2, 10.3, 10.6, 10.5, 10.5 and 11.0 respectively.

The region including the variable star in Octans in R. A. 5^h 56.8^m Dec. — 86° 26′ was contained on one hundred and five photographs taken between May 9, 1889, and April 26, 1892, its magnitude being about 7.6 on the first date when it was probably near its maximum. At the following minimum it was fainter than the magnitude 11.0. It was again bright on June 22, 1890, and on Aug. 16 and Sept. 3, 1891, when its magnitude was 8.9, 8.2 and 8.2 respectively. Between these two maxima its minimum was fainter than 11.3 and on March 30 and April 26, 1892, it was fainter than the magnitude 10.8.

The region including the variable star in Octans in R. A. 17^h 25.9^m, Dec. — 86° 46′, was contained on eighty-nine photographs taken between May 14, 1889, and April 26, 1892. On Aug. 29, 1889, its magnitude was 8.4 when it was probably near its maximum. At minimum it was fainter than 10.5. It was bright again an April 8, 1890, when its magnitude was 8.5. At minimum it was fainter than 11.7. On Sept. 20, 1891, it again attained the magnitude 8.4 and on March 30, 1892 it was fainter than the magnitude 10.5.

Photographs of the spectra of A. G. C. 9326, R. A. 7^h 14.8^m, Dec. — 36° 33′ (1900), Magn. 5.3, and of A. G. C. 10963, R. A. 8^h 9.7^m, Dec.—35° 35′ (1900), magn. 5.3 taken on April 18, 1892, and on March 16, 1892, respectively, show the F line bright and place them in the same class with δ and μ Centauri.

The magnitudes given above depend on measures derived from the photographs by using the magnitudes of the comparison stars as given in the Argentine General Catalogue. Since all of these variables are probably red stars, as indicated by their class of spectrum, it will be necessary to apply to the magnitudes given above a correction for color before comparing them with magnitudes obtained from visual observations.

Interesting photographs have been obtained of the spectra of the two objects A. G. C. 6744, R. A. 5^h 39.4^m, Dec.—69° 9′ (1900), magn. 6¼, and A. G. C. 20937 R. A. 15^h 21.9^m, Dec. — 24° 49′ (1900), magn. 8. The first of these is the well known gaseous nebula surrounding 30 Doradus. The photograph shows that its spectrum is unlike that of ordinary gaseous nebulæ. A. G. C. 20937 gives a spectrum which appears to be similar and is probably an object of the same class although its nebulous character has not hitherto been suspected. A photograph of the spectrum of G. C. 2581, R. A. 11^h 45.3^m, Dec. — 56° 37′ (1900), magn. 9½, showing bright lines was obtained on Aug. 2, 1892 at Arequipa in Peru. The research which has resulted in the discovery of the above list of objects forms part of the Henry Draper Memorial.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., Oct. 10, 1892.

THE NEBULAR HYPOTHESIS.*

Continued from p. 570.

We will now project some views on the screen, illustrating the great variety of forms which nebulæ assume.

We have now reviewed such information about the nebulæ as the telescope and the photographic camera can give us; but there is another instrument at the command of the astronomer which has even more wonderful powers than the telescope. You, all know that the spectroscope is an instrument for studying the chemical constitution of a body by means of the light which it emits.

There is not time, within the limits of a single lecture, to explain the principles of spectrum analysis. I will remind you, however, that a glowing gas emits light of certain definite colors only, which going to their appropriate places in the spectrum, and contrasted with the black background due to the absence of other light, appear as bright lines; that a glowing solid or liquid (or greatly compressed gaseous body) gives out light in which all colors are present, forming a continuous spectrum; and that if a cooler gas is placed in front of a luminous solid or liquid body it will absorb some of the light of the latter—just those kinds of rays which the gas is capable of emitting—and the continuous spectrum of the solid will be darkened where the bright lines of the gas would appear if the solid body were removed. Every element has its own characteristic spectrum, which can be recognized either by its appearance or by measurement. It is not possible to consider here all the modifications which should be made of these very general statements.

The spectroscope, when applied to the study of the heavenly bodies, is used in connection with a telescope, as without the latter there would be insufficient light. The spectrum of a nebula was observed with such a combination of instruments for the first time by Dr. Huggins in 1864.

What do we learn about the Andromeda nebula when we direct our spectroscope upon it? The result is disappointing. The spectrum is continuous, and it is very faint. So far, then, the nebula appears to be composed of solid or liquid bodies, but we must be cautious about drawing even this very general conclu-

---

* A lecture by James E. Keeler, Allegheny Observatory, delivered before the Academy of Science and Art, of Pittsburg, on Nov. 6, 1891.

NOTE.—References to the lantern slides which were exhibited in connection with this lecture have been largely omitted. The list of such illustrations was large, showing the latest and best work done in observing the nebulæ. We are sorry that we can not, as we intended to do, give some of these illustrations.—Ed.

sion. So feeble a continuous spectrum may be due to a gas, even under a moderate pressure. The testimony of the spectroscope is simply inconclusive. It is true that some very slight brightenings have been suspected at two or three places in the continuous spectrum, but, if real, they are so very faint that without further investigation it would be unprofitable to base any conclusions on them.

Here is a magnificent photograph of the Orion nebula, taken by Mr. Common. I may remark that as the different parts of a nebula are of very different degrees of brightness, it is impossible to show the whole object clearly in one photograph. The exposure which is necessary to bring out the faint portions is too great for those that are bright. The exposure of the picture which is on the screen was skillfully chosen so as to show the greatest possible extent of the nebula without obscuring the outlines which are familiar to the eye. Here is another very wonderful photograph, taken at Harvard College Observatory. The exposure was so long that the nebula, as we see it in the telescope, is unrecognizable, but this over-exposed photograph shows that the nebula extends to vastly greater distances than it can be traced by the eye, so that it covers a large part of the great constellation of Orion.

The chief characteristic of the Orion nebula, as compared with the class of nebulæ hitherto considered, is its spectrum, which consists of a number of bright lines. Apparently we have to do, in this case, with an immense mass of glowing vapor, and nebulæ giving a bright line spectrum have been classed as *gaseous nebulæ*.

Scattered through the sky are many nebulæ of this class which present small round discs of a greenish blue color, and from their resemblance to the disc of a planet they were called by Herschel *planetary nebulæ*. The diagram represents the planetary nebula known as G. C. 4390. (No. 4390 in Sir John Herschel's General Catalogue of nebulæ.) It shows a round disc, brightening toward the center, where there is a small star.

Viewed with a large telescope, the structure of a planetary nebula is not always as simple as it appears to be when seen with small optical power. Here is a diagram of the nebula G. C. 4373 from a drawing by Professors Holden and Schaeberle with the Lick telescope. Within the circular nebulous background is what appears at first sight to be a bright double ring, but careful study led the observers to conclude that it is really a great spiral.

As in the nebulæ represented in these diagrams, the middle point of a planetary nebula is usually marked by a small star. With the Lick telescope I have never found an exception, all the nebulæ of this class which I have examined having a star usually exactly in the center.

It is impossible that this critical position of a star should in every case, be the result of chance. There is some connection between the star and the nebula. Is the bright point always found at the center of a real star, or is it a condensation of nebulosity, or are both the same thing?

In the case of G. C. 4390, the stellar point in the center is shown by both the telescope and the spectroscope to be undoubtedly a condensation of nebulous matter, but in other planetary nebulæ it is more like a star, and in some cases it is difficult to say whether the object is a planetary nebula with bright nucleus, or a nebulous star. Some stars, then, at least, are formed by the condensation of nebulosity, for the reverse of the relationship, that the star is the parent of the nebula, is hardly admissible.

It is interesting to note that it was the consideration of this class of objects which led Herschel to conclude (of course long before the spectroscope was invented) that there is a "shining fluid" in space, and that all nebulæ are not, as was then supposed, clusters of stars too remote to be resolved by the telescope. The bright star, he argued, must actually be in the center of the nebula. If, then, the nebula is so remote, the magnitude of the central star must be so great as to transcend all the bounds of probability. On the other hand, if the central point is an ordinary star, comparatively close to us, the bodies which give out the nebulous light must be so small as not properly to be regarded as stars at all. He further regarded this self-luminous matter as "more fit to produce a star by its condensation, than to depend on the star for its existence."

Let us now turn to this colored diagram, representing the spectrum of the planetary nebula G. C. 4390, with a solar spectrum above, for reference. The spectrum consists, as you see, of a number of bright lines, only three of which are conspicuous, and a narrow continuous spectrum due to the nucleus of the nebula. There is also a very faint continuous spectrum from the same part of the nebula which gives the bright lines. The spectrum of the nucleus blends somewhat gradually into that of the nebula, and the bright lines of the latter are greatly strengthened where they cross the continuous spectrum. The spectroscope, therefore, shows conclusively that the central star is really in the nebula, and a part of it.

Does the spectroscope tell us what the substances are that give these bright lines? We observe that three of the lines correspond exactly in position with lines of hydrogen in the solar spectrum above. Beyond the limits of the diagram are other hydrogen lines which have been photographed. Hydrogen, therefore, is certainly an important constituent of the nebulæ. The two brightest lines in the nebular spectrum have not been accounted for. No terrestrial element that we are acquainted with gives lines in exactly the same place. There is some slight evidence that both lines are due to the same substance.

The nebulæ, then, appear to be immense masses of glowing vapor, containing hydrogen and unknown substances. From the character of the lines, the gases seem to be very hot and extremely tenuous.

Mr. Lockyer, the distinguished English spectroscopist, holds a very different view from this. He regards the nebulæ as made up of swarms of meteorites, their luminosity being due to innumerable collisions among the separate particles of the swarm. The brightest of the nebular lines is, according to him, a band or "fluting" due to magnesium, its fluted aspect not being apparent on account of insufficient brightness. It is stated that the magnesium fluting in question appears at low temperature, and hence it is not necessary to consider the nebulæ as intensely heated. This view of Mr. Lockyer's is but a part of a very general hypothesis which he has advanced, covering the whole field of stellar evolution.

Some phenomena presented by the nebulæ are certainly more easily explained by this hypothesis. It is difficult to conceive of the nebulæ as intensely heated, but if we regard them as purely gaseous we must suppose them to be either very hot or else electrically excited, and we have no independent evidence in favor of the latter supposition. On the other hand, the meteoritic hypothesis, so far as the nebulæ are concerned, finds little support in the actual phenomena observed with the spectroscope. With powerful apparatus the brightest nebular line does not agree either in appearance or in position with the fluting of magnesium. Other lines, which should be present according to the hypothesis, are missing. The general testimony of the spectroscope is in favor of the view first mentioned, that the nebulæ are mainly gaseous.

However this may be (and future investigation will probably decide the question), we have seen that in some cases stars are formed by the condensation of this nebulous matter. Is this true of other stars? Have all the stars in the sky been formed in the same way?

It is impossible to answer this question definitely, because so few cases come under our actual observation. In extending our generalizations we are apt to try to make everything conform to one pattern, and not to sufficiently take into account the possibility of fundamental difference of structure. The spectra of such stars as we have considered differ from ordinary stellar spectra, and if the difference is due merely to a progressive change of development, the steps of the process are not obvious. There is, however, evidence to show that condensation of nebulous matter may produce stars of a kind better known. In the beautiful cluster called the Pleiades we have an assemblage of stars, with spectra of the most common type, which in no way seem to differ from other stars in the sky. But only a few years ago the Henry Brothers, of the Paris Observatory, found by photography that the whole background of the Pleiades is nebulous. Faint wisps of nebulousity, so dim that for years they eluded the telescope, cling to the principal stars, and establish beyond doubt the fact of physical connection between the stars and the nebula.

The stars in the trapezium of the nebula of Orion are shown by the spectroscope to be formed from the surrounding nebula, and in other parts of the heavens are stars in various stages of the process of evolution.

Having shown that the stars are formed from nebulæ, we cannot consider that our own Sun, which is nothing more than an average star, is an exception, and of course his retinue of planets, including the Earth, must have been formed by the same process. We thus arrive at the same conclusion which was reached by Kant and La Place, reasoning on different data in the opposite direction. These great philosophers gave independently substantially the same explanation of the phenomena presented by the solar system, before the facts which we have just reviewed were known. That of La Place was the most complete and elaborate, and the "nebular hypothesis" is generally mentioned in connection with his name. It was formed before the great principle of the conservation of energy was discovered, and before it was known that heat and other forms of energy are mutually convertible. Hence some of the details as originally worked out by La Place require modification in the light of present knowledge, although his hypothesis is still the basis of that which is accepted to-day.

Let us see what facts we find in the solar system that are *independent of the laws of gravitation*. I will state them as they are given by Professor Young in his *General Astronomy*.

The orbits of the planets and satellites are all nearly circular.

They are all nearly in one plane.

The revolution of all planets is in the same direction.

There is a regular progression of distances.

There is a regular progression of density.

The plane of the planets' rotation is nearly that of the orbit (except probably Uranus).

The direction of the rotation is the same as that of the orbital revolution (excepting probably Uranus and Neptune).

The plane of orbital revolution of the satellites coincides nearly with that of the planets' rotation.

The direction of the satellites' revolution coincides with that of the planets' rotation.

The largest planets rotate most swiftly.

All these relations cannot be accidental. If the planets had come into the system from outer space, like the comets, they would exhibit every diversity of orbit, rotation, etc., conceivable. We must suppose that the Sun and the planets had a common origin.

La Place took for the beginning of the solar system a nebulous mass at a high temperature, rotating slowly on its axis, and extending beyond the orbit of the farthest planet,—in other words, the *Sun*, before it had contracted to a sphere as great in diameter as the solar system. As the mass contracted, its angular velocity increased, according to a well-known mechanical law, and when the centrifugal force at its boundary balanced the attraction of the central mass, a ring was abandoned, while the rest of the material went on contracting. The ring subsequently contracted into a spherical form, forming a planet, and in the process secondary rings might be abandoned, forming satellites.

According to La Place's hypothesis the outer planets are the oldest, and the Sun is younger than any of the planets.

The theory we have considered must be modified somewhat to explain all the facts of the solar system as we now know them. The satellites of Neptune and Uranus have a *retrograde* motion in their orbits, and it is probable that the rotation of the planet is in the same direction. Again, according to the unmodified hypothesis of La Place, no satellite could revolve in a shorter time than the period of rotation of its primary; but the inner satellite of Mars makes a revolution in only 7½ hours, while the period of the rotation of Mars is about 24 hours. How are these apparently anomalous facts to be accounted for?

Another difficulty in elaborating the details of the hypothesis, is to show how a ring is separated from the parent mass. The particles of material in the solar system, diffused throughout a sphere of such enormous magnitude as to fill the orbit of one of the outer planets, would have little or no cohesion. A series of indefinitely thin rings would apparently be continually separating at the circumference of the nebulous mass, instead of a small number of large rings at great intervals apart.

The following explanation appears to be correct; an exactly uniform distribution of matter in the beginning is improbable; it is much more likely that small variations of density would occur. Denser portions would then become local centers of condensation, and thus it would be possible for the whole mass to separate into a small number of large bodies, instead of a great number of very small ones.

The direction in which one of these large masses would rotate after contraction into a spherical form would depend on the distribution of matter in the mass with respect to the center of motion of the mass as a whole, *i.e.*, to the center of gravity of the whole nebula. The rotation might come out direct, or it might come out retrograde.

In general, then, we should expect a permanent *ring* to be formed only under exceptional conditions of uniform density. We have an example of such a ring in the rings of Saturn,—indeed it was this ring system which first suggested the general explanation.

In regard to the short period of Phobos, the inner satellite of Mars, certain researches of Professor George Darwin show that a retardation of the motion of a satellite, and hence *increase in its orbital velocity* may result from tidal action between a planet and its satellite. The enormous length of time required for such action to produce a perceptible effect need not give us any trouble. Our resources in this direction are unlimited.

We now know that it is not necessary to assume that the original nebulous mass was intensely heated, for in the potential energy of its separated particles we have a sufficient explanation of the present high temperature of the Sun. It is the *shrinkage* of the Sun which still keeps up its supply of heat, although thousands of years would be required to make the diminution of its diameter visible to us. A shrinkage of only 250 feet a year would be sufficient to afford the outflow of heat which we actually see. To show how great the heat resulting from arrested motion may be, I will mention that the falling of the Earth into the Sun would generate nearly 6000 times the quantity of heat that would result from burning it, if it were a solid lump of coal. Falling slowly through resistance, the same amount of heat would be generated, but it would not then be developed suddenly.

Have we, finally (for it is impossible to consider at length all these interesting questions), any evidence in the physical aspect of the planets that they have been evolved in the manner which has been described, or at any rate do we find anything which is inconsistent with this view as to their origin?

In the case of the Earth, there is abundant evidence that the surface has been subjected to vastly higher temperatures in the past than those which prevail at present, and also that the temperature of the interior is still high. The spectroscope shows than the Sun and the Earth are made up of essentially the same substances. There are differences, it is true, but they are not greater than we should expect to find under such dissimilar conditions. According to Professor Rowland, the Earth, if heated up to the temperature of the Sun, would give essentially the same spectrum.

In the largest planets we should expect to find the stage of cooling less advanced, and the density small. This latter condition, at least, actually obtains for the larger planets, for we have:

Density of Jupiter = 1.33.
Density of Saturn = 0.72.
Density of Uranus = 1.22.
Density of Neptune = 1.11.

that of water being 1. The density of the Earth is 5.58.

The physical conditions we have referred to can best be studied by the aid of some views of the planets, Saturn and Jupiter.

On studying the heavens, then, we learn that stars are formed by the condensation of nebulæ, which recent investigations have shown to occupy immense tracts of sky. The high temperature of the stars is a necessary result of the process of contraction. As our own Sun is a star, it is probably formed in the same way. Internal evidence, the phenomena presented by the solar system, is in harmony with the external evidence. The nebular hypothesis unites all the known facts in a manner satisfactory to the reason. Of what was before the assumed beginning of the origin of the nebula which is the starting point of the hypothesis, science can tell us nothing, and but little more of the end. In the solar system we have, so far as we can tell, a clock which is running down. After a time which has been estimated at something like ten million years, the Sun will have contracted so far that no more shrinkage will be possible, its outflow of light and heat will cease, and all living things must perish. It is, of course, possible that something unseen by our imperfect vision may intervene to avert this dismal end, but with the real beginning and the real end we have nothing to do. The nebular hypothesis is a reasonable explanation of the origin of the solar system as we see it today, by the action of forces which we still see in operation around us, and the limits in time which it considers are finite, though separated by an interval inconceivably vast.

ON THE RELATIVE ALBEDO OF PLANETS.

W. H. S. MONCK.

The results hitherto arrived at with regard to the *albedo* or reflective power of planets (including the Moon) cannot I think be regarded as satisfactory. The reason appears to be that an attempt has been made to determine the absolute *albedo*, and for this purpose a comparison of the Sun's light with that of the planet is necessary. But the disproportion is too great for anything like accurate measurement. Even as compared with the full Moon the intensity of sunlight varies according to different observers between 300,000 to 1 and 800,000 to 1. If we desire more accurate results we must, I apprehend, compare the light of the planets with each other directly.

Supposing that the entire surface of a planet is illuminated and its figure is spherical, the light which it sends us will be proportional to $\frac{a \cdot m^2}{d^2}$ where a is its *albedo*, m its apparent diameter and d its distance from the Sun. (When the whole disc is not illuminated an allowance for the dark part can be easily made.) Then if I_1 and I_2 represent the intensity of the light of two planets photometrically determined, we have:

$$\frac{I_1}{I_2} = \frac{\frac{a_1 \cdot m_1^2}{d_2^1}}{\frac{a_2 \cdot m_2^2}{d_2^2}} \text{ ; whence again}$$

$$\frac{a_1}{a_2} = \frac{I_1 \cdot m_2^2 \cdot d_1^2}{I_2 \cdot m_1^2 \cdot d_2^2}$$

---

[*] Communicated by the author.

(It may be noticed that the value of the fraction $\frac{d_1^2}{d_2^2}$ can be known with much greater accuracy than either d_1 or d_2).

Adopting the *albedo* of any particular planet as our unit we can easily obtain the relative *albedo* of any other planet by this formula provided that we know the value of the fraction $\frac{I_1}{I_2}$. This, I think, Professor Minchin's photo-electric cells when used with a powerful telescope and with adequate precautions, will give us with greater accuracy than any other known method; for according to the observations of the inventor the sensitiveness of the cells is but little affected by the color of the incident light. We shall also, I believe, be able to extend our results from the planets to the Moon—taking care, of course, that the whole light of the planet in the one case and of the moon in the other is falling on the cells. An accurate determination of the relative *albedo* of different planets might lead to important results as regards both their atmospheres and their surfaces. I may remark that if the *albedo* of the Moon is really as low as 0.17 or 0.18—in other words if 82 or 83 per cent of the incident light is absorbed—it is difficult to suppose that the temperature is as low as modern research seems to indicate.

I have assumed that the planets shine by reflected light only and that no light is lost in transmission between the Sun and the planet. On the latter point, it is, I think, pretty certain that there is a loss, but the amount is probably so small as to be inappreciable. In the case of distant fixed stars, however, this loss may attain considerable dimensions.

The light of some of the planets can be easily compared with that of the fixed stars and when the distance of a fixed star is known we could thus compare its brightness with that of the Sun if we knew the absolute *albedo* of the planet. But knowing only the relative *albedo*, one hypothetical element will enter into all our computations. Nevertheless we may be able to make a fair approximation.

THE LUNAR ATMOSPHERE AND THE RECENT OCCULTATION OF JUPITER.*

WILLIAM. H. PICKERING.

According to Schroeter, Gruithuisen, Webb and MM. Henry, one can occasionally with more or less distinctness see a faint lunar twilight prolonging the cusps of the crescent Moon. This twilight, so called, has been frequently seen at Arequipa. It is most conspicuous when the Moon has nearly reached the first quarter, and renders those portions of the dark limb that are situated near the cusps distinctly brighter than the remaining portion. It is best seen with a rather high power, and has been traced either across plains or upon distant mountains to a distance of sixty seconds of arc. This distance upon the Moon would correspond to a difference of latitude amounting to four degrees. The terrestrial twilight extends through about eighteen degrees, which indicates that there is matter capable of dispersing the Sun's light at an altitude above the Earth of about forty miles.†

According to the Greenwich observations of occultations, if we assume the diameter of the Moon accurately known, the lunar atmospheric refraction amounts to about 2″. Based upon this figure Neison says, "At present it can be taken with some degree of probability that the density of the lunar atmosphere does not differ much from between three and four hundredths of that of the Earth's." * * *

In the SIDEREAL MESSENGER for April, 1890, I published a paper upon some photographs taken at the Boyden Station in California during an occultation of Jupiter. Unfortunately I have not a copy of that paper with me, but the point of particular interest in this connection was that measurements were made of the diameters of Jupiter just after occultation, and that a slight flattening was detected in the direction of the lunar radius due presumably to refraction by the lunar atmosphere. This flattening, if I remember correctly, indicated for the atmosphere a density not far from one four-thousandth of that of the Earth.

At the recent occultation of August 12, these photographs were repeated under much more favorable conditions, and the flattening of the disc of Jupiter again measured. Satisfactory negatives were obtained both immediately before and immedi-

---

* Communicated by the author.

† A. C. Ranyard in *Knowledge*, Nov. 1891, p. 213.

ately after the occultation. It was found from these measurements that the refraction produced by the lunar atmosphere certainly did not exceed one second, and probably not one-half of a second of arc. This result is considerably smaller than that given by the Greenwich star occultations, but, as was stated at the time that they were published, their value is probably too large by an unknown quantity, depending upon our lack of information as to the true diameter of the Moon. Adopting these latest observations, the density of the lunar atmosphere can not exceed one four-thousandth, and probably not one eight-thousandth of that of the Earth. It would, therefore, be equivalent to a pressure of about $\frac{1}{250}$ of an inch of mercury at the surface. Although this value seems small, it is by no means insignificant, and would correspond to a pressure of hundreds of tons per square mile of the lunar surface.

In the case of the Earth, the atmospheric pressure is reduced one-half by an ascent of every three and a half miles. Thus at an altitude of seven miles the pressure is but one quarter of that at sea level. On the Moon, however, owing to the diminished force of gravity, we must ascend to an altitude of twenty-one miles in order to reduce the atmospheric pressure one-half. It will thus be seen that the temperature of the lunar summits cannot differ greatly from that of the lunar plains, a result indeed which is more or less confirmed by the researches of Professor Very. It has been suggested that the comparative whiteness of the lunar summits was due to the presence of snow. We should not, however, expect the difference of temperature between them and the lunar plains to be greater than that produced by an increase of elevation of three or four thousand feet upon the Earth.

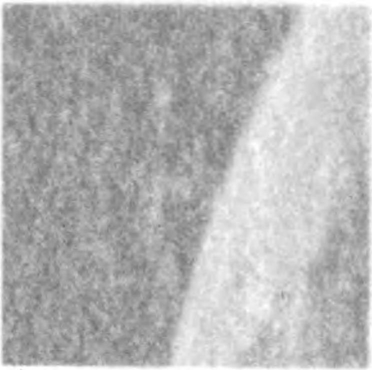
It has been found that shooting stars and meteors upon entering our atmosphere first become luminous at an altitude of about eighty miles. The barometric pressure at this altitude, at 0°, is found by computation to be $\frac{4}{1000000}$ of an inch. In the night time with a lower temperature, the pressure must be much less. It will therefore be seen that the lunar atmosphere is quite sufficient to render luminous and destroy all the smaller meteors before they can strike the surface. Indeed the atmospheric pressure at the Moon's surface as determined by the photographs of the recent occultation should be about equal to, but not much exceed, that at forty-five miles above the surface of the Earth. But we have already seen that the Earth's atmosphere at an altitude of forty miles above the surface is capable of producing the phenomenon of twilight. If the lunar twilight described at the beginning of this paper is a genuine phenomenon, we should then expect that the lunar atmosphere at an altitude of one or two miles above the surface should be about equal to that of the Earth at an altitude of forty miles. The two results agree quite within the limits of accuracy of the observations.

Owing to the slow diminution of pressure in the Moon's atmosphere, we find that at an altitude of fifty-three miles, the lunar and terrestrial atmospheres have the same density, and that above that point the lunar atmosphere is actually the denser of the two. Owing to this circumstance its atmosphere rises to a considerably greater height than does that of the Earth, shooting stars upon the Moon first becoming luminous at an altitude of about two hundred and ten miles.

In the photograph taken when Jupiter was half concealed by the bright limb of the Moon, a dark band three seconds in breadth is seen stretching across the face of the planet, tangent to the Moon's limb. This dark band was also observed visually. When Jupiter reappeared from behind the dark limb of the planet no such band was seen, nor does it appear upon the photographs. Since this band was photographed it cannot well be due to an optical illusion, and since it was seen it can hardly be classed as a photographic defect,—unless indeed we suppose that by a coincidence both conspired to produce the same result. The visual observations were made by Mr. Douglass, who employed a five-inch refractor with a power of seventy-five diameters. A ray of light tangent to the Moon's limb would pass through 160 miles of its atmosphere before it reached an altitude of 3″ as seen from the Earth. Unless this atmosphere contained some dust or moisture in the form of cloud, it would hardly seem sufficient to produce the absorption observed. If the absorption were due to moisture, it would naturally not be seen upon the dark limb, as it would be condensed and precipitated by the cold.

It is sometimes referred to as a singular fact that the lunar atmosphere should be so rare. It is possible, however, that an explanation may be found for this phenomenon. If we adopt Professor Darwin's ingenious hypothesis that the Moon once formed part of the Earth, we may fairly assume that when the two bodies parted company they divided their common atmosphere equally between them, in proportion to their respective masses. Since the Moon's mass is to that of the Earth as 1 to 81.4, and its surface as 1 to 13.5, its atmosphere would then have contained almost exactly one-sixth as many molecules per square mile as that of the Earth. But since the force of gravity

1



3

Photographs of Jupiter at the

Taken by Professor

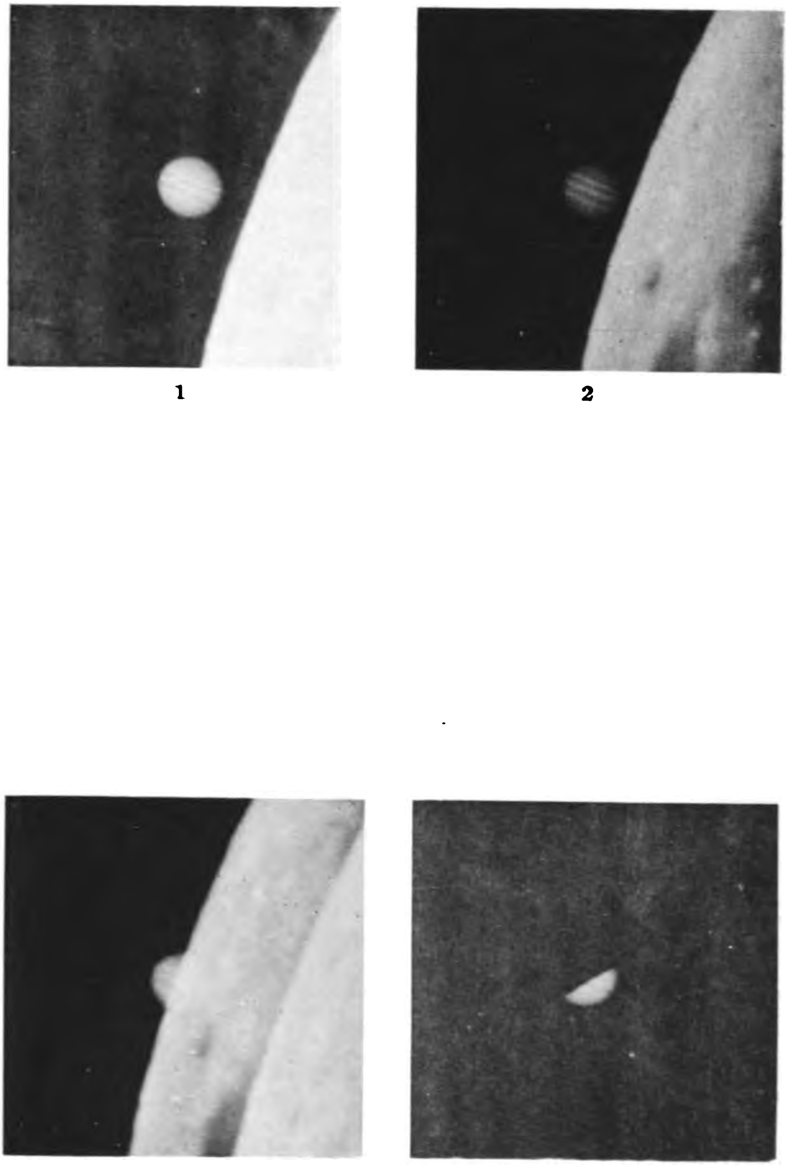
[illegible] paper is a genuine phenomenon, we sho [illegible] lunar atmosphere at an altitude of [illegible] surface should be about equal to that of [illegible] forty miles. The two results agree [illegible] accuracy of the observations.

[illegible] diminution of pressure in the Moon's at[illegible] that at an altitude of fifty-three miles, the [illegible] atmospheres have the same density, and [illegible] point the lunar atmosphere is actually the [illegible] Owing to this circumstance its atmosphere [illegible] greater height than does that of the [illegible] upon the Moon first becoming luminous [illegible] two hundred and ten miles.

[illegible] taken when Jupiter was half concealed by the Moon, a dark band three seconds [illegible] across the face of the planet, tangent [illegible] This dark band was also observed visually [illegible] appeared from behind the dark limb of the [illegible] was seen, nor does it appear upon the ph[illegible] band was photographed it cannot well be [illegible] illusion, and since it was seen it can hardly be [illegible] defect,—unless indeed we suppose the [illegible] conspired to produce the same result. The [illegible] were made by Mr. Douglass, who employed [illegible] with a power of seventy-five diameters. [illegible] tangent to the Moon's limb would pass through 160 miles of its atmosphere before it reached an altitude of 3″ as seen [illegible] Unless this atmosphere contained some dust or moisture in the form of cloud, it would hardly seem sufficient to produce the absorption observed. If the absorption were due to moisture it would naturally not be seen upon the dark limb, [illegible] would be condensed and precipitated by the cold.

It is sometimes referred to as a singular fact that the lunar atmosphere should be so rare. It is possible, however, that an explanation may be found for this phenomenon. If we adopt Professor Darwin's ingenious hypothesis that the Moon once formed part of the Earth, we may fairly assume that when the two bodies parted company they divided their common atmosphere equally between them, in proportion to their respective masses. Since the Moon's mass is to that of the Earth as 1 to 81.4, and its surface as 1 to 13.5, its atmosphere would then have contained almost exactly one sixth as many molecules per square mile as that of the Earth. But since the force of gravity

PLATE XXXVIII.



1 2

3 4

Photograp iter at the O of August 12, 1892

T Wm. H uipa, Peru.

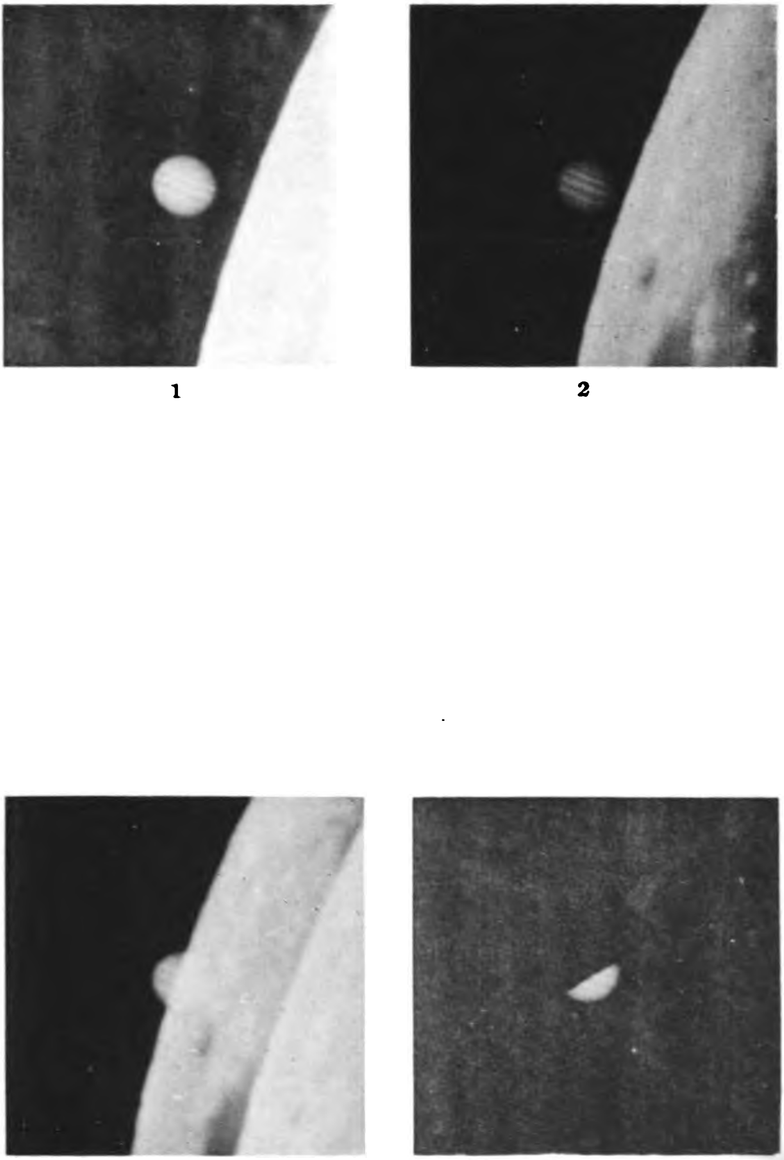
the beginning of this paper is a genuine phenomenon, we should then expect that the lunar atmosphere at an altitude of one or two miles above the surface should be about equal to that of the Earth at an altitude of forty miles. The two results agree quite within the limits of accuracy of the observations.

Owing to the slow diminution of pressure in the Moon's atmosphere, we find that at an altitude of fifty-three miles, the lunar and terrestrial atmospheres have the same density, and that above that point the lunar atmosphere is actually the denser of the two. Owing to this circumstance its atmosphere rises to a considerably greater height than does that of the Earth, shooting stars upon the Moon first becoming luminous at an altitude of about two hundred and ten miles.

In the photograph taken when Jupiter was half concealed by the bright limb of the Moon, a dark band three seconds in breadth is seen stretching across the face of the planet, tangent to the Moon's limb. This dark band was also observed visually. When Jupiter reappeared from behind the dark limb of the planet no such band was seen, nor does it appear upon the photographs. Since this band was photographed it cannot well be due to an optical illusion, and since it was seen it can hardly be classed as a photographic defect,—unless indeed we suppose that by a coincidence both conspired to produce the same result. The visual observations were made by Mr. Douglass, who employed a five inch refractor with a power of seventy-five diameters. A ray of light tangent to the Moon's limb would pass through 160 miles of its atmosphere before it reached an altitude of 3″ as seen from the Earth. Unless this atmosphere contained some dust or moisture in the form of cloud, it would hardly seem sufficient to produce the absorption observed. If the absorption were due to moisture, it would naturally not be seen upon the dark limb, as it would be condensed and precipitated by the cold.

It is sometimes referred to as a singular fact that the lunar atmosphere should be so rare. It is possible, however, that an explanation may be found for this phenomenon. If we ad Professor Darwin's ingenious hypothesis that the Moon formed part of the Earth, we may fairly assume that when two bodies parted company they divided their common atmosphere equally between them, in proportion to their respec masses. Since the Moon's mass is to that of the Earth as 1 to 81.4, and its surface as 1 to 13.5 its atmosphere would have contained almost exactly one-sixth as many mole square mile as that of the Earth. But since the force of g

PLATE XXXVIII.



1 2

3 4

Photographs of Jupiter at the Occultation of August 12, 1892

Taken by Professor Wm. H. Pickering at Arequipa, Peru.

at the Moon's surface is also one-sixth of that at the surface of the Earth, the density of the lunar atmosphere must have been one thirty-sixth of that of the Earth. This would correspond to a pressure of 0.83 inches of mercury at the Earth's surface, and we should not under any circumstances expect to find a lunar atmosphere of greater density than this.

If a particle should fall upon the Moon from an infinite distance acted upon solely by the Moon's gravity, it would acquire a velocity of 1.5 miles per second. And conversely, if thrown from the Moon with this velocity, it would never return.

According to the researches of Professors Langley and Very, the temperature of the Moon's surface may be taken at about 0° centigrade. There is no reason to suppose that any particle situated in the immediate vicinity of the Earth's orbit, would possess a much lower temperature than this, if exposed to the Sun's rays. At this temperature the molecules of nitrogen composing our atmosphere have a mean velocity of rather less than one-third of a mile per second, and the molecules of oxygen a mean velocity of rather more than one quarter of a mile. These are their mean velocities, but some of these particles are undoubtedly moving at a very much slower rate than this, and some a great deal faster. When there are many of them they are changing their velocities millions of times every second, owing to mutual collisions. But where there are only comparatively few of them as would be the case, for instance, near the outskirts of the lunar atmosphere, it would frequently happen that one of these molecules possessing five or six times the average velocity of the rest would not meet any other molecule in its path to stop it, and it would then be carried away from the Moon never to return to it again, unless brought back by the attraction of some other outside body such as the Earth or the Sun. We thus see that even now the Moon must be constantly losing whatever atmosphere it possesses, while it has no means whatever of recovering it.

This course of reasoning does not apply to the same extent to the Earth, for owing to its greater mass, a molecule to escape from its grasp must have a velocity of very nearly seven miles per second. It must be a rare thing for a molecule to have twenty times the mean velocity of its neighbors, and therefore if we are losing our atmosphere at all from this cause, it must be taking place very slowly indeed. If our atmosphere instead of consisting of oxygen and nitrogen, had been made up wholly of hydrogen gas, it would have been a very different matter. At a temperature of 0° the mean velocity of the hydrogen molecules is over a mile per second, and any molecule having six times the mean velocity of its fellows, and not suffering from a collision, would be carried away from the Earth never to return. Thus at the present time it would be quite impossible for the Earth to retain for a long period a dense atmosphere of hydrogen gas. If this is the case at present it must have been still more markedly so in pre-geological times, if the Sun were then hotter, because the latter would then have been able to maintain the hydrogen molecules exposed to its rays at a temperature higher than 0°, and their velocities would therefore have been still greater. Under these circumstances the question arises whether the temperature of the Earth could then have been high enough to disassociate steam into its component gases. It does not seem as if the temperature of the Earth and Moon could have been as great as this when they parted company, for we find apparently evidences of the action of water upon the surface of the latter, and we can hardly conceive of a volcanic eruption without the presence of some water.

It will thus be seen that only upon large bodies could we expect to find an atmosphere of hydrogen gas, unless the body is located in a portion of space where the temperature is very low. Also that upon small bodies like our Moon, we should expect to find the proportion of oxygen and carbonic acid in the atmosphere greater than with us, and that their atmospheres would also be less dense. This course of reasoning applies with less force to the planet Mars, since being at a greater distance from the Sun, the velocity of the outer molecules of its atmosphere would be materially diminished, still it would not surprise us to find that it possessed less water and less atmosphere than the Earth. The condition of Venus is similar to that of the Earth, but with Mercury quite a new condition of affairs arises. At perihelion distance this planet receives from the Sun ten times as much heat per square mile as does the Earth. Since the velocities of the molecules of a gas increase as the square roots of their absolute temperatures, it will be seen that notwithstanding its considerable density, it would be quite impossible for this planet to retain any atmosphere at all comparable with that of our Earth. I may add that our observations upon the length of the cusps of Mercury made in Arequipa entirely confirm this view.

AREQUIPA, Peru, Aug. 29, 1892.

A LARGE SOUTHERN TELESCOPE.

PROFESSOR EDWARD C. PICKERING.

The wide interest in astronomical research is well illustrated by the freqent gifts of large telescopes to astronomical observatories by wealthy donors who are not themselves professional students of astronomy. The number of these gifts is continually increasing, and in no department of science has greater liberality been displayed. Unfortunately, the wisdom shown in the selection of good locations for the telescopes has not equalled the generosity with which they have been given. Political or personal reasons, rather than the most favorable atmospheric conditions, have in almost all cases determined the site. These telescopes have been erected near the capitals of countries or near large universities, instead of in places where the meteorological conditions would permit the best results to be obtained. The very conditions of climate which render a country or city great, are often those which are unfavorable to astronomical work. The climate of western Europe and of the eastern portion of the United States is not suited to good astronomical work, and yet these are the very countries where nearly all the largest observatories of the world are situated. The great number of telescopes thus concentrated renders it extremely difficult for a new one to find a useful line of work. The donor may therefore be disappointed to find so small a return for his expenditure, and the opinion has become prevalent that we cannot expect much further progress in astronomy by means of instruments like those now in use. The imperfections of our atmosphere appear to limit our powers, and are more troublesome relatively with a large than with a small telescope. Accordingly, it has not been the policy of the Harvard College Observatory to attempt to obtain a large telescope to be erected in Cambridge. In order to secure the greatest possible scientific return for its expenditures, large pieces of routine work have by preference been undertaken, which could be done with smaller instruments. These conditions are now, however, changed. A station has been established by this Observatory near Arequipa in Peru, at an altitude of more than eight thousand feet. During a large part of the year the sky of Arequipa is nearly cloudless. A telescope having an aperture of thirteen inches has been erected there, and has shown a remarkable degree of steadiness in the atmosphere. Night after night atmospheric conditions prevail which occur only at rare intervals, if ever, in Cambridge. Several of the diffraction rings surrounding the brighter stars are visible, close doubles in which the components are much less than a second apart are readily separated, and powers can be constantly employed which are so high as to be almost useless in Cambridge. In many researches the gain is as great as if the aperture of the instrument was doubled. Another important advantage of this station is that, as it is sixteen degrees south of the Equator, the southern stars are all visible. A few years ago a list was published of all the refracting telescopes having an aperture of 9.8 inches or more (SIDEREAL MESSENGER, 1884, p. 193). From this it appears that nearly all of the largest telescopes are north of latitude + 35°, although this region covers but little more than one-fifth of the entire surface of the Earth. None of the seventeen largest and but one of the fifty-three largest telescopes are south of this region. Of the entire list of seventy-four, but four, having diameters of 15, 11, 10, and 10 inches, are south of + 35°. The four largest telescopes north of + 35° have apertures of 36, 30, 29, and 27 inches respectively. But few telescopes of the largest size have been erected since this list was prepared, and the proportion north and south is still about the same. It therefore appears that about one quarter of the entire sky is either invisible to, or so low that it cannot be advantageously observed by, any large telescope. The Magellanic clouds, the great clusters in Centaurus, Tucana, and Dorado, the variable star η Argus, and the dense portions of the Milky Way, in Scorpius, Argo, and Crux, are included in this neglected region. Moreover, the planet Mars, when nearest the Earth, is always far south. The study of the surface of this and of the other planets is greatly impeded by the unsteadiness of the air at most of the existing observatories. Even under the most favorable circumstances startling discoveries—relating, for example, to the existence of inhabitants in the planets—are not to be expected. Still it is believed that in no other way are we so likely to add to our knowledge of planetary detail as by the plan here proposed. The great aperture and focal length and the steadiness of the air will permit unusually high magnifying powers to be employed, and will give this instrument corresponding advantages in many directions,—for instance, in micrometric measures, especially of faint objects. It can be used equally for visual and photographic purposes, and in photographing clusters, small nebulæ, double stars, the Moon, and the planets, it will have unequalled advantages.

A series of telescopes of the largest size (including four of the six largest, the telescopes of the Lick, Pulkowa, U. S. Naval, and McCormick observatories) has been successfully constructed by the firm of Alvan Clark and Sons. But one member of the firm now survives, Mr. Alvan G. Clark; and he expresses a doubt whether he would be ready to undertake the construction of more than one large telescope in the future. The glass is obtained with difficulty and often only after a delay of years. A pair of discs of excellent glass suitable for a telescope having an aperture of forty inches has been cast, and can now probably be purchased at cost, $16,000. The expense of grinding and mounting would be $92,000. A suitable building would cost at least $40,000. If the sum of $200,000 could be provided it would permit the construction of this telescope, its erection in Peru, and the means of keeping it at work for several years. Subsequently, the other funds of this Observatory would secure its permanent employment. Since a station is already established by this Observatory in Peru, a great saving could be effected in supervision and similar expenses, which otherwise would render a much larger outlay necessary.

An opportunity is thus offered to a donor to have his name permanently attached to a refracting telescope which besides being the largest in the world would be more favorably situated than almost any other, and would have a field of work comparatively new. The numerous gifts to this Observatory by residents of Boston and its vicinity prevent the request for a general subscription; but it is believed that if the matter is properly presented, some wealthy person may be found who would gladly make the requisite gift, in view of the strong probability that it will lead to a great advance in our knowledge of the heavenly bodies. Any one interested in this plan is invited to address the undersigned.

CAMBRIDGE, MASS,, U. S. A., September 1892.

GROUPS OF ASTEROIDS.*

PROFESSOR DANIEL KIRKWOOD.

The conjecture of Dr. Olbers was not unnatural when in 1802 a second asteroid was found, having nearly the same distance from the Sun as Ceres. The nebular hypothesis had not then taken the scientific place which it soon afterward gained. The phenom-

---

* Communicated by the author.

ena of two planets with intersecting orbits had been hitherto unknown. The clustering planetoids of the opening century had awakened a bold conjecture which was not wholly abandoned for many years to come. When the number of telescopic planets, however, had grown to hundreds, and when the perihelion distance of some had become greater by many millions of miles than the aphelion of others—the theory of explosion was necessarily abandoned. But the doctrine of a *similarity* of origin was not so easily disposed of. The original dimensions of nebulous asteroids were probably many times greater than those of the present. The disrupting tendency of the great bodies of the system, especially when resisted only by the slight central attraction of nebulous asteroids, is easily imagined. Such separation, in short, has no improbability whatever. The dismemberment of comets, as is well known, has actually occurred under our own eyes. Why not also the pulling asunder of nebulous planets?

The fact that in many cases the motions of asteroids indicate a common origin, affords strong presumptive evidence in favor of the nebular hypothesis. Possibly, indeed, its true form may have differed from that proposed by La Place. The ancient dismemberment of Vera, 245, and Semele, 86, for instance, is infinitely more probable than the violent explosion of Ceres and Pallas as consolidated planets. The elements of the former, as has been shown, are almost exactly coincident. But these are only specimens of eighty similar cases. How many primitive, *separate* nebulæ were contained in our system, and how many of these primitive masses suffered dismemberment while Mars and the then future earth were yet floating in the solar atmosphere, cannot now be told. An indefinite number, however, may undoubtedly be traced. May not similar processes be also indicated in the slow evolution of binary and multiple stars in the sidereal heavens?

The following table includes several groups by M. Tisserand, of Paris, and Mr. Monck, of Dublin, as well as those given by the author in the *Publications of the Astronomical Society of the Pacific*. It contains over eighty members of groups—the largest number yet published:

NOTES:

1. The distance from the outer margin of the gap at 3.27 to the orbit of Thule, 4.27, is unity. The number of asteroids now known in this section is 13, nine of which are included in the four outer groups. From the inner margin at 3.22 to the ring's interior edge is a distance of 1.05, only slightly greater than the

breadth of the outer ring, but containing 317 asteroids—24 times the number in the outer section.

2. A remarkable clustering tendency is found from 3.16 to 3.08; a group of five occurring in a narrow strip whose breadth is but 0.0162. This remarkable group is where we find the relation

$$n^{(a)} - 3n^{V} + 2n^{VI} = 0;\ \text{or}\ n^{(a)} = 656''.4 \pm$$

Other similar sections may be found in like manner.

a represents the mean distace; *e* the eccentricity; *i* the inclination; *π* the longitude of the perihelion.

GROUPS OF ASTEROIDS.

	Name	*a*	*e*	*i* °	*i* ′	*π* °	*π* ′
	1						
153	Hilda	3.9538	0.1641	7	52	285	29
190	Ismene	3.9471	0.1634	6	7	105	39
	2						
107	Camilla	3.4847	0.0756	9	54	115	53
87	Sylvia	3.4833	0.0922	10	55	333	48
	3						
260	Huberta	3.4586	0.1103	6	16	329	45
121	Hermione	3.4535	0.1254	7	36	357	50
	4						
65	Maximiliana	3.4339	0.1062	3	29	259	54
76	Freia	3.4140	0.1699	2	3	90	49
229	Adelinda	3.4059	0.1518	2	10	333	37
	5						
122	Gerda	3.2177	0.0415	1	37	203	45
300	Geraldina	3.2083	0.0423	0	47	331	1
	6						
154	Bertha	3.1976	0.0787	20	59	190	47
286	Iclea	3.1942	0.0123	17	57	352	40
	7						
92	Undina	3.1851	0.1024	9	57	331	27
297	Cecilia	3.1752	0.1450	7	31	329	2
	8						
106	Dione	3.1670	0.1788	4	38	25	57
104	Clymene	3.1556	0.1470	2	53	62	30
171	Ophelia	3.1554	0.1142	2	33	148	31
	9						
94	Aurora	3.1602	0.0827	8	4	48	46
252	Clementina	3.1552	0.0837	10	2	355	8
	10						
250	Bettina	3.1524	0.1303	12	54	87	28
57	Mnemosyne	3.1510	0.1145	15	24	53	25
	11						
62	Erato	3.1241	0.1756	2	12	39	0
257	Silesia	3.1190	0.1217	3	40	65	16
212	Medea	3.1157	0.1013	4	16	56	18

	Name	*a*	*e*	*i*		*π*	
				°	′	°	′
	12						
86	Semele	3.1015	0.2193	4	47	29	10
305		3.0973	0.1927	4	26	104	37
245	Vera	3.0966	0.1975	5	11	27	48
223	Rosa	3.0937	0.1206	1	59	106	35
268	Adorea	3.0853	0.1285	2	25	184	48
	13						
280	Philia	2.9722	0.1374	7	22	10	56
179	Clytemnestra	2.9711	0.1133	7	47	355	39
	14						
22	Calliope	2.9090	0.1012	13	45	59	58
238	Hypatia	2.9081	0.0876	12	23	28	24
191	Kolga	2.8967	0.0876	11	29	23	21
	15						
235	Carolina	2.8795	0.0595	9	4	268	29
195	Euryclea	2.8790	0.0471	7	1	115	48
	16						
158	Coronis	2.8714	0.0548	1	0	56	56
243	Ida	2.8609	0.0419	1	10	7	22
167	Urda	2.8533	0.0340	2	11	296	4
	17						
264	Libussa	2.7963	0.1380	10	27	26	39
28	Bellona	2.7800	0.1491	9	22	124	1
	18						
1	Ceres	2.7693	0.0763	10	37	149	38
237	Cœlestina	2.7607	0.0738	9	46	282	49
	19						
116	Sirona	2.7669	0.1433	3	35	152	47
55	Pandora	2.7604	0.1429	7	14	10	36
278	Pauline	2.7575	0.1331	7	50	199	52
213	Lilæa	2.7563	0.1437	6	47	281	4
	20						
203	Pompeia	2.7376	0.0588	3	13	42	51
160	Una	2.7287	0.0624	3	51	55	57
301	Bavaria	2.7258	0.0660	4	53	24	4
	21						
103	Hera	2.7014	0.0803	5	24	321	3
58	Concordia	2.7004	0.0426	5	2	189	10
	22						
123	Brunhilda	2.6950	0.1232	6	25	69	25
34	Circe	2.6865	0.1073	5	27	148	41
	23						
249	Asporina	2.6947	0.1050	15	35	256	6
218	Bianca	2.6653	0.1155	15	13	230	14
	24						
66	Maia	2.6454	0.1758	3	6	48	8
37	Fides	2.6440	0.1750	3	7	66	26
	25						
53	Calypso	2.6175	0.2060	5	7	92	52
269	Justitia	2.6167	0.2024	5	25	274	38
	26						
119	Althea	2.5824	0.0815	5	45	11	29
32	Pomona	2.5873	0.0830	5	29	193	22

	Name	a	e	i		π	
				°	′	°	′
	27						
79	Eurynome	2.4436	0.1945	4	37	44	22
19	Fortuna	2.4413	0.1594	1	33	31	3
	28						
249	Ilse	2.3793	0.2195	9	22	14	16
115	Thyra	2.3791	0.1939	11	35	43	2
84	Clio	2.3629	0.2360	9	40	339	20
	29						
306	Unitas	2.3623	0.1515	7	14	305	48
169	Lelia	2.3577	0.1313	5	31	326	20
163	Erigone	2.3560	0.1567	4	42	93	46
	30						
219	Thusnelda	2.3542	0.2247	10	47	340	34
220	Stephania	2.3505	0.2571	7	34	333	36
12	Victoria	2.3342	0.2189	8	23	301	39
284	Amelia	2.3532	0.2195	8	5	288	57
18	Melpomene	2.2956	0.2197	10	9	15	5
	31						
207	Hedda	2.2838	0.0301	3	49	217	2
40	Harmonia	2.2673	0.0466	4	16	0	54
	32						
270	Anahita	2.1976	0.1501	2	26	332	23
281	Lucretia	2.1859	0.1322	5	19	45	36
244	Sita	2.1765	0.1370	2	50	13	8

Formation of the Baltimore Astronomical Society.—The Baltimore Astronomical Society, which was organized in this city on September 6th, held its first regular meeting at No. 323 North Charles street. The society is in its infancy, and is composed of amateur scientists, who devote much time to the study of the planets. There were twenty persons present at the meeting. The officers of the society are George Gildersleeve, president; Dr. J. R. Hooper, vice president; Justice Stahn, secretary, and William Numsen, treasurer. The members of the society who have observatories are as follows: George Gildersleeve, observatory on North Charles street, consists of 6-inch telescope, made by Dr. Hastings. Most of his observations are confined to the Sun, and he possesses records of spots on the Sun, all double stars and comets seen for the last fifteen years. Dr. J. R. Hooper's observatory is on Lincoln avenue, and consists of a 5-inch Clark telescope. Comets are his pet subjects of observation. Dr. Clark is also the possessor of the 4-inch telescope used at the Eclipse expedition in 1884, by Dr. Hasting who at that time was connected with the John Hopkins University. William Numsen's observatory is located at Arlington, and has a 4-inch Cook telescope. Wm. Pitt's observatory on St Paul street is equipped with 6-inch refractor and reflector, and two small telescopes. Mr. Justice Stahn, the secretary of the society has an observatory at his home on Ensor street, where he uses a 4½-inch refractor and spectroscope.

The society will hold meetings once a month.

ASTRO-PHYSICS.

THE YERKES OBSERVATORY OF THE UNIVERSITY OF CHICAGO.*

GEORGE E. HALE, DIRECTOR.

Through the munificence of Charles T. Yerkes of Chicago, the University of Chicago is to have an astronomical observatory of the first class. Indeed, it is Mr. Yerkes' express desire that in every particular the new observatory shall as nearly as possible attain the existing ideas of perfection. No definite limit has as yet been assigned to the expenditure contemplated, but the generosity of the donor is fully indicated bv his wish that the completed observatory shall be second to none.

The aperture of the great telescope, which will form the central feature of the establishment, will shortly be decided upon in accordance with the condition that it must surpass that of the largest existing instrument—the 36-inch refractor of the Lick Observatory. It is probable that a size between 40 and 45 inches will be selected. A pair of 40-inch discs of glass, which were made some time ago for the University of Southern California, are now for sale, and these may possibly be obtained. Should they be secured, some time would be saved in completing the telescope, but it is not altogether certain that they will be considered large enough by the liberal donor.

The mounting of the telescope is already under discussion, and its general features have been decided upon. The quick and slow motions of the telescope, clamping in right ascension and declination, rise and fall of the floor upon which the observer stands, rotation of the dome, etc., will all be operated by electric push-buttons within easy reach of the astronomer at the eye-end of the instrument. They will also be under the control of an assistant seated at a table on the rising floor. Electric devices for operating large telescopes have not hitherto been employed, even on the great Lick telescope. They were long ago suggested, however, notably by Sir Howard Grubb and Dr. David Gill.

The diameter of the dome will naturally depend upon the focal length of the telescope, but it will probably be in the neighborhood of 85 feet. As in the case of the Lick Observatory and the new Naval Observatory at Washington, the entire floor of the observing room will be made to rise and fall by means of hydraulic rams. The cumbrous observing chair once in vogue is

---

* Communicated by the author.

thus done away with, and the utmost convenience to the astronomer secured.

The remainder of the observatory's equipment is still undetermined, but it will probably include a 16-inch refractor, 12-inch "twin" equatorial, with visual and photographic objectives, 6-inch meridian circle, and 20-inch siderostat.

But the equipment of an observatory is only a means to an end. Many an instance could be cited of an elaborate collection of instruments lying almost unused, or at best contributing little or nothing to the advancement of science. It is intended that the Yerkes Observatory shall be devoted to investigation, and even at this early day an outline of the work which may profitably be undertaken will not be without interest.

It is of the first importance that the exceptional instrumental equipment of the new observatory shall not be wasted by a mere duplication of work done equally well elsewhere. Evidently a telescope of the great aperture contemplated should not be employed in the observation of objects within easy reach of much smaller instruments. This principle was steadfastly adhered to by Mr. Burnham in all of his work with the great Lick refractor. Wide and easy double stars were passed over, and the whole time devoted to the discovery and measurement of extremely difficult pairs. In the field of general research the Yerkes telescope should be applied to the search for new satellites, the study of faint and difficult details of planetary markings, the measurement of Burnham's more difficult doubles, and many similar observations. In stellar spectroscopy a great opportunity will be open, for the immense light-grasping power of the new objective will allow the spectra of stars now beyond our reach to be investigated. The work so ably begun by Keeler at the Lick Observatory, on the spectra and motions of the planetary nebulæ, should be continued and extended. A new departure in the work of large observatories will be the inauguration of a more extensive study of the Sun than has previously been undertaken. This department will be the special province of the writer, and plans for the work have been fully matured.

It is safe to say that an unprejudiced student, in examining the various classes of work pursued by astronomers, would be struck by the small attention given to solar investigation. It is true that in 1869 there was a great awakening of interest in the study of solar spots and prominences, due to the novel methods of spectroscopic research which had just been introduced. But, outside of Italy, there are but two or three observatories which at the present time make a systematic record of solar phenomena. One of these is in England, another in Hungary, and in this country there is one. Fragmentary records are kept elsewhere, but while important, they do not admit of a well-balanced study of the Sun. In Italy the subject has received more attention, and the *Societa degli Spettroscopisti Italiani* (the only existing society of spectroscopists) has faithfully preserved the traditions of Secchi and his associates. Under the leadership of Professor Tacchini, this society seems fully to realize the importance of closely investigating the only one of all the stars which is near enough the Earth to be examined in detail. But in spite of their untiring labors, and the cloudless blue of their propitious skies, it is possible to greatly extend the work of the Italian observers. And this for two reasons. In the first place, their instrumental equipment includes no telescopes of very large size, and in the second, photographic methods have not yet been introduced into their researches. In view of this latter point especially, it is easy to see what possibilities lie open to the solar department of the Yerkes Observatory. In applying on a large scale the photographic methods devised and now in use at the Kenwood Observatory, and in adding to and extending them, it will for the first time be possible to completely investigate every variety of solar phenomena. The corona should perhaps be excepted, but it is not altogether impossible that a new instrument now being constructed at the Kenwood Observatory for the purpose of photographing it in full sunlight may prove a success. With an automatic apparatus, also devised here recently, photographs of the Sun, showing all of the phenomena of its surface, will be taken at intervals of about five minutes throughout the day. Photographs will also be taken at frequent intervals with a 12-inch photographic objective and amplifying lens, showing the Sun on a scale of about four inches to the diameter, and others of individual spots on a scale of sixteen inches to the diameter. A spectroheliograph will be so attached to the great telescope that photographs of groups of faculæ and prominences may be taken on a scale of about seven inches to the Sun's diameter, and also, by the use of an amplifying lens, on a scale of sixteen inches to the diameter. These photographic observations will be supplemented by simultaneous visual observations, and the spectra of faculæ, spots and prominences will be investigated both photographically and visually. Various special investigations on the Sun will also be undertaken, and the records of self-registering magnetic instruments will assist in the solution of the perplexing question as to the relation existing between solar and terrestrial phenomena.

The astronomers who are to be in charge of the other departments of work having not yet been appointed, no more definite plans can at present be formulated for the investigations other than solar. It is hoped that the importance of the Observatory will be measured rather by its work than by its instruments, and that the expectations naturally raised by so perfect an equipment will not be disappointed.

KENWOOD OBSERVATORY, University of Chicago,
Oct. 17, 1892.

NOTE ON SPECTROSCOPIC INVESTIGATIONS AT THE PHYSICAL INSTITUTION OF THE ROYAL SWEDISH ACADEMY OF SCIENCES.*

PROFESSOR B. HASSELBERG.

Among the works on spectrum analysis which as a necessary complement followed the fundamental investigations of Angström upon the solar spectrum, the researches of Thalén on the emission spectra of metals have long occupied a prominent place. And this with every reason, for these researches not only represent the first really scientific inquiry on this subject, but also laid the first solid ground for the physical interpretation of solar and stellar spectra generally. For their epoch these two works are to be regarded as the very corner stone, indeed, of the whole growing science of astro-physics. The immense progress which in some twenty years since then elapsed has been made in the construction of the spectroscope, together with the introduction of modern photography in spectroscopy, could not but totally transform this field of science, and thus we now not only find ourselves confronted by a great many questions then not raised, but also are in possession of most powerful means for their solution.

The chief effect of the improved spectroscope was to show the possibility of greatly improving upon the normal solar spectrum as given by Angström, not only in regard to completeness but above all as to precision of absolute determination of wave-lengths. The successive steps taken in this direction by Cornu, Vogel, Fievez, Müller and Kempf, Thollon, and more re-

---

* Communicated by the author.

cently by Rowland in his magnificent photographic chart of the solar spectrum, I scarcely need to point out here. Indeed this Atlas, together with the unprecedented diffraction gratings which Rowland has put in the hands of spectroscopists of to-day, have, I think, so totally and profoundly changed the whole face of spectroscopic research that almost everything previously done is to be gone over again before any real progress in its application to molecular and stellar physics can be made. This is especially the case with the emission-spectroscopy of the chemical elements, in which the progress since Thalén has been slow and by no means comparable with the advancement in our knowledge of the structure of the solar spectrum, and the accuracy with which the wave-lengths of the lines contained therein are now determined.

From this point of view I have undertaken a detailed revision of the metallic spectra as they appear in the voltaic arc. A similar series of researches is, as is well known to spectroscopists, also in progress at Hannover, Germany, where Professors Kayser and Runge are making very thorough investigations on this subject, but without special attention to the elimination of foreign lines from the spectra. Although I am fully aware of the extraordinary difficulty connected with such an elimination, and do by no means hope herein to reach perfection, I think it nevertheless, worth while to try it in the hope thus at least to diminish the almost insupportable confusion which now prevails in this branch of spectroscopy.

As stated by Professors Kayser and Runge, the main scope of their researches is to find harmonic series of lines in the spectra of the elements, and thus to create a solid basis for the spectroscopic study of molecular physics. My researches are following up a somewhat different line namely, to give the means for a more accurate investigation of solar and stellar chemistry. In regard to this application of spectroscopy to astronomy the present state of science must be acknowledged as lamentably imperfect, indeed not only with reference to the Sun, of whose spectral lines only a small part are as yet identified with sufficient certitude, but, above all with reference to the stars. As an nstance of this the fact may be mentioned that, notwithstanding the great accuracy now obtainable in the measurement of photographic spectra of stars, no reliable inference can be made therefrom as to their chemical constitution, on account of our present ignorance of the structure of the spectra of the chemical elements, and the utterly insufficient accuracy in the position of their lines. It is also next to certainty that much of the latest speculation in stellar physics will break down as soon as the spectra of the chemical elements become known with an accuracy of the same order as the solar spectrum.

For the execution of this plan—which, of course, was also the leading principle of the work at the astro-physical laboratory under my charge at the Pulkowa Observatory—the physical institution of the Academy had to be equipped with new and adequate installations for spectroscopy and photography of the highest possible order. Up to the year 1889, when the direction of this institution was intrusted to me, the work carried on there had been chiefly electrical, under the direction of the late Professor Edlund; and thus it is plain that for the new purposes the necessary experimental means could not be available. My next task was then to supply this want, and, as proved by the work already done, the apparatus and appliances acquired are in every way satisfactory. First among these are to be named the excellent Rowland gratings obtained from the workshops of Brashear in Allegheny. A flat grating of 4 inches and 14,438 lines to the inch forms the dispersive part of the large spectrograph ordinarily used. As collimator to this instrument a Steinheil 3½-inch refractor is employed and a similar objective as camera lens. The focal lengths of these objectives are 1.5 metres. The grating is supported by the horizontal circle of a transit instrument, thus enabling the observer to bring the different spectra into the field of view by turning the grating, while the collimator and camera are fixed at about 40° to one another. The excellent performance of this instrument, and the special peculiarities of the spectra given by it, have been fully described in my memoir on the absorption spectrum of bromine.* A great 6-inch concave Rowland grating with 20,000 lines to the inch will also soon be mounted, and for spectra of feeble luminosity a smaller spectrograph with prisms is available. The electric current for production of the voltaic arc is generated by a very fine Siemen's shunt dynamo worked by a gas engine of 4 HP. For the study of the spectra of gases the institution possesses, besides several induction coils of small and medium size, a great Ruhmkorff capable of giving, when worked by a battery of 12 large Bunsen cells, a stream of sparks of 50 cm.

After putting all these appliances in working order some time was spent in several preliminary researches, mainly in the view to test the efficiency of the apparatus. One of these re-

---

* Svenske Vetenskapsakademiens Handlingar, Bd. 24, No. 3, 1891.

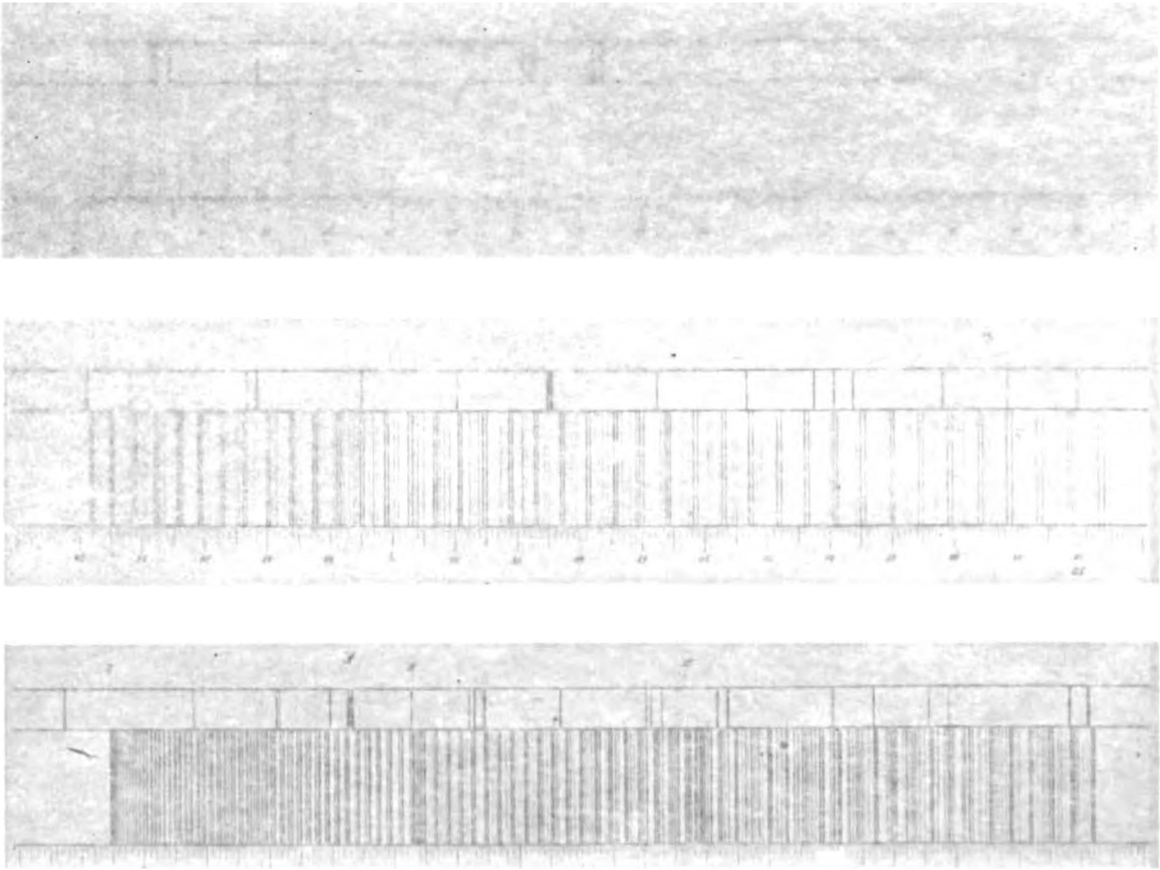
searches concerns the spectrum of aluminium oxide, which, when generated in the arc and viewed with the above-named spectroscope presents itself with a lustre and richness of detail never before observed. This circumstance induced me to make a careful investigation thereof, although the spectrum has no recognized relation to solar or sidereal physics. Perhaps a brief account of the results of this investigation* will be of interest to the readers of this journal.

As well known the spectrum of aluminium oxide consists of five groups of flutings in the yellow, green, blue and violet, each group composed of a number of smaller partial flutings of decreasing intensity in the direction of increasing wave-lengths. The first description we owe to Thalén, who, in the same manner as Lockyer and Lecoq de Boisbaudran, employed the uncondensed induction spark. Under these circumstances, the intensity being small, it is obvious that only very moderate dispersion could be used, and thus we find that all these older investigations do not give any more details than the positions of the sharp edges of the flutings. As moreover, the employment of the condensed spark in order to increase the intensity is out of the question because the temperature then surpassing that of dissociation, the spectrum of the oxide is replaced by that of the metal, it occurred to me that the electric arc, whose temperature lies between that of the uncondensed and condensed spark, would do good service, a supposition which experiment has most satisfactorily confirmed.

The whole investigation was made with the help of photography in the third order. With the great dispersion thus obtained every fluting of the spectrum was resolved into very bright separate sharp lines. The spectrum was photographed on Edward's isochromatic plates, together with the corresponding parts of the solar spectrum, thus giving the means for determining the wave-lengths of the lines by measurements on the dividing engine. For these determinations the Rowland standard lines were employed, as a thorough comparison had showed that the *relative* accuracy of this system notably exceeds that of the Potsdam catalogue. Moreover, a good many (about 50 per cent) of the Potsdam standard lines are under the great dispersion here used not single, but form groups of two, three, or sometimes four lines, in which cases any certain identification of the given positions is impossible. As to the question which of the two systems is to be considered *absolutely* more correct, nothing

---

* Zur Spectroskopie der Verbindungen. Spectrum der Thonerde. Svenska Vetenskapsakademiens Handlingar. Bd. 24, No. 15, 1892.



[illegible] of aluminium oxide which [illegible] viewed with the above [illegible] size and richness of det[illegible] [illegible] nce indeed are to make [illegible] although the spectrum has [illegible] sidereal physics. Perhaps [illegible] vestigation[1] will be [illegible] to

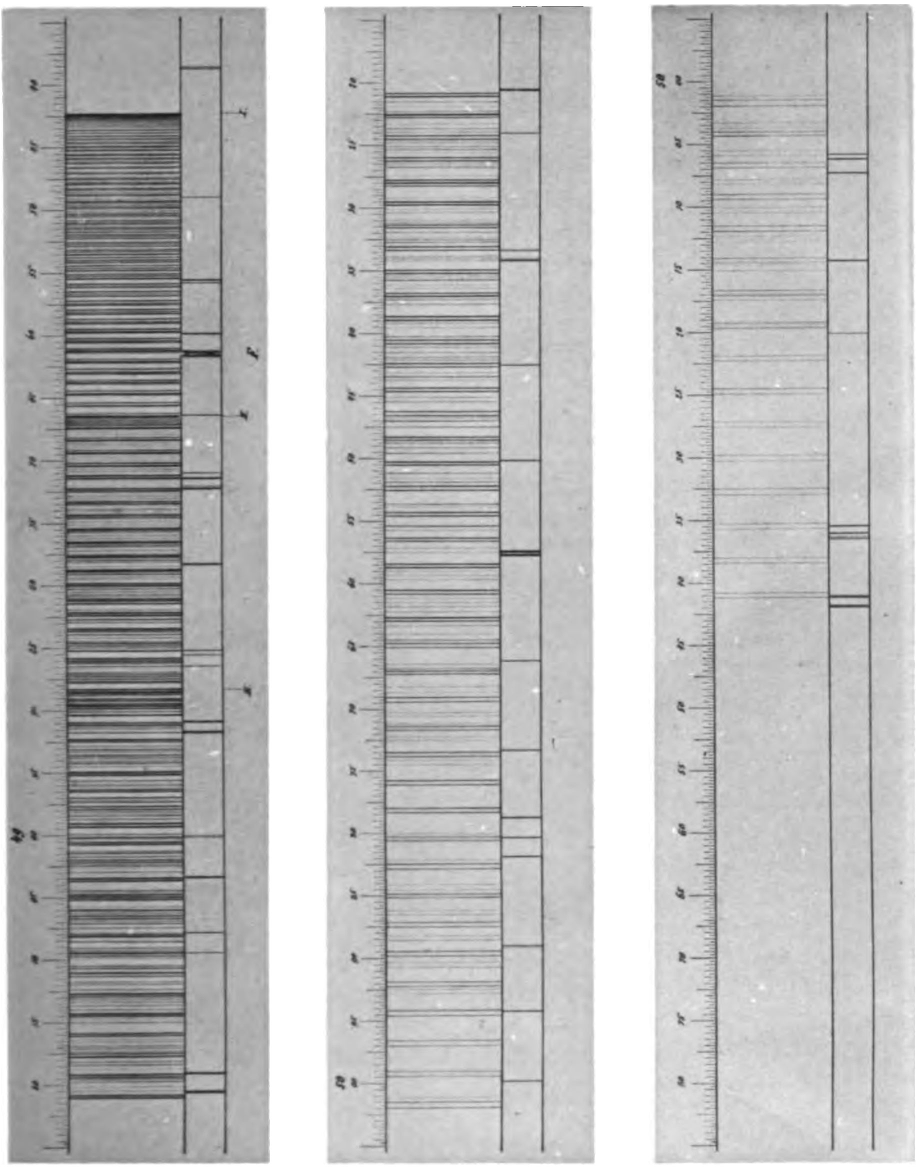
[illegible] of aluminium oxide consists of five [illegible] yellow, green, blue and violet, each [illegible] of smaller partial flutings of de- [illegible] tion of increasing wave-lengths [illegible] e to [illegible], who in the same manner [illegible] employed the uncondensed [illegible] circumstances, the intensity being [illegible] very moderate dispersion could [illegible] these other investigations do not [illegible] positions of the sharp edges of the [illegible] employment of the condensed spark in [illegible] is out of the question because the [illegible] that of dissociation, the spectrum of [illegible] that of the metal, it occurred to me that [illegible] whose temperature lies between that of the un[illegible] condensed spark would do good service, a [illegible] experiment has most satisfactorily confirmed.

[illegible] investigation was made with the help of photo[illegible] order. With the great dispersion thus ob[illegible] fluting of the spectrum was resolved into very [illegible] sharp lines. The spectrum was photographed [illegible] orthochromatic plates, together with the correspond- [illegible] of the solar spectrum, thus giving the means for [illegible] the wave-lengths of the lines by measurements on [illegible] dividing engine. For these determinations the Rowland standard lines were employed, as a thorough comparison had shown that the *relative* accuracy of this system notably exceeds that of the Potsdam catalogue. Moreover a good many (about 50 per cent) of the Potsdam standard lines are under the great dispersion here used not single, but form groups of two, three, or sometimes four lines, in which cases any certain identification of the given positions is impossible. As to the question which of the two systems is to be considered *absolutely* more correct, nothing

---

[1] Zur Spectroskopie [illegible] Spectrum der [illegible] [illegible] Bd. 24 N[illegible] 15, 1892.

PLATE XXXIX.



The Spectrum of Aluminium Oxide as Photographed by Professor B. Hasselberg.

evidently can as yet be affirmed, but the *relative* homogeneity of the system being the main point, this is here a circumstance of subordinate weight, which perhaps only the employment of quite new methods for wave-length determination may be apt to settle.

For igniting the oxide the employment of massive bars of aluminium as electrodes in the lamp is not practicable, because the current is soon interrupted by the oxide immediately formed. Instead of this I have introduced small fragments of the metal into the crater of the lower hotter carbon electrode and thus obtained an arc of sufficient steadiness, in which the oxide was evaporated. Together with the spectrum of the oxide the plates then of course contain also a number of foreign lines mainly pertaining to iron from the carbon poles. Happily the carbons now prepared by Siemens at Berlin are very pure, and in consequence neither the number nor the strength of these lines is of any importance. On the contrary, their presence, namely that of the iron lines, is of very great use as a check on the unaltered position of the spectrograph during the time of exposure. Nothing short of such an immediate criterion can assure freedom from constant errors in relative determinations of wave-lengths of the present nature.

The results obtained are contained in a catalogue of wave-lengths of about 3,000 lines. The probable error of these values does not in general exceed ± 0.02 X-metres. Besides the lines of aluminium-oxide the catalogue contains also the standard solar lines employed, in order that every correction which these standards may need in the future can immediately be applied to the corresponding part of the catalogue. It must be understood, however, that this list of lines does not include everything visible of the spectrum, but only the most prominent features of it, as contained in the four great flutings in the green, blue and violet. The yellow fluting, which in instruments of small power is well seen, becomes here very insignificant, and therefore does not deserve more special attention than the crowd of very feeble lines which fill almost the whole extreme violet and whose determination would have unduly prolonged this preliminary inquiry.

In order to give an idea of the magnificent structure of these flutings as seen on my photographs, the memoir is accompanied by a phototypic reproduction of my drawing of the main fluting in the neighborhood of F. From the same drawing the annexed plate is also copied in reduced size.

After terminating this inquiry, the main investigations on the arc-spectra of metals were commenced. From an astro-physical point of view, the spectrum of iron is indeed of first importance.

As, however, through the investigations of Thalén and Kayser and Runge, our knowledge of this spectrum may be considered tolerably perfect, I thought it of next importance to make a similar study of chromium, nickel, cobalt and manganese, of whose spectroscopy only the outlines are as yet roughly known. In the first of these spectra, the researches of Huggins, Thalén and Lockyer give altogether only about 70 lines, whereas on my plates, about 800 have been recorded between D and λ 345. A similar proportion will also probably hold good for the other metals. With the aim to eliminate foreign lines, the spectra are also photographed by pairs on the same plate, *e. g.*, chromium and nickel, chromium and iron, and so on, thus enabling the observer to judge exactly of any coincidence, and in such cases to trace the lines in question to their most probable origin. In this way, I have found that when exact coincidence occurs between lines in two such spectra the origin of the lines may generally be determined without difficulty from the ratio of their intensities. In a few instances (for iron and chromium perhaps one per cent of the whole number) exact coincidence has of course been recorded also for lines of equal intensity. These lines, which generally are faint and most probably originate in impurities common to both metals or from the electrodes, are in general to be excluded. From this circumstance, and from the fact that lines whose distances exceed 0.04 or 0.05 X-metres are easily and undoubtedly separated on my plates, I think it may be safely concluded that lines really common to two or more metals most probably do not exist.

For such metals as are to be obtained only in fragments or powder, as for example, cobalt and chromium, carbon electrodes, in the crater of which the metallic fragment or powder is placed, have generally been used. For those spectrum regions, however, in which the strong carbon flutings lie, other electrodes are to be employed, because in the crowd of carbon lines the fainter metallic lines cannot be surely discerned. For this purpose, thick copper electrodes have served very well, especially in the lower ultra-violet where the copper lines are few in number and easily distinguished.

In connection with these remarks, a singular observation concerning the corona line of the Sun may be mentioned. As proved for the first time by Young this line is double, a fact easily confirmed in my spectrograph not only in the third order, where the components are widely separated, but also in the second order. Of these two lines the upper one is as yet of unknown origin, whereas the lower component has been attributed to iron. In fact, there exists in this place a very feeble iron line, but it is, I think, next to certainty that this line is only an impurity in the iron spectrum caused by the presence of cobalt. On the photographs of this region of the cobalt spectrum which I have taken in the third order the solar line in question has a strong counterpart in the spectrum of this metal. The coincidence is undoubtedly perfect, but as to the iron line I do not feel sure, because on account of its weakness I have as yet not succeeded in bringing it out on my plates. This point will shortly be more closely investigated. So much seems, however, to follow from this observation, that the solar line in question most probably is due to cobalt and not to iron.

THE SPECTRUM OF NOVA AURIGÆ IN FEBRUARY AND MARCH, 1892.[*]

W. W. CAMPBELL.

The announcement of the appearance of a new star in Auriga reached Mt. Hamilton the 6th of February. This paper relates to spectroscopic observations made by me on seven nights between February 8 and March 13 inclusive. On the latter date the magnitude of the star was about 7.4. During the succeeding six weeks its brightness decreased fairly uniformly until, when the last reliable visual observation was made, April 24th, it was of about the sixteenth magnitude. In this period of decline the nights available for my use were cloudy for the most part, and the few attempts to secure observations were frustrated by the fogging of the object-glass.

APPARATUS.[†]

The observations, both visual and photographic, were made with the large Brashear spectroscope and 36 inch equatorial. In the visual observations the 10½-inch view telescope and an eyepiece magnifying 13.3 times were used. The third and fourth orders of a grating of 14,438 lines to the inch were not found suitable for the study of this spectrum, principally on account of the strength of the continuous spectrum and the great breadth of the

---

[*] Communicated by the author.

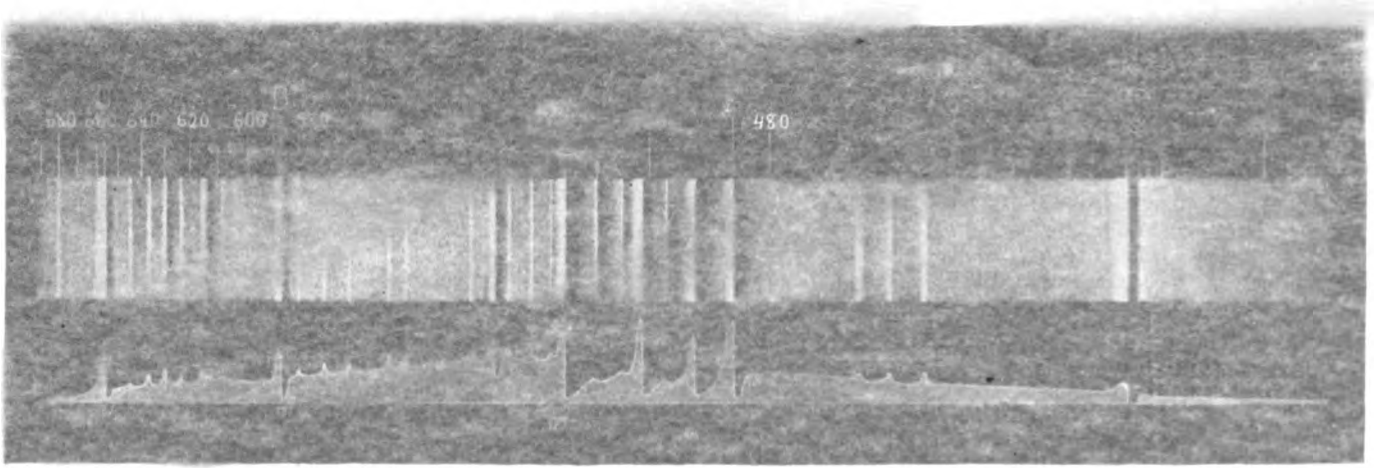
[†] A portion of the apparatus used in this work was purchased by a grant of money from the Thompson fund of the Amer. Ass. Adv. Science.

lines. The Observatory did not then possess first and second order gratings, which could probably have been used to advantage. A dense thallium compound prism, dispersing 12° between B and H, was used several evenings in fixing the positions and examining the character of the bright hydrogen lines, the D sodium lines, and a few other important lines. But an excellent 60° dense flint prism by Brashear, dispersing 5½° between B and H, was for several reasons better adapted to a general determination of the wave-lengths and was usually employed. With this prism the power of the spectroscope is such as easily to separate b_1 and b_4 in the solar spectrum, which are 1.6 tenth-metres apart.

In the photographic observations the eyepiece and micrometer were replaced by a camera box suitable for holding a small plateholder. No other changes were required to adapt the spectroscope to photography. In the winter I had decided to apply photography to spectroscopic work here; and, fortunately, on February 5 I had fitted the camera box and determined the photographic focus. It is to be regretted that the Observatory did not then possess apparatus suitable for photographing the spectrum with greater dispersion than that given by the 60° prism.

THE VISIBLE SPECTRUM.

The general character of the visible spectrum is shown in the accompanying drawing of the spectrum and of the intensity curve; though in the former the contrast between the faint lines and the continuous spectrum was necessarily overdrawn. Many of the lines between D and F were so nearly masked by the continuous spectrum that under stronger dispersion they would have escaped detection entirely. The region between F and Hγ was seen to contain a large number of bright lines. A few of the more prominent ones were located the first evening: but two photographs taken later the same evening showed the lines in this region so satisfactorily that thereafter no effort was made to observe them visually. The drawing therefore, really refers only to the portion of the spectrum below and including the F region, and is based upon the observations of February 8, 9 and 28. The intensity curve was drawn almost wholly from sketches made February 28, when the continuous spectrum had faded slightly, unmasking many of the lines previously invisible. On March 13, the continuous spectrum had in many regions wholly disappeared, and interfered with only a few of the measurements. A line at λ 5885 observed on the latter date only is not shown in the drawing.

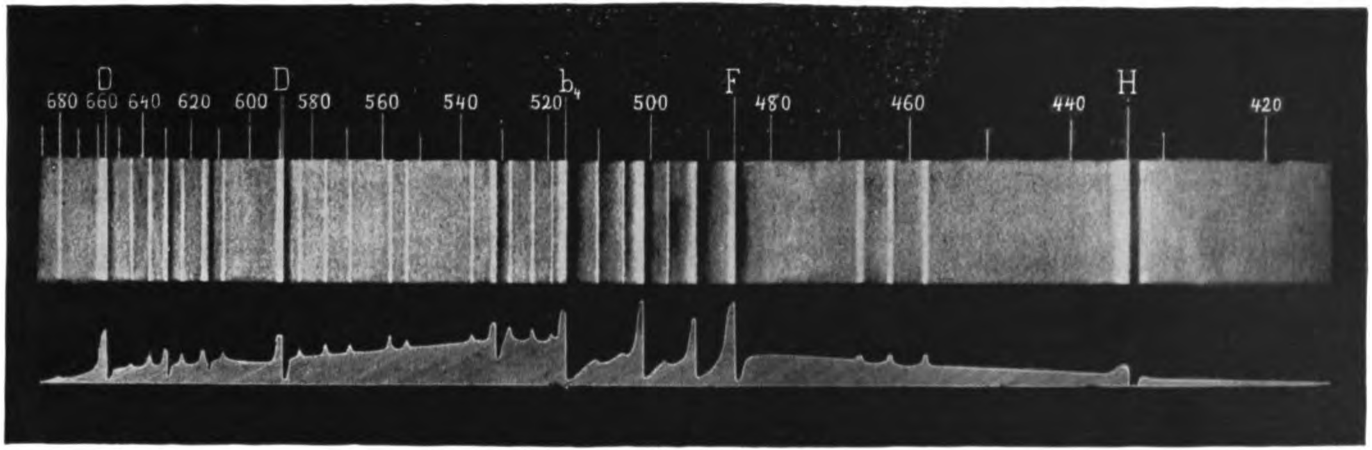


Visible Spectrum of Nova Aurigæ, 1892, February 28, from Observations at the Lick Observatory by W. W. Campbell [illegible] did not then possess first and second [illegible] could probably have been used to [illegible] compound prism, dispersing 12° between [illegible] several evenings in fixing the positions [illegible] of the bright hydrogen lines, the D [illegible] other important lines. But an excellent [illegible] Brashear, dispersing 5½° between B and H, [illegible] better adapted to a general determination [illegible] lengths and was usually employed. With this [illegible] the spectroscope is such as easily to separate [illegible] spectrum, which are 1.6 tenth-metres apart. [illegible] observations the eyepiece and micrometer [illegible] a box suitable for holding a small plate [illegible] changes were required to adapt the spectro- [illegible] In the winter I had decided to apply [illegible] to spectroscopic work here; and, fortunately, on [illegible] I had fitted the camera box and determined the po- [illegible] focus. It is to be regretted that the Observatory did [illegible] possess apparatus suitable for photographing the spec- [illegible] greater dispersion than that given by the 60° prism.

THE VISIBLE SPECTRUM.

The general character of the visible spectrum is shown in the accompanying drawing of the spectrum and of the intensity curve, though in the former the contrast between the faint lines and the continuous spectrum was necessarily overdrawn. Many of the lines between D and F were so nearly masked by the continuous spectrum that under stronger dispersion they would have escaped detection entirely. The region between F and H was seen to contain a large number of bright lines. A few of the more prominent ones were located the first evening; but two photographs taken later the same evening showed the lines in this region so satisfactorily that thereafter no effort was made to observe them visually. The drawing, therefore, really refers only to the portion of the spectrum below and including the F region, and is based upon the observations of February 8, 9 and 28. The intensity curve was drawn almost wholly from sketches made February 28, when the continuous spectrum had faded slightly, unmasking many of the lines previously invisible. On March 13, the continuous spectrum had in many regions wholly disappeared, and interfered with only a few of the measurements. A line at λ 5885 observed on the latter date only is not shown in the drawing.

PLATE XL.



Visible Spectrum of Nova Aurigæ, 1892, February 28, from Observations at the Lick Observatory, by W. W. Campbell.

Altogether there were observed visually thirty bright lines, not counting a bright region at λ 432 and a faint line occasionally glimpsed near λ 680; and ten broad dark lines in contact with the more refrangible edges of ten of the strongest bright lines. Careful searches for lines below C were made, but only the trace of a line near λ 680 could be seen. In each of the ten dark lines, except that above Hγ, a background of continuous spectrum was still visible, and was so noted on several evenings. These lines were sharply defined below by the bright lines, but were diffuse above. They were from twelve to fourteen tenth-metres broad, and their centres were about eleven tenth-metres more refrangible than the most intense points in the corresponding bright lines. But the dark and bright lines evidently overlapped, and it is probable that their real centres were slightly less refrangible than their apparent centres. Possibly the real centres were near the fine bright lines shown in the photographs, which will be referred to later.

As stated in ASTRONOMY AND ASTRO-PHYSICS for March, 1892, the normal positions for the hydrogen C, F and Hγ lines and the D sodium lines were occupied by bright lines. These and the lines λ 5168 and 5016 were carefully studied to obtain very accurately their positions and light curves. On the first few evenings all these lines were examined with the compound prism and extremely narrow slit, but no evidence of doubling was obtained; though with the exception of the D lines they were certainly very far from being uniformly bright throughout their breadth. The hydrogen lines C, F and Hγ, and the lines λ 5168, λ 5016 and λ 4923 were at least fifteen tenth-metres broad. Their more refrangible edges were quite sharply terminated. From the most intense points, which were about four tenth-metres below the upper edges, the intensity decreased about as shown in the drawing of the intensity curve, finally gradually merging into the continuous spectrum. The bright D line was about fifteen tenth-metres broad, quite sharply defined above, nearly uniform in brightness for ten or twelve tenth-metres, then merging gradually (but more sharply than the others) into the continuous spectrum below. The D line had greatly decreased in brightness by February 28; on March 13 it had apparently disappeared, and a faint line more refrangible than D was observed at λ 5885. The appearance of the spectrum at this point had changed considerably.

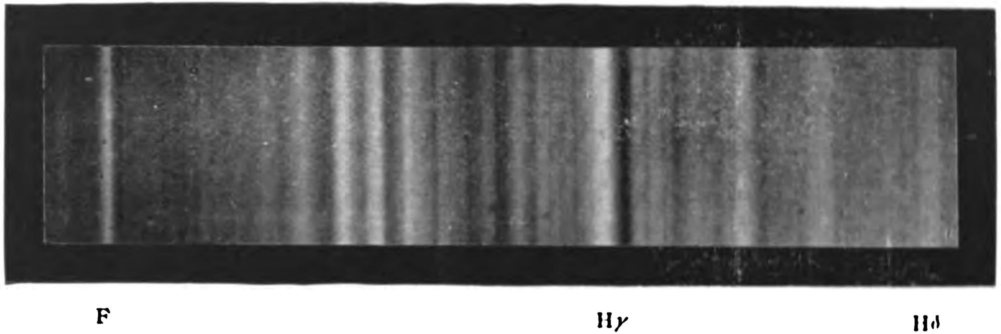
The points of maximum intensity in the C, F, and Hγ bright lines were well enough defined to permit their wave-lengths to be determined within one tenth-metre, as was found by first setting the micrometer wire on the star lines and then throwing in the hydrogen comparison spectrum. These comparisons were made on several nights, and the star lines were found to coincide with the comparison lines within the limits stated above. I therefore adopted for the wave-lengths of these lines their usual values 6563, 4862 and 4341. On three nights the D star line and the D sodium lines of the spark spectrum and of the flame were carefully compared. With the compound prism and narrow slit the comparison lines were widely separated. When the micrometer wire was placed in contact with the upper edge of the star line it was also in contact with the upper edge of D_2. The comparison line D_1 appeared to fall in the exact centre of the broad star line, and I have accordingly adopted for it the wave-length 5896. The point of maximum brightness in the line λ 5168 was not well defined; but comparisons with magnesium b_4 showed that the wave-lengths were practically equal. The regions of maximum brightness in the lines λ 5016 and λ 4923 were likewise quite broad, which made an accurate determination of their wave-lengths impossible.

Assuming the wave-lengths either of the comparison lines or of the star lines at λ 6563, λ 5896, λ 5168, λ 4862 and λ 4341, the wave-lengths of the intermediate lines were generally obtained from the readings of the large circle (12 inches in diameter, reading to 10″) corresponding to the different lines in the star, by interpolating between the assumed wave-lengths by means of curves based upon the solar spectrum. In some cases the wave-lengths could probably have been obtained more accurately by making micrometer comparisons, but usually the method employed was the most satisfactory for this spectrum. The wave-lengths resulting from the visual observations on five nights are given below. The appearance of a line depended upon its breadth, intensity and position in the continuous spectrum, and it is impracticable to give a verbal description of the lines in this place. Reference can be made to the general intensity curve.

WAVE-LENGTHS OF BRIGHT LINES OBTAINED VISUALLY.

Feb. 8	Feb. 9	Eeb. 22	Feb. 28 [680]	March 13	Means [680]
6563	6563	6563	6563	6563	6563
6447	......	......	6456	......	6451
6363	6380	......	6367	6367	6369
6294	6299	......	6296	6295	6296
6251	6236	......	6234	......	6240
6151	6156	......	6158	......	6155

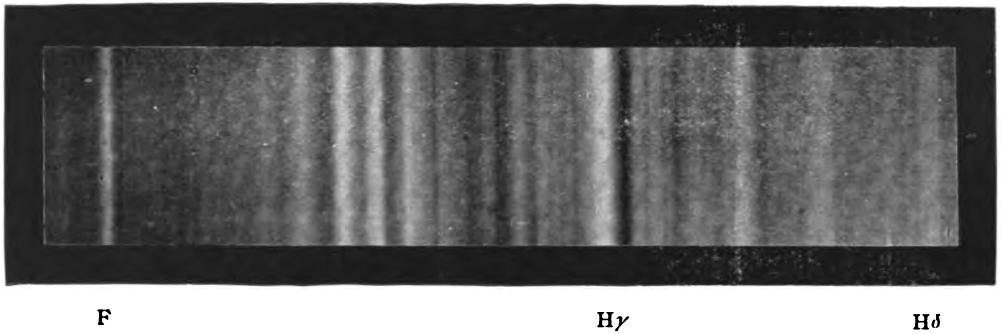
PLATE XLI.



Photographic Spectrum of Nova Aurigæ, $H\gamma$ Region, 1892, February 9.

ASTRONOMY AND ASTRO-PHYSICS, No. 109.

PLATE XLI.



Photographic Spectrum of Nova Aurigæ, Hγ Region, 1892, February 9.

Feb. 28	March 13	Means
6087	......	6087
5896	......	5896
......	5885	5885
841	......	5841
59	5763	5761
0	......	5690
[illegible]	5576	5578
	......	5535
	5390	5378
	5313	5318
	5274	5280
	5233	5232
	5193	5193
	5168	5168
	5103	5102
	5055	5055
	012	5014
	...	4969
	1	4923
	[illegible]	4862
		4670
		4629
		4583
		4341
		[432]

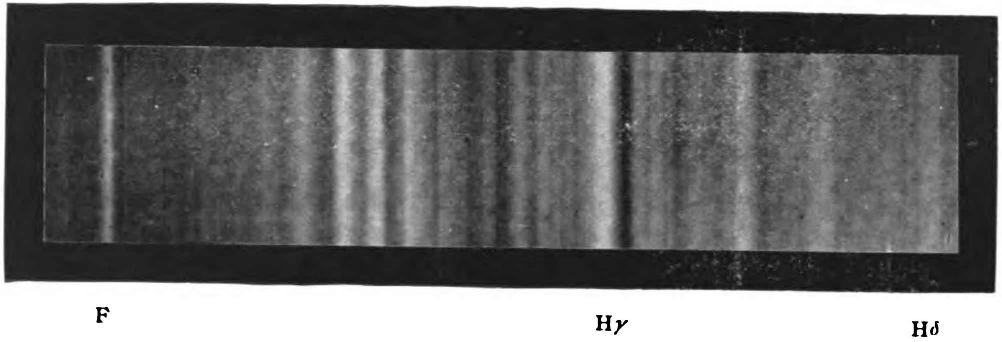
for a ly of the
limited
ime to
-inch
v of
m.
er
e

Nova

ion

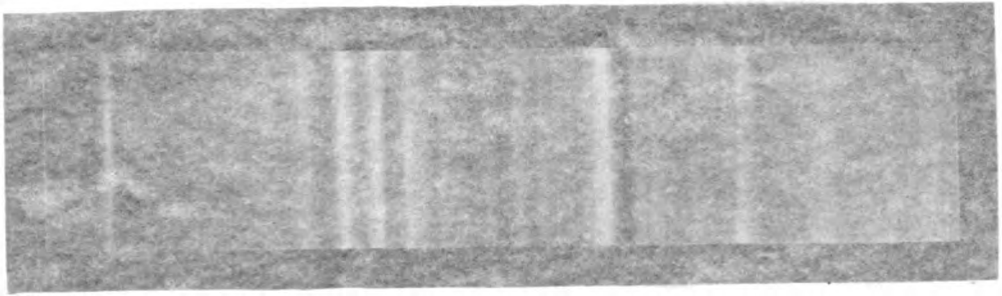
In

PLATE XLI.



Photographic Spectrum of Nova Aurigæ, Hγ Region, 1892, February 9.

[illegible]



Photographic Spectrum of Nova Aurigae. H. [illegible], 1892, February 9

Feb. 8	Feb. 9	Feb. 22	Feb. 28	March 13	Means
......	......	......	6087	......	6087
5896	5896	5896	5896	......	5896
......	......	......	......	5885	5885
......	......	......	5841	......	5841
......	......	......	5759	5763	5761
......	......	......	5690	......	5690
5585	5576	......	5575	5576	5578
......	......	......	5535	......	5535
5376	5372	......	5375	5390	5378
5320	5317	......	5321	5313	5318
5282	5282	......	5281	5274	5280
5229	5228	......	5237	5233	5232
5193	......	......	......	5193	5193
5167	5168	5168	5168	5168	5168
5103	5101	......	......	5103	5102
5056	......	......	......	5055	5055
5016	5013	5015	5016	5012	5014
4969	4972	......	4965	......	4969
4926	4922	......	4925	4921	4923
4862	4862	4862	4862	4862	4862
4670	......	......	......	......	4670
4629	......	......	......	......	4629
4583	4584	4582	......	......	4583
4341	4341	......	4341	4341	4341
......	......	......	[432]	......	[432]

THE PHOTOGRAPHIC SPECTRUM.

The 36-inch telescope is not suitable for a general study of the photographic portions of stellar spectra. Only a very limited region of a stellar spectrum can be photographed at one time to advantage, for the reason that the color curve of the 36-inch objective is very steep in the blue and violet, and only a few of the rays enter the slit. The focal length of the objective is 37mm. greater for the Hγ rays than for the F rays, and 34mm. greater for the Hδ than for the Hγ rays. For a given position of the spectroscope slit the rays of a certain wave-length come to a focus (a point) on the slit and pass through properly; those of greater wave-length are in focus before reaching the slit, and only a few of them pass through; those of smaller wave-length do not reach their focus and only a few of them pass through the slit. Beyond Hδ the curve is so steep as practically to prevent the taking of photographs in that region. Another serious difficulty enters in that region of the spectrum: the image formed on the slit plate by the brighter visual rays is large and interferes very greatly with keeping the point in focus in the slit.

The photographs of Nova Aurigæ's spectrum were taken in two sections and with two sets of adjustments: first, with the slit in the focus for the F rays and the prism at minimum deviation for F; second, with the slit in the focus for the Hγ rays and the prism in minimum deviation for Hγ. In the first case the F rays proceeding from all parts of the object-glass entered the slit, while of the rays of greater or less wave-length only those proceeding from a region of the object-glass along and near the diameter parallel to the slit entered the slit at all. A similar result obtained for the Hγ setting. With ordinary dry plates the F photographs extend from the slightly actinic region λ 5200 to λ 4300, and are densest near and above F; and the Hγ photographs from λ 5000 to λ 4100 and densest in the Hγ region. One successful F photograph was obtained on an isochromatic plate, on February 14, which is measurable from λ 5686 to λ 4341. It is evident that the relative photographic brightness of lines in different parts of the spectrum cannot be obtained from these plates.

With the above limitations the photographs were successful from the first, and in all seven measurable negatives were obtained. A list of them is given below:

Date.		Region.	Slit Width.	Exposure.	Remarks.
1892, Feb.	8	F	0.0020 inch	15m	
"	8	Hγ	0 0020 "	15m	
"	9	F	0.0015 "	32m	
"	9	Hγ	0.0015 "	26m	
"	14	F	0.0011 "	37m	
March	6	F	0.0010 "	120m	Very windy
"	6	Hγ	0.0010 "	150m	" "

The spectrum of hydrogen was photographed on each plate for purposes of comparison, very near the stellar spectrum; on one side of it before beginning the exposure on the star and on the other side after closing the exposure. The original negatives were measured by means of a Stackpole measuring engine, and the measures were converted into wave-lengths by the aid of photographic interpolation curves. A list of the wave-lengths of bright lines obtained from each of the plates is given below. The results are corrected for the observer's motion and for curvature of the comparison lines. In a few cases it is impossible to determine from the negatives whether the lines measured were bright lines or were strong continuous spectrum between dark lines. In order to test the adjustments of the instrument, the lunar and hydrogen spectra were frequently photographed on the same plate, likewise the solar and hydrogen spectra, with the hydrogen tube both in front of the slit and at one side, and no displacement could be observed. A photograph of the spectrum of α Orionis showed the lines to be fine and sharp, while with the same adjustments and settings those of Nova's spectrum were broad and diffuse.

WAVE-LENGTHS OF BRIGHT LINES OBSERVED PHOTOGRAPHICALLY.

Feb. 8. F	Feb. 8. $H\gamma$	Feb. 9. F	Feb. 9. $H\gamma$	Feb. 14. F	Mar. 6. F	Mar. 6. $H\gamma$	Means.	Remarks.
....	....	....	....	5685	....	....	5685	Maximum in broad line.
....	....	....	....	5630	....	....	5630	Maximum in broad line, poorly defined.
....	....	....	....	5584	....	....	5584	Two prominent lines, clearly separated.
....	....	....	....	5575	....	....	5575	
....	....	....	....	5534	....	....	5534	Maximum in broad line.
....	....	....	....	5454	....	....	5454	Maximum in broad line.
....	....	....	....	5379	....	....	5379	Maximum in broad line.
....	....	....	....	5329	....	....	5329	Double line very similar to F line.
....	....	....	....	5318	....	....	5318	
....	....	....	....	5285	....	....	5285	Prominent line, probably double, but not clearly separated.
....	....	....	....	5276	....	....	5276	
....	....	....	....	5234	....	....	5234	Very faint, poor.
....	....	....	....	5200	....	....	5200	Very faint, poor.
....	....	....	....	5176	....	....	5176	Similar to F line, double, but not clearly.
....	....	5170	....	5168	5170	....	5169	
....	....	....	....	5159	....	....	5159	Very faint companion to above.
....	....	....	....	5142	....	....	5142	Very faint line.
....	....	....	....	5095	....	....	5095	Faint line, poor.
5017	....	5019	....	5018	5018	....	5018	Similar to F line, no signs of doubling.
....	....	trace	....	5007	trace	....	5007	Companion to above.
4969	....	trace	....	4969	4969	....	4969	Faint, poorly defined.
....	....	....	....	....	4929.1	....	4929	Well defined March 6, equal to line below.
4922	....	4923	4923	4922.9	4921.7	4923	4923	Maximum of line resembling F line.
trace	....	trace	....	4913.2	4913.0	....	4913	Companion to above.
....	4871.3	....	4871.2	4868.9	4868.2	....	4869.9	Well defined March 6.
4861.7	4862.2	4861.4	4861.5	4861.1	4860.8	4862	4861.6	Principal F line.
4851.6	....	4851.8	4851.6	4852.0	4849.1	....	4851.2	Companion to above.
4777	....	4772	....	4773	....	....	4774	Estimated centre of very broad bright region.
4733	....	4739	....	4739	....	....	4737	Estimated centre of very broad bright region.
4700	....	4703	4715	4709	....	4710	4707	Estimated center of broad bright region.
4671	....	4666	4672	4669	....	4668	4669	Centre of broad bright line.
4628	4632	4628	4631	4630	4631	4630	4630	Centre of broad bright line.
4588	4585	4587	4586	4587	4581	4585	4586	Centre of broad bright line.
4575	....	4576	4576	....	....	....	4576	Either well defined bright lines or continuous spectrum between absorption lines.
4570	....	4570	....	....	....	....	4570	
....	....	4564	4565	4564	....	....	4564	A group of lines, defined on fourth and fifth negatives, blended on the others.
4556	....	to	4559	....	....	4561		
to	4553		4554	4556	4554	to	4554	
4546	....	4547	4549	4549	....	4545	....	
4533	4533	4538	4524	4538	....	4528	....	
to	to	to	to	to	4516	to	4518	Appears like a group of lines, but not well defined.
4504	4504	4500	4509	4511	....	4504	....	
4490	....	4493	4494	....	....	4496	....	A group of lines not well separated, with maximum about λ4481.
4483	....	to	to	4479	4480	to	4481	
4469	....	4478	4470	....	....	4469	....	
....	....	4455	....	....	....	....	....	
4446	....	to	4445	4444	....	4446	4445	A group of lines with maximum about λ4445.
....	....	4441	....	....	....	....	....	
....	....	4436	4437	....	....	....	4436	Broad bright line.
4421	....	4420	4418	4418	....	4420	4419	Maximum of broad line.
4383	....	....	4386	....	....	4387	4385	Centre of bright region, apparently containing several lines.
....	....	4374	....	....	....	4376	4375	Rather broad line.
....	....	....	....	....	....	4355	4355	Apparently a third component of Hγ line.
....	4347.9	4348.0	4348.9	4347.9	....	4346.2	4347.8	Component of Hγ line, usually well defined.
4340.5	4340.2	4340.7	4341.5	4340.6	....	4340.1	4340.6	Principal Hγ line.
4332.1	4332.2	trace	4331.5	trace	....	4329.4	4331.3	Companion to above.
....	....	....	4316	....	....	....	4316	Broad, appears double.
....	4296	....	4297	....	....	....	4296	Broad, well defined.
....	4266	....	4269	....	....	....	4267	Centre of broad line.
....	....	....	4246	....	....	....	4246	Broad diffuse line.
....	4238	....	4234	....	....	....	4236	Broad bright line, resembles F and Hγ groups.

WAVE-LENGTHS OF BRIGHT LINES.—*Continued.*

Feb. 8. F	Feb. 8. Hγ	Feb. 9. F	Feb. 9. Hγ	Feb. 14 F	Mar. 6 F	Mar. 6 Hγ	Means.	Remarks.
....	....	....	4227	....	....	....	4227	Faint companion to above.
....	....	....	4209	....	....	....	4209	Broad diffuse line.
....	....	....	4180	....	....	....	4180	Very bright line.
....	....	....	4166	....	....	....	4166	Broad defined line.
....	....	....	4126	....	....	....	4126	Broad defined line.
....	....	....	4108	....	....	....	4108	Component of Hδ.
....	....	....	4102	....	....	....	4102	Principal Hδ line.
....	... .	....	4095	....	....	....	4095	Companion to Hδ.
....	....	....	4082	....	....	....	4082	Maximum of broad line.

An enlargement of the Hγ photograph of February 9 is shown in Plate XLI. A few defects in the original negative, mostly in the region of F, have been made to appear as lines by the cylindrical lens used in enlarging.

IDENTIFICATION OF THE LINES.

It was early noted by Professor Vogel and others that the half dozen prominent lines in Nova's spectrum coincided with prominent lines in the spectrum of the solar chromosphere. The probability that any line would be observed is a function of its intensity and the frequency with which it occurs, and therefore of the product of these two quantities. In the following table I have arranged a list of chromosphere lines whose wave-lengths agree closely with those of the lines in Nova's spectrum, placing opposite them the name of the element from which they originate, and the product F × I of their frequency and intensity. They are selected from Professor Young's catalogue of 273 chromosphere lines, as given in Scheiner's *Spectralanalyse*. A few of the identifications are doubtful and are enclosed in brackets [ ]. The faint and infrequent chromosphere lines are not inserted in the list. It appears that nearly all the prominent lines in Nova Aurigae's spectrum are prominent lines in the chromosphere spectrum, and *vice versa*. In the last two columns of the table are given a few other probable identifications. Many of the lines left unidentified fall near prominent lines or groups of lines in the spectrum of iron; while practically all of the lines can be matched by lines in the spectra of those elements which are prominent in the chromosphere. As surmised by Professor Young, ASTRONOMY and ASTRO-PHYSICS for April, the lines λ 6296 and λ 5578 are near the auroral lines λ 6298 and λ 5571. Likewise, the lines λ 5378, λ 5232, λ 5196, λ 4630 and λ 4355 are near other auroral lines; but the presence of so many iron lines in the spectrum renders it probable that these also are iron lines.

Nova Aurigæ.		Chromosphere Lines.			Other Lines.	
Visual	Photographic	λ	F x I	Element	λ	Element
[680]	......	......	......	......	......	......
6563	......	6563	10000	Hydrogen	......	......
6451	......	[6455]	60	——	6451	Calcium
6369	......	......	......	......	......	......
6296	......	......	......	......	6303.98	Iron
6240	......	[6247]	40	Iron	......	......
6155	......	......	......	......	6161.55	Sodium
6087	......	......	......	......	......	......
		5896	1500	Sodium	......	......
5896	......	5890	1500	Sodium	......	......
5885	......	[5876]	9000	Helium	......	......
5841	......	......	......	......	......	......
5761	......	......	......	......	......	......
5690	5685	......	......	......	5688.83	Sodium
......	5630	......	......	......	......	......
5578	5584	......	......	......	5587	Iron
	5575	......	......	......	5576.70	Iron
5535	5535	5535	600	Iron	......	......
......	5454	5456.47	80	Iron	......	......
5378	5379	[5372]	30	Iron	......	......
5318	5329	5317	4500	Iron, Cor.	......	......
	5318	5317	4500	Iron, Cor.	......	......
5280	5285	5285	200	Iron	......	.. ...
	5276	5276	450	Iron	......	......
5232	5234	5235	80	Iron, Mn.	......	......
5193	5200	5198	150	. ....	......	......
5168	5176	5184.72	3250	Magnesium	......	......
	5169	5169.68	1800	Iron, Mg.	......	......
	5159			......	......	......
......	5142	. ...	......	......	......	......
5102	5095	......	......	......	......	......
5055	trace	......	......	......	......	......
5014	5018	5019	450	Iron	......	... ..
	5007	5016	300	Titanium	......	......
				......	......	......
4969	4969	......		......	......	......
				......	......	......
4923	4929	4924	480	Iron	......	......
	4923	......	......	......	......	......
	4913	4919	60	Iron	......	......
				......	.....	......
4862	4869.9			......	......	......
	4861.6	4861.6	8000	Hydrogen	......	......
	4851.2			......	......	......
......	4774	......	......	......	......	......
......	4737	......	......	......	......	......
......	4707	......	......	......	4705	Magnesium
4670	4669	......	......	......	4669.65	Sodium
4629	4630	4630	270	Iron	4629	Cerium
4583	4586	4584	90	Iron	......	......
......	4576	......	......	......	[4573]	Cerium
......	......	......	......	......	[4572]	Titanium
......	4570	......	.... .	......	[4571]	Magnesium
.. ...	4564	4566	30	Iron	......	......
......	......	4564	50	Titanium	......	......
......	4559	4560	16	Iron	......	......
......	......	4556	50	Iron	......	......

Nova Aurigæ.		Chromosphere Lines.			Other Lines.	
Visual	Photographic	λ	F x I	Element	λ	Element
......	4554	4554	50	Barium	......	......
......	4549	4550	80	Iron	......	......
......	4534	4534	25	Iron	......	......
......	to			......	......	......
......	4502	4502	90	Titanium	......	......
......	4490	4492	160	Manganese	......	......
......		4490	45	Iron	......	......
......	4481	4482	10	Iron	4481	Magnesium
......		4472	2500	Cerium	......	......
......	4471	4470	100	Iron	......	......
......	4445	4444	20	Iron	......	......
......	4436	......	......	......	4435	Calcium
......	4419	......	......	......	......	.....
......	4385	4385	16	Ca., Ce.	......	......
......	4375	4376·75	39	Iron	......	......
......	4355	......	......	......	4354	Calcium
	4347·8			......	......	......
4341	4340.6	4340·7	6500	Hydrogen	......	......
	4331·3			......	......	......
[432]	4316	......	......	......	4318	Calcium
......	4296	......	......	......	......	.....
......	4267	......	......	......	......	......
......	4246	4246	90	Iron	......	......
......	4236	4236	150	Iron	......	......
......	4227			......	[4227]	Calcium
......	4209	[4216]	180	Calcium	.....	......
......	4180	......	......	......	......	......
......	4166	......	......	......	4167	Magnesium
......	4126	......	......	......	......	......
......	4108			......	......	......
......	4102	4102	5000	Hydrogen	......	......
......	4095			.....	......	......
......	4082	4078	50	Calcium	......	......

Near the centres of all the broad absorption lines shown on the photographs were comparatively fine bright lines. They were measurable at λ 5159, λ 5007, λ 4913, λ 4851 and λ 4331. They probably existed also at λ 6552, λ 6285, λ 5885 and λ 5307, since it was noted that the continuous spectrum showed faintly in the emission lines at those places, which effect was probably due more to the presence of the fine lines than to the very much fainter continuous spectrum shown in a few of the photographs.

If they existed on the more refrangible sides of other prominent bright lines they were either concealed by the strong continuous spectrum, or, in certain regions, confused with other lines. We can probably say they existed in all the broad absorption lines, but we cannot say whether or not they existed quite independently of the absorption lines.

CONCLUSIONS.

It has generally been conceded that Nova Aurigæ was a system of at least two bodies, one giving rise to the system of very bright lines, the other to the system of broad absorption lines. On several photographs a very faint continuous spectrum showed as a background in the absorption lines. This probably belonged to the bright line spectrum or spectra. The strong continuous spectrum which masked many of the fainter bright lines probably belonged to the dark line spectrum. Nearly all the photographs show the F and Hγ bright lines to be double, with different degrees of clearness. There are signs of doubling in the strong lines in the green, and on the F negative of March 6, the line λ 4923 is distinctly separated into two nearly equal components.

Professor Vogel has accounted for the observed phenomena in this manner: the fine bright lines within the broad absorption lines were due to reversals such as are sometimes observed in the spectra of Sun-spots, and were caused by eruptions of gases from the interior of the body furnishing the dark line spectrum; the doubling of the bright lines was due to the presence of two bodies possessing bright line spectra; and therefore Nova was a system of three bodies moving with very different velocities in the line of sight.

Dr. and Mrs. Huggins have suggested a further simplification, and have ingeniously explained the apparent doubling and great breadth of the bright lines by combining the reversion theory of Zöllner and Vogel with the tidal theory of Klinkerfues and Wilsing. They consider Nova as a system of two bodies, one yielding a bright line spectrum and the other a dark line spectrum.*

The reappearance of Nova as a planetary nebula, apparently with only one system of lines, favors a simple origin. But the fact that the present system of lines does not coincide with any one of the four former systems either makes the original spectrum more complex, or it shows conclusively that orbital motion has ensued. In the latter case much light must be thrown upon the question by continued observation of Nova's velocity, and considerable time may be required.

While the hypothesis of two bodies quite generally satisfies the observations and has the further very great advantage of simplicity, there are a few not unimportant points furnished by the

---

* See ASTRONOMY AND ASTRO-PHYSICS for August, 1892.

photographs which favor the existence of three or four bodies: two or three yielding bright line spectra and one a dark line spectrum. These points are:

First.—The two components of the bright lines are much more clearly defined in the later photographs than in the earlier. This was partly but not wholly due to the decline of the continuous spectrum. The photographs taken earlier in February show the broad bright lines F and λ 4923 to be double only with difficulty. Two condensations, the more refrangible one being the stronger, show certainly, but not clearly. The F photograph of March 6 shows these lines as well defined doubles. In the line λ 4923 the two components are separated too widely to present the appearance of reversion, and the continuous spectrum shows only very thinly in that region.

Second.—In all the double lines shown on the March 6th photographs the two components are nearly equal, while in the earlier photographs the more refrangible components were the stronger.

Third.—There is some reason to believe that the intervals between the components were less in March than in February, though on the earlier negatives the measures were subject to considerable uncertainty, and photographs taken elsewhere do not seem to show this variation.

Fourth.—The normal position of the fainter lines throughout the spectrum (as compared with the chromosphere spectrum) is evidence that they were mostly associated with the more refrangible components of the double lines, *and not with the double lines as a whole*.

Fifth—The fine bright lines appeared not only in the dark F and Hγ lines, but also in three dark lines in the green, all apparently in the same position relative to the principal series of bright lines.

Sixth—During the decline of Nova in brightness the continuous spectrum belonging mostly to the dark line star decreased more rapidly than the bright lines, while the fine bright lines decreased certainly no more rapidly than the principal bright lines.

The above evidence is far from conclusive, and is inserted now merely for completeness. On the hypothesis of four bodies, the principal system of bright lines was not displaced appreciably, and the star yielding it was practically at rest with reference to the solar system. Another system was displaced towards the red a distance corresponding to a velocity of recession of about 315 miles per second. The system of fine bright lines and likewise the system of dark lines were displaced towards the violet a distance corresponding to a velocity of approach of about 400 miles per second.

The relation of the early spectrum of Nova to its present spectrum was considered by me in the October number of ASTRONOMY AND ASTRO-PHYSICS. A careful re-examination of the negatives has revealed none of the present lines, though it is possible that the F plate of February 9 would have recorded the line now at λ 5002 had it then existed.

While it is possible for an observer to work alone in making spectroscopic observations with the great telescope, it is far from convenient and involves a serious loss of observing time. As no other person was available Professor Holden kindly volunteered to assist me in the spectroscopic observations until some other arrangement could be made. I wish here to acknowledge this efficient assistance, without which the foregoing observations would have been much more incomplete.

MT. HAMILTON, 1892, Sept. 30.

SOME RESULTS AND CONCLUSIONS DERIVED FROM A PHOTOGRAPHIC STUDY OF THE SUN.*

GEORGE E. HALE.

In view of the fact that the study of prominence, facula and Sun-spot spectra by photographic means has now been taken up by several investigators, it seems desirable to bring together the results of the work in this direction which has been in progress at the Kenwood Observatory since April, 1891. Some of these results have been published before or casually referred to in papers on other branches of solar work, but they cannot fail to be of greater value for comparison with the investigations of others if grouped in a single article. There also remain to be mentioned several disconnected matters to which attention has not yet been called.

The following are some of the results, with several conclusions to which I have been led; further investigations may very possibly render necessary material modifications in the views here expressed.

---

* Communicated by the author.

CHROMOSPHERE AND PROMINENCES.

1. H and K are always present as the strongest lines in the chromosphere and prominence spectrum.

2. These lines extend to the highest parts of all prominences, but have not yet been traced to any greater distance from the limb, *i. e.*, into the corona.

3. K seems to be invariably stronger than H, and extends farther from the limb.

4. In cases of motion in the line of sight the distorted forms of the H and K lines are similar.

5. Prominences have the same form in both lines. Where apparent differences exist they may probably be ascribed to the greater brightness of K. (This remark also applies to 4).

6. Both H and K expand rapidly in width from the upper surface of the chromosphere to its base. Consequently photographs taken with the slit just tangent to the limb show these lines more than twice as broad as they appear in the higher regions of prominences.

7. Both lines are often doubly reversed (narrow dark lines running down the center of the bright lines) in the chromosphere, and sometimes in the base of bright prominences.

8. H is always accompanied by a hydrogen line (Hϵ), but this line is much fainter, and does not extend so high in prominences.

9. The entire series of ultra-violet hydrogen lines have been photographed in very bright prominences, but in faint prominences the lines more refrangible than α_1 or β_1 are usually absent from the photographs. They may, however, be present as very faint lines in all prominences, but remain invisible on the photographs on account of the brilliancy of the atmospheric spectrum.

10. The line α_1 is frequently accompanied by a line slightly more refrangible, which is probably not due to hydrogen. In a few cases α_1 has been single in certain parts of a prominence, and double in other parts.

11. The upper component of α_1 is sometimes doubly reversed in the chromosphere.

12. No prominence has yet been found which showed the H and K lines alone, *i. e.*, without some of the less refrangible hydrogen lines.

13. The forms of prominences as observed in C and in H and K seem to be the same, though they may be more extensive in the latter lines.

14. Prominences seem to have the same motion in the line of sight, whether observed in C or in H and K.*

15. The spectra of eruptive prominences frequently contain many metallic lines in the ultra-violet; notably the magnesium triplet at λ 383.†

16. Eruptive prominences sometimes exhibit a continuous spectrum in the ultra-violet.

17. Prominences frequently show evidences of spiral motion.

FACULÆ.

18. Both H and K are always reversed in faculæ.

19. These reversals are usually (if not invariably) double, a narrow dark line running down the center of the broader bright line. The appearance on the photograph is consequently as if there were two narrow bright lines separated by a narrow dark line, in the centers of the broad dark shades at H and K. In some instances I have noticed that one of these narrow bright lines was missing in certain portions of a facula, an unsymmetrical double reversal resulting.

20. Distortions in the doubly reversed H and K lines of the faculæ are rare. I have found but one or two instances of this kind, and in these cases the distortions took the form of expansions in the lines.

21. H is usually unaccompanied by the slightly less refrangible hydrogen line, referred to above as being always present in prominences. In a few cases, however, this line has been found extending across spots, and for some distance in the faculæ on either side.

22. Neither α_1 nor any other bright lines more refrangible than H and K, have been found in faculæ or spots.

23. Curved forms predominate in faculæ, and suggest some relation with spiral forms in prominences.

SPOTS.

24. The bright H and K lines seem to invariably extend entirely across every Sun-spot. Both lines are doubly reversed in the faculæ which probably completely surround every spot. In the umbra the reversals are narrower, and the dark central line is usually absent.

---

* In one case where the motion of the entire prominence was considerable, a large number of lines in the ultra-violet (all that were visible on the photograph) were equally displaced with H and K.

† See my article on "The Ultra-Violet Spectrum of the Solar Prominences" in this number of ASTRONOMY AND ASTRO-PHYSICS.

25. Small spots, especially when members of a group containing large spots, are frequently completely covered with faculæ.

26. In the ultra-violet spectra of spots the dark lines of the solar spectrum do not seem to undergo selective widening, as in the less refrangible parts of the spectrum. Beyond the presence of the bright H and K lines, and the infrequent appearance of H_ϵ, the spot spectrum seems to differ from the ordinary solar spectrum only by the increased general absorption.

27. Distorsions of the bright H and K lines in spots are extremely rare.

CONCLUSIONS.

28. The exact agreement of H and K with the two strongest lines in the spectrum of the calcium spark leads me to attribute these prominence lines to calcium. While the properties of calcium in its terrestrial condition make it difficult to see how its vapor can form the most important constituent of the prominences, yet I do not see how we are to escape from this conclusion.

29. No other than a negative conclusion can as yet be offered in regard to the perplexing question of the so-called "white prominences." At the eclipse of August 29, 1886, a large prominence was photographed which was said by Professor W. H. Pickering to have no other lines in its spectrum than H and K, and a faint trace of an ultra-violet line, in addition to a bright continuous spectrum. He goes on to add:[*] "It was therefore quite invisible, both before and after totality, by the usual spectroscopic method, as was in fact noted at the time by Professor Tacchini." The character of the photograph, at least so far as can be judged from the reproduction accompanying the report, was hardly such as to warrant any very positive statement as to the absence of the hydrogen lines, particularly as they might have been partly obscured by the bright continuous spectrum. The prominence might also have been eruptive in nature, not lasting longer than the duration of totality, and thus may not have existed when Professor Tacchini made his observations before and after the eclipse. However this may be, for this is only one of a number of cases in which "white prominences" have been recorded, I have as yet found no prominences which exhibited H and K without the hydrogen lines. This point has not been made the subject of special investigation, however, and it

---

[*] Annals of Harvard College Observatory, Vol. XVIII, No. 5, p. 100.

may be that some cases of the kind may ultimately be brought to light.

30. The fact that small spots are sometimes completely covered with faculous matter (or possibly with prominences) may assist in explaining the anomalous heat radiations recently measured in certain spots by Professor Frost.* I hope to take up this point more in detail elsewhere.

31. Photographic methods have abundantly substantiated the conclusions long ago drawn from visual observations in regard to the nature of faculæ. In a great many photographs taken with the spectroheliograph, faculæ are shown projecting above the Sun's limb. And the intimate relationship between faculæ and eruptive prominences is not less evident, especially in composite photographs showing faculæ and prominences on the same plate. When we consider that eruptive prominences probably rise from faculæ, it is not at all surprising that such prominences sometimes show a continuous spectrum in addition to their bright lines. For a violent eruption would naturally carry up with the prominence some "dust-like"† matter from the facula, which would give a continuous spectrum.

32. The reversals of the H and K lines over spots seem to be readily explainable. As has been stated above, the reversals are double in the penumbra, and also for a considerable distance on either side of the spot, but usually single in the umbra. As spots seem to be always surrounded by faculæ, which frequently encroach upon the penumbra, the double reversals occur in these just as they do in faculæ not in the vicinity of spots. The single reversals in the umbra, however, probably take their rise in the chromosphere, which presumably overlies the cooler regions of the spot.

KENWOOD OBSERVATORY, University of Chicago,
Oct. 18, 1892.

THE SOLAR DISTURBANCE OF JULY, 1892.‡

JOHN S. TOWNSEND.

In his paper on "A remarkable solar disturbance," (ASTRONOMY AND ASTRO-PHYSICS, Aug. 1892), Professor Hale calls attention to an outburst similar to that witnessed by Carrington and

---

* ASTRONOMY AND ASTRO-PHYSICS, October, 1892.

† See Fényi, ASTRONOMY AND ASTRO-PHYSICS, May, 1892, p. 431.

‡ Communicated by the author.

Hodgson in 1859, which occurred in the neighborhood of a spot of high southern latitude which entered on the Sun's disk on July 8th. In this connection the following observations of the spot, made by me at my Observatory of Sevenoaks may not be without interest.

The instruments employed were a refractor of 4½-inches aperture and a Rowland grating spectroscope of 14,438 lines to the inch. The spot was first detected as a few small dots on June 13th. These dots rapidly developed into a spot of large area. On June 17th and again on June 20th the C line over the spot was both reversed and displaced. The spot appeared again on the E. limb on July 8th, and on both this and the succeeding date the spot and the surrounding faculæ showed strong reversals over the C line. The slit of the spectroscope was adjusted E. and W. over the spot. The position was determined by using the grating as a white light reflector and viewing the spot through the open jaws of the slit. The movable jaw was then closed, and the grating turned to give the order of spectrum required. This method permits the position of the slit relatively to a Sun-spot under observation to be determined with great accuracy.

On July 11th the spot was again examined with the spectroscope, and was found at 11:45 A. M., G. M. T., to be greatly agitated. The C line was so strongly reversed over the two most southern nuclei, that the slit could be opened to the full width of the nuclei without passing beyond the reversed position, the whole of the enclosed area glowing with flame. I have lately examined over one hundred spots with the spectroscope for reversals of the C line, and none of these, not even the great spot of Feb. 1892, showed such strong bright reversals as did this spot. The appearance was very like that observed by Professor Young in the F line over a prominence on August 3, 1872, and pictured at p. 210 of his work "The Sun." Nor were the reversals of C confined to the nuclei, for the line was also strongly reversed in the penumbra preceding the nuclei. Over the nuclei reversals were also observed in the lines D_1 D_2 D_3 b_1 b_2 b_3 b_4 F G′, and in the line λ 6676.9 of Rowland's maps. The three lines D and the *b* lines were brighter than I have ever observed them even in prominences; F and G′ showed out sharply, while λ 6676.9 was plainly reversed both in the 2d and 3rd order spectrum. Over the penumbra D_3 appeared as a shaded line, long and spindle-shaped. At 12:30 P. M. the disturbances began to subside, the four *b* lines appearing as widened though not reversed, although C and F still continued to be reversed. At 1:30 P. M. C only was affected, being reversed over the nuclei, and distorted alongside of its reversed portion towards the red end of the spectrum. At 4 P. M. the storm had quite ceased. On July 18th the spot was examined with the spectroscope for the last time, and the C line was both reversed and displaced over the spot, although only to a moderate extent.

SEVENOAKS, ENGLAND, Sept. 9, 1892.

THE SOLAR DISTURBANCES OF JULY, 1892, AND THE ACCOMPANYING MAGNETIC STORMS.*

WALTER SIDGREAVES.

The remarkable outbursts witnessed by Professor Hale and Mr. Townsend in the spot which effected its second passage across the solar disc in the middle of last July, has led to an examination of the Stonyhurst observations of the Sun, and of the photographic records of the magnets in order to trace the life history of the spot, and to detect any possible connection of such magnetic storms as occurred during its life, with the more than ordinary outbursts recorded in this spot.

The spot was first drawn at Stonyhurst on June 14, and presented the appearance of a few dots in S. latitude 32°, and heliographic longitude 45.75°. On June 21 the spot was near the W. limb of the Sun, and had now developed into a large single spot or cluster of nuclei, surrounded by a ring of brilliant faculae. On this date also the spectroscopic examination of the Sun's limb showed a band of prominences of moderate height but extending over about 12° of arc immediately in advance of the spot. On July 8th the spot was again drawn as it reappeared at the E. limb. It was preceded by extensive faculae, and was itself still surrounded by a ring of brighter faculae. Its general appearance was very similar to that it presented when leaving the W. limb on June 21. As its area was then increasing it must have attained its maximum when on the invisible side of the Sun. The appearance was still not very much altered on July 11, the date of the outburst recorded by Mr. Townsend. On July 15, although the Sunspots were drawn at about the very time Professor Hale witnessed the phenomena he has described, a thick haze unfortunately prevented more than the mere outline of the spot being drawn. Our last record of the spot during the sec-

---

* Communicated by the author.

ond rotation was obtained on July 18, when it was near the W. limb. On Aug. 4 the place of the spot was occupied by a bright cluster of faculae. It is noteworthy that a second spot made its appearance and was drawn on Aug. 9th in the same latitude, but following by about thirteen degrees in longitude.

The magnets had been perfectly quiet from June 11, until at about 3 P. M., G. M. T., on the 16th, a slight disturbance commenced in the horizontal force magnet. This continued, and later appeared in all three elements as a series of small intermittent oscillations which lasted until the morning of the 18th. The spot which was forming would have been on the central meridian about the 16th. The series of small oscillations in the magnets again recommenced on the 21st, and continued until the morning of the 26th. The spot passed across the W. limb of the Sun between the 21st and 22nd. During the 26th the magnets were perfectly quiet, until quite suddenly at about 5 A. M. on the morning of the 27th, a considerable disturbance commenced in the horizontal force and declination magnets. The greatest oscillation in all three elements occurred at about 4 P. M. on the 27th, the declination magnet moving West through 24′.81. The extreme range of this magnet during the disturbance was 49′.07 The movement in the vertical force magnet at 4 P. M. on the 27th was very marked. The storm ended at about midnight of the 28th. The spot would at this date have been nearly central on the invisible hemisphere of the Sun, and judging from its appearance at the second rotation, would likewise have been of considerable area. On the visible hemisphere of the Sun nothing of any importance was to be seen. The magnets now remained generally quiet with the exception of some slight movements, the more noticeable taking place at early morning and at midnight of July 10th.

The spot had reappeared on the Sun's visible disk on July 8th. On the 11th, the day Mr. Townsend observed the remarkable reversals of the C line over the spot at about 12-15 P. M., G. M. T., a single sharp upward movement both on the declination and horizontal force magnets alone interrupted their otherwise quiescent state. In a very similar outburst observed by Professor Young over a spot on Aug. 5, 1872, (The Sun, p. 158), a shivering of the otherwise quiet magnet coincided in time with the solar storm. On the afternoon of July 12th, the magnets again began to be more violently disturbed, the storm continuing over the 13th until the morning of the 14th. The spot crossed the central meridian about the 14th. On the 15th, at the actual time when Professor Hale witnessed the remarkable phenomenon similar to that observed in 1859 by Carrington and Hodgson, there was not the slightest disturbance on the vertical force and declination magnets. There was, however, a slight trembling in the horizontal force magnet which was the prelude to the violent storm which set in and lasted over the 16th until midnight of the 17th. On the morning of the 16th unfortunately the horizontal force magnet was dismounted in order to lessen its sensibility, which had been found to be too great, but judging from the trace of the declination magnet, this storm must have been the most violent of the series. The extreme range of the swing of this magnet at 7 P. M., G. M. T., on July 16th was 1° 34.73′. After this storm the quiet was only disturbed by a few sharp movements of the magnets on the mornings of the 21st and the 22nd, until in the early hours of the 26th a disturbance set in which consisted mainly of a series of moderate oscillations, which passed away on the 29th at midnight. At this time the spot would have been about central on the other side of the Sun. On Aug. 4th bright faculæ alone reappeared in the place of the spot.

With regard to the storm of July 16 and 17, two groups of spots which appeared at the Sun's E. limb on July 4 were in transit across the disc and were each of considerably larger area than the spot in question. But on collating the magnetic curves with these spots they do not seem to be connected with the disturbances. On July 16 they were far past the central meridian, and moreover there was no storm to correspond with them as they advanced across the Sun's disc. Again at the time of the storm July 26-29, several large spots had just entered on the disc.

But that three magnetic storms should have coincided with three separate meridian passages of the same spot, and that the outburst witnessed by Mr. Townsend should have been marked by a simultaneous tremor in the magnets, while the more extraordinary phenomenon observed by Professor Hale should have been followed in a few hours by a violent storm, would seem to point to more than merely accidental coincidences, and to stamp this spot of July, 1892, as exercising a special magnetic influence. If this is so, it only serves to confirm the opinion expressed in the Stonyhurst College Observatory Report for 1883 "that there is some evidence to show that the auroræ and magnetic storms synchronize rather with particular classes of spots than with solar disturbances generally."

STONYHURST COLLEGE OBSERVATORY,
Lancashire, England, Sept., 1892.

RECENT OBSERVATIONS OF NOVA AURIGÆ, (SEPT. 8 TO OCT. 13, 1892).*

W. W. CAMPBELL.

Unfavorable weather has made it impossible to obtain many observations of Nova's spectrum in the last month. However, the position of the chief nebular line has been measured on three mornings, and the following wave-lengths and probable errors obtained:

	Sept. 15, 16^h	Sept. 22, 16^h	Oct. 12, 16^h
Compound prism†	....	5002.34 ± 0.12	....
Grating, 1st order	5002.54 ± 0.19	5002.39 ± 0.23	5003.67 ± 0.26
Grating, 2d order	5002.05 ± 0.18	5002.70 ± 0.15	5003.57 ± 0.13
Means	5002.29	5002.48	5003.62

These measures make it certain that the velocity of approach is not increasing at present, and seem to show that it is now decreasing. The observations in August and the early part of September seemed to show an increase. Such results are not opposed to the theory of orbital motion; though as stated in my paper of Sept. 8 (ASTRONOMY AND ASTRO-PHYSICS for October), the difficulties in the way of deciding the question arise not from the faintness of the lines, but from their great breadth, and further observations must be awaited. However, it seems to me that the measured increase of wave-length, 1.6 tenth metres, is a real variation.

The line in Nova's spectrum at λ 4359 is by far the brightest line shown in the photographs, and is about ten times as intense as the faint Hλ line. This line exists in the three other nebulæ which I have thus far examined for it. In Σ 6 its wave-length obtained from two negatives is 4363, and its intensity is about one-tenth that of the Hγ line. In N. G. C. 7027 its wave-length from two negatives is 4363 and its intensity is about one-fourth that of Hγ. In a photograph of the spectrum of the Orion Nebula (showing about 25 lines between λ 5007 and λ 3800) this line is shown at λ 4364, and its intensity is about one-twentieth of that of Hγ. Two negatives of the spectrum of Σ 6 show a line at about λ 4636. This undoubtedly corresponds to the line in Nova's spectrum at λ 4630. Thus both lines referred to at the close of my former paper are shown to be nebular and are properly displaced.

---

* Communicated by the author.

† The dispersion with the dense compound prism is slightly greater than with the grating in the first order.

A recent photograph of Nova's spectrum shows not only all the lines on the September photographs, but also three additional ones at λ 471, λ 460 and λ 451. The first two of these exist in the spectrum of Σ 6.

The prominent line in Nova's spectrum at λ 5751 has not yet been thoroughly searched for in other spectra. It does not appear to correspond to any of the prominent lines in the Wolf-Rayet stars. Last night I measured the wave-lengths of several bright lines in the spectrum of the star D. M. + 36° 3956. The prominent lines in the yellow are at λ 5812 ± 0.9 and λ 5688 ± 1.3. Thus the Nova line falls about midway between these.

Neither the magnitude nor the spectrum of Nova seems to have changed any since August 17, when it was first seen here. It is difficult to estimate the magnitude of Nova, on account of the distribution of the light in its spectrum. Its apparent magnitude is a function of the focusing and the color curve of the telescope. The very different estimates made by different observers can be explained largely by these facts. In the finder of the 36-inch telescope practically all the light of Nova is brought to a focus at one point, and it is clearly half a magnitude brighter than the star just north following it. In the great telescope, however, with the eyepiece adjusted to the stellar focus, the Nova and the star are very nearly of the same magnitude. When the eyepiece is in focus for the rays of wave-length 5007, the Nova is clearly brighter than the star.

In my former paper I should have stated that Professor Keeler's adopted wave-length of the chief nebular line, λ 5007.05, was taken from his unpublished manuscript, and is based upon Rowland's scale.

1892, Oct. 14.

THE ULTRA-VIOLET SPECTRUM OF THE SOLAR PROMINENCES.

III.

GEORGE E. HALE.

A photograph of the spectrum of a metallic prominence, taken at the Kenwood Observatory by my assistant, Mr. G. Duwalt, on Oct. 15, 1892, at $3^h 15^m$ (Plate D 1407) contains 74 bright lines in the ultra-violet between λ 3970 and λ 3630. The 12-inch photographic objective by Brashear and the spectrograph with 4-inch 14,438 grating and 3¼-inch glass objectives were employed.

The large number of lines obtained is rather surprising when the absorption of ultra-violet light in the three objectives is considered. All of the lines that I have previously photographed, as well as all those obtained by M. Deslandres with apparatus in which no glass is used, are shown on the photograph. In addition to these there are the following 32 lines, which were not previously known:

λ
3964
3956.9
3945.2
3938.1
3913.5
3965
3895.5
3893.8
3891
3878.8

λ
3863
3850.5
3813.5
3774
3767.1
3758
3757.0
3749.7
3741 7
3733.3

λ
3724.3
3716.9
3710 3
3699.5
3683
3681
3679.5
3674.2
3662.2
3647.8
3632
3630.8

New lines are also suspected at λ 3807.2, 3802, 3764, 3763, 3758.2, 3709.5, 3707.8, 3676, 3643.

The above wave-lengths are to be regarded as only approximate, as the conditions under which many of them were determined rendered great accuracy impossible.

KENWOOD OBSERVATORY, University of Chicago,
Oct. 25, 1892.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectrescopy and other subjects properly included in ASTRO-PHYSICS, should be addressed to George E. Hale, Kenwood Observatory of the University of Chicago, Chicago, U. S. A. Authors of papers are requested to refer to page 848 for information in regard to illustrations, reprint copies, etc.

The Editorial Board of Astro-Physics.—Since the establishment of ASTRO-PHYSICS it has been the constant endeavor of its Editor to improve its contents in every possible way. A most important step has just been taken in this direction by the formation of a body of Associate Editors, consisting of Professor James E. Keeler, Director of the Allegheny Observatory, Dr. Henry Crew, Professor of Physics at Northwestern University, and Dr. Joseph S. Ames, of Johns Hopkins University. The important investigations by which these gentlemen have contributed to our knowledge of astronomical and terrestrial physics are so well known as to render unnecessary any word of introduction for the investigators themselves. It will be seen, however, that stellar and nebular spectroscopy will henceforth be fully represented in this journal through the services of Professor Keeler, while the more purely physical side of astro-physics will receive ample recognition through Professor Crew and Dr. Ames. We congratulate our readers and ourselves on the results which such coöperation must lead us to expect.

Asorption of Radiant Energy.—An interesting study of the absorption of radiant energy has recently been made by Mr. Bjerknes, and forms one of the contributions to the current number of *Wiedemann's Annalen.*

The writer confines his attention to the long wave-lengths and to metallic media. Using a primary conductor of Hertz's pattern, the radiations produced are examined in succession with a series of geometrically identical secondary circuits (resonators), each made of a different metal.

In this manner, each secondary receives the same amount of electro-magnetic energy and the same impressed electromotive force between the terminals of its spark micrometer.

But the *size* of the spark was found to vary between wide limits, thus showing that some metals dampen vibrations much more quickly than others. Of the six metals tried, copper gave the largest and iron the smallest spark. Copper is, therefore, the most transparent and iron the most opaque, substance on the list. In order of transparency, the list runs copper, brass, german silver, platinum, nickel, iron. This leads to the surprising result that *in these metals, at least,* the transparency is proportional to the electrical conductivity. Iron and nickel stand alone at the bottom of the list and appear to be more opaque than non-magnetic metals of the same conductivity.

In regard to this work, there may be some question as to just how much of the effect observed by Mr. Bjerknes may be due to the fact that these rapidly alternating currents travel only in the skin of the wire. At any rate, a comparison of the absorptive powers of these same metals, in thin films, for visible rays, and for that part of the ultra-red accessible to the bolometer, would be valuable. For here the displacement currents would be compelled to take place in the interior of the medium, albeit the medium might be very thin.

Method for Detecting and Exhibiting Hertzian Vibrations.—Among the many methods recently offered for the detection and exhibition of Hertzian vibrations one of the neatest is that proposed by Mr. Zehnder (*Wied. Ann. Bd. 47, pp. 77-92*). He employs the secondary spark to diminish the resistance between the electrodes of a Geissler tube, these electrodes being already connected to a source of electromotive force, nearly but not quite sufficient to produce a luminous discharge. The manner in which this is done is to seal the terminals of the resonator into the Geissler tube near the kathode.

The kathode and anode are then connected to the respective poles of a small induction coil which is synchronized with the Hertzian primary. Thus at the instant when the resonator spark passes there exists a pressure on the electrodes of the tube, and the sudden diminution of resistance due to the secondary spark makes this pressure sufficient to light the tube.

The method is evidently one requiring delicate adjustment and is useful only in the focal lines of reflectors: but it is a beautiful experiment for placing a large audience at once in possession of evidence for Maxwell's theory of light.

Line Spectrum of Hydrogen in the Oxyhydrogen Flame.—Professor Liveing of Cambridge has been making a very careful search for the line spectrum of hydrogen in the oxyhydrogen flame and has failed to find the slightest trace of any one of the hydrogen lines. Photographs and eye observations were each called into service.

Professor Liveing therefore concludes that Plücker was mistaken in his supposed observation of *C* and *F* in this flame. Those interested will find Professor Liveing's note in the October number of the *Philosophical Magazine*.

Solar Observations at Mt. Hamilton.—In the current number of *Nature*, Professor Henry Crew calls attention to the fact that the daytime seeing at the Lick Observatory is so influenced by local conditions as to make the 36-inch glass almost useless for visual work on the Sun.

On comparison of all three refractors belonging to this Observatory, the 6-inch and 12-inch were each found to give definition superior to that of the large instrument.

The cause of this is supposed to be the heated air which rises off the steep sides of the mountain and floats up over the Observatory at the top. The explanation will appeal to anyone who has spent a summer's day on Mt. Hamilton. In a comparison of this kind, the greater magnifying power of the larger lens is not to be forgotten.

On the Central Star of the Ring Nebula in Lyra.—The following note by Professor Keeler is reprinted from *A. N.* 3111:

Dr. Scheiner's interesting note in *A. N.* 3086, on the character of the central star in the Lyra nebula, leads me to mention some visual observations of my own which have a bearing on the same subject. The central star is beyond the reach of the Allegheny refractor, and all my observations were made in California, with the thirty-six inch telescope of the Lick Observatory. With this instrument the central star was always easily visible, although it was too faint for observation with the spectroscope.

Owing to the considerable chromatic aberration of so large a telescope, a gaseous nebula and its stellar nucleus cannot be seen distinctly at the same time; if the focus is adjusted on the star, the eye-piece must be drawn out a little to give a distinct view of the nebula. If the nebula presents any well-marked details, (like the beautiful planetary nebula G. C. 4373, in Draco), this peculiarity becomes very noticeable, and the difference of focus for the two objects may be easily measured. Professor Holden and Professor Schaeberle found the change of adjustment required in the case of the Draco nebula to be 0.44 inch. From a consideration of the color-curve of the objective, obtained by Vogel's spectroscopic method, the difference would appear to be somewhat less than this, perhaps from 0.35 to 0.40 inch, the exact value depending upon the position which the observer assigns to the focal plane for the three principal nebular lines, as the most satisfactory compromise. Thus the telescope itself roughly serves the purpose of a spectroscope, and in default of more accurate methods may give indications of value. Applying this method to the Ring Nebula in Lyra, I found that the same difference of focus was required, as nearly as I could judge, as for G. C. 4373, the central star being sharply seen when the eye piece was considerably inside the position required for the ring. Hence the maximum of light in the spectrum of the star is in the yellow or green, as it is in the nuclei of all the planetary nebulæ which are sufficiently bright for examination with the spectroscope.

Dr. Scheiner's conclusions in regard to the character of the central star therefore require some modification. It can hardly be doubted that the central star is actually formed from the nebula by a process of condensation; but it is not merely a brighter portion of the nebula, emitting radiations of the same character as the rest. Increased radiation in the lower part of the spectrum has accompanied the process of condensation. The nucleus so nearly approaches the stellar character that the general distribution of light in its spectrum is that of an ordinary star.

It may very well be, however, that the photographic energy of the star is due to bright lines in the violet part of its spectrum (most probably the hydrogen lines), the presence of which would add greatly to the photographic effect without displacing the maximum general brightness from the yellow. The nuclei of some planetary nebulæ which are within reach of the spectroscope are of this character.

It is possible to give another explanation, which accounts for the observed phenomena without attributing unusual properties to the central star. The photographic energy of a gaseous nebula resides very largely in the fourth line in its spectrum, or the Hγ line of hydrogen, and in different nebulæ various relations of brightness are found to exist between the hydrogen lines and the first and second nebular lines, while to these two last almost the whole visual effect is due. In the Orion nebula the hydrogen lines are relatively bright; in the intrinsically brilliant nebula N.G.C. 7027 they are relatively faint. Hence the brightness of a nebula is not a trustworthy indication of its photographic activity. Now the intrinsic brightness of the Ring Nebula is far below that of many smaller nebulæ, and moreover the hydrogen lines are relatively faint. Hence it may be that the prominence of the central star in the photographs may be due not to strength of photographic action of the star, but to weakness of that of the nebula, which is taken as the term of comparison. Obviously the true test would be to compare the central star, not with the nebulous ring, but with other stars on the plate, of the same visual magnitude, which are outside the limits of the nebula. It is possible that such comparisons have been made, although I do not know of any published results. In the only photographic representation of the Lyra nebula which I have, the plate in Pubblicazioni della Specola Vaticana, Fascicolo II, both the central star and the well known star following the ellipse are shown, The magnitudes of these stars have been variously estimated by different observers, and the former is sometimes regarded as variable. Mr. Burnham rates them as 15.4 and 12.4 respectively. In the plate mentioned, the larger star is about twice the diameter of the smaller. Whether two other stars of the same magnitudes would give similar discs I have no means of telling. The exposure of the photograph was one hour and fifty minutes.

It is quite possible that the photographic prominence of the central star is due to both causes, namely: partly to feeble action of the nebulous ring, and partly to strong action of the central star.

It should also be borne in mind that the relative prominence of these two features in the photograph is not determined solely by their natural difference of constitution, but in a large measure by the dimensions of the telescope employed. The brightness of the image of the nebula follows one law, that of the stellar image, another.

JAMES E. KEELER.

Allegheny Observatory, Allegheny, Pa., 1892, July 5.

Schumann's Researches on the Extreme Ultra-Violet Part of the Spectrum.— Herr Victor Schumann has published in pamphlet form, as a reprint from the "Photographische Rundschau" for 1892, an account of his researches on the extreme ultra-violet spectra of the metals. The pamphlet gives a narrative of his experiments in this difficult field, rather than a final statement of the results obtained, and describes a number of improvements in his original apparatus which have enabled him to trace the ultra-violet spectrum farther than before, or above λ 1820. The experimental difficulties encountered in such work may be estimated from the fact that according to Cornu four inches of air are sufficient to completely absorb rays of wave-length 1566, and Schumann finds the absorption of air even greater than this. The optical train of fluor spar and the camera are therefore enclosed in a tight vessel which is exhausted by means of an air-pump, the sensitive plate being introduced through a kind of air-lock. According to Herr Schumann the spectrum of hydrogen has no fewer than five hundred lines in the extreme ultra-violet, their wave-lengths being, of course, subject to great uncertainty. An exhaustive account of his researches on the hydrogen spectrum will shortly be contributed by Herr Schumann to this journal.

Drawings of Mars.—The great number of drawings of Mars which have doubtless been made during the opposition just past will probably illustrate the personality of the observer in interpreting the faint markings presented to his eye, as well as serve their main purpose of recording the surface features of the planet. Certainly such drawings as have already been published show the effect of this personal interpretation very strongly. It is probable that fewer discrepancies would occur, particularly in the case of drawings made with telescopes differing greatly in size, if observers would pay more attention to the relative strength of markings. It is necessary to exaggerate the contrasts, but a uniform scale of intensity should be preserved throughout. A drawing made with a small telescope would then have a general resemblance to a distant view of one made with a large telescope.

The Cyclone Theory of Sun-spots.—The following note is from *Nature*, Sept. 22, 1892.

A somewhat prolonged absence from home has prevented me seeing until now your note on July 21, page 280, in which the writer remarks that the results of M. Camille Flammarion—published in the July number of *L'Astronomie*—"seem to confirm the view suggested by M. Faye that the constitution of [Sun] spots resembles somewhat that of the cyclones with which we are familiar.

I write to point out that this is not the theory of M. Faye, but, on the contrary, is the theory of Mr. Herbert Spencer, which he published in the *Reader* for February 25, 1865, and which has since been republished in his collected essays under the title, "The Constitution of the Sun." In it Mr. Spencer first points out the untenability of M. Faye's hypothesis, and then goes on to say:—"The explanation of the solar spots above suggested, which was originally propounded in opposition to that of M. Faye, was eventually adopted by him in place of his own. In the *Comptes Rendus* for 1867, vol. lxiv., p. 404, he refers to the article in the *Reader*, partly reproduced above, and speaks of me as having been replied to in a previous note. Again, in the *Comptes Rendus* for 1872, vol. lxxv., p. 1664, he recognizes the inadequacy of his hypothesis, saying:—'Il est certain que l'objection de M. Spencer, reproduit et développée par M. Kirchhoff, est fondée jusqu'à un certain point; l'intérieur des taches, si ce sont des lacunes dans la photosphère, doit être froid relativement . . . . Il est donc impossible qu'elles proviennent d'éruptions ascendantes.' He then proceeds to set forth the hypothesis that the spots are caused by the precipitation of vapour in the interiors of cyclones. But though, as above shown, he refers to the objection made in the foregoing essay to his original hypothesis, and recognizes its cogency, he does not say that the hypothesis which he thereupon substitutes is also to be found in the foregoing essay. Nor does he intimate this in the elaborate paper on the subject read before the French Association for the Advancement of Science, and published in the *Revue Scientifique* for March 24, 1883. The result is that the hypothesis is now currently ascribed to him. I should add that, while M. Faye ascribes solar spots to clouds formed within cyclones, we differ concerning the nature of the cloud. I have argued that it is formed by rarefaction, and consequent refrigeration, of the metallic gases constituting the stratum in which the cyclone exists. He argues that it is formed within the mass of cooled hydrogen drawn from the chromosphere into the vortex of the cyclone. Speaking of the cyclones, he says:—'Dans leur embouchure évasée ils entraîneront l'hydrogène froid de la chromosphère, produisant partout sur leur trajet vertical un abaissement notable de température et une obscurité relative, due à l'opacité de l'hydrogène froid englouti' (*Revue Scientifique*, March 24, 1883). Considering the intense cold required to reduce hydrogen to the 'critical point,' it is a strong supposition that the motion given to it by fluid friction on entering the vortex of the cyclone, can produce a rotation, rarefaction, and cooling, great enough to produce precipitation in a region so intensely heated."—(*Essays*, 1891 Edition, vol. i., pp. 188-9.)

Churchfield, Edgbaston. F. HOWARD COLLINS.

Solar Prominence Photography.—The following letter from Mr. Evershed is of such general interest that we insert it here.

KENLEY, SURREY, Sept. 11, 1892.

PROFESSOR GEORGE E. HALE, Chicago,

Dear Sir:—During the past summer I have been able to make a few further experiments in solar prominence photography, and believing you will be interested to hear of my success, I send you a short account of results so far obtained.

In the first place I have quite changed my opinion with regard to the supposed superiority of 'F' in this work, for to my great surprise I found H and K are not only very easy to photograph but are also easily seen reversed even with a wide slit.

The results, which appear to agree in every particular with your work, may be summarized as follows:

(1). H and K are strongly reversed in the chromosphere and in every hydrogen prominence.

(2). The forms of prominences in H and K are similar, but sometimes seem to be more extensive than in C.

(3). There is always a companion line to H on the lower side reversed in the chromosphere.

(4). On the disk immense regions near spots are brilliantly reversed in H and K, but the companion to H does not appear, nor do these reversals correspond at all with F reversals.

(5). These long reversals are frequently doubled over large areas, a fine absorption line appearing in the centre.

(6). In two negatives obtained the absorption shade in K (H is out of the field) is almost entirely wanting, whilst the centre is almost filled up with a brilliant double reversal.

(7). At the limb these reversals do not extend into (or above) the chromosphere except when overlaid by a hydrogen prominence.

I have not yet found any instance of a calcium prominence unaccompanied by hydrogen, or *vice versa*, and in this connection it is of interest to compare my drawing of May 21st with the photograph in the August number of

ASTRO-PHYSICS. Every prominence photographed is represented in my drawing in exactly the same relative position. I enclose copy of drawing. The only difference is in the very great depth of the chromosphere on the N. F. limb. Is this real or due to irradiation?

I enclose one or two film negatives to give an idea of the kind of results I get. The exposure ranges from one-fifth to one-half second and the image is magnified 4 or 8 times on the film.

I may mention also that I find the prismatic spectrum near H (5 prisms of 60°) is many times more brilliant than even the 1st order spectra of a small 14,438 line grating which the British Astronomical Association has lent to me. I therefore use the latter entirely for visual work and the prisms for photography. The negative with the date 3, 7, '92, was taken with a circular slit and shows the companion to H distinctly; also a bright metallic prominence in which the calcium lines are much widened; this was on the E limb just over a spot at 3:35 P. M. The paper print shows K with scarcely any absorption shade. It was taken at 2^h 5^m P. M. on June 5th, the slit being radial near a point on the S. P. limb where a brilliant eruption had occurred 4 hours earlier. Believe me, Yours truly,

J. EVERSHED, JR.

The photographs which accompanied the letter are excellent, and well illustrate Mr. Evershed's success with small instruments. The apparently greater depth of the chromosphere on the N. F. limb of the Sun in the photograph reproduced in the August number of ASTRO-PHYSICS is due to the fact that the diaphragm used in excluding the direct light from the Sun's surface was not exactly concentric with the image, and thus a portion of the photosphere was shown in the photograph.

Nova Aurigæ.—In *Nature* for September 22, 1892, Mr. H. F. Newall communicates his observations of the Nova on the night of September 14. The spectrum was observed with a compound prism between the eye and eye-piece, and was found to be faintly continuous, varying from C to F or G. There were also seen "a bright line quite, or nearly, coincident with C; three bright lines close together in the green, the least refrangible one seeming considerably broader than the others; a faint bright line in the blue (?F)," and a very faint line occasionally seen in the violet. No dark companion lines were seen. Observing with a power of 215 (without spectroscope) it was at first thought that the Nova was diffuse, and resembled a minute planetary nebula. It was eventually found, however, that the concentration of nearly all the Nova's light in the green caused it to have a focus different from that of other stars, and when compared with a neighboring equally bright star it was found when carefully focused to be distinctly the more point-like of the two.

In the *English Mechanic* for Oct. 7, 1892, Rev. T. E. Espin states that his estimate of the Nova's magnitude was hurriedly made, and should be given no weight. He further adds "I have found a close identity between the spectrum of Mira Ceti and the Nova Aurigæ. Comparing the photographs of Mira and the Nova, the lines are found generally to coincide, and, moreover, the duplication of the bands or lines in Mira is obvious. The conditions are, however, reversed in the Nova; the bright bands were on the less refrangible side; in Mira they are on the side of greater refrangibility. The mysterious line at 500 is probably present in the spectrum of Mira. Dr. Becker also calls attention to the correspondence of certain lines in the Nova and R Cygni, and R Andromedæ."

Telescopes for Amateurs.—The opposition of Mars and the discovery of a fifth satellite of Jupiter have caused a great accession of interest in astronomical matters among amateur observers. Mr. Brashear furnishes the following list of instruments which he has recently sold, or for which he has received orders, and says that in many cases the motive for ordering a telescope is stated to be that given above: 15-inch refractor, Mr. Sommers N. Smith, Newport News, Va.; 12-inch refractor, Beirut, Syria; 6-inch refractor, Lebanon, Ohio; 4½-inch refractor, Mr. F. G. Bennett, New Haven, Conn., 4½-inch refractor, Mr. J. H. Wilson, Brooklyn, N. Y.; 4½-inch refractor, Mr. D. H. Burrell, Little Falls, N. Y.; 4-inch refractor, Mr. Park Painter, Pittsburgh; 4-inch refractor, Mr. H. C. Frick, Pittsburgh; 4-inch refractor, Oil City High School; 3-inch refractor, State Normal School, Farmville, Va.; 3-inch refractor, Dr. A. C. Runion, Canonsburg, Pa.; 6-inch objective, Mr. N. Johnson, Manistee, Michigan; 6-inch photographic objective, Mr. Wm. Post, Bayport, N. Y.; 6-inch objective, Warner & Swasey, Cleveland, Ohio; 5-inch objective, Mr. Dayton C. Miller, Cleveland, Ohio; 4-inch objective, Mr. A. S. Grant, Palestine, Texas; 6½-inch reflector, Mr. J. A. Parkhurst, Marengo, Ill.; 6½-inch reflector, Mr. F. Dienelt, Loda, Ill.; 8½-inch speculum, Mr. H. Bradford, North Ferrisburg, Vt.

Besides the instruments above mentioned, which are mostly in the hands of amateurs, Mr. Brashear has since the beginning of the year, either furnished the following instruments to well-known observatories, or has them in course of construction:

12-inch objective with photographic lens, and 8¼-inch objective, for the new Dudley Observatory, Albany, N. Y.; 12-inch photographic objective, Kenwood Observatory, Chicago; 6 inch short focus photographic objective, Georgetown College Observatory; 6-inch photographic doublet, and 5-inch long-focus objective with amplifier, Goodsell Observatory, Northfield, Minn.; 5⅝-inch photographic objective and accessories for the Observatory of Meudon, France.

Photographing the Ultra-Violet Rays.—The following is the second report of the committee appointed to co-operate with Dr. C. Piazzi Smyth in his researches on the ultra-violet rays of the solar spectrum.

The present report is on the proposed experiments (from September, 1891, to January, 1892), for enabling Dr. C. Piazzi Smyth to improve certain points in the taking of his solar-spectrum photographs in the ultra-violet by aid of additions to the apparatus obtained through means of a grant from the British Association at Leeds in 1890.

The report continuates the last one by the same committee, as printed in the British Association's Cardiff volume of 1891, at pp. 147 and 148 thereof, said space being then taken up with little more than descriptions of what the apparatus, then only just finished, was intended for. Now, however, a sufficient amount of experiments have been obtained to allow the results to be classified and collated under three several heads, or thus:—

(1). Improved focussing means for setting the focus of the viewing, or photographic telescope, both more accurately and easily as well, from previous book-record, rather than from renewed eye-and-hand observation on every occasion. This was carried out mainly and successfully by supplying wheels ten inches in diameter, and nicely graduated on their circumferences to either end of the ordinary axle of pinion-movement of the focussing tube, taking care also to turn the said pinion at the last moment in the direction of increasing the readings and noting what they were. This record method of focussing, too, it is believed, is one which will be found of very general application, and much used every coming year, now that photography is continually substituting more and more the observer's eye and hand, with almost all kinds of optical notation of luminous phenomena.

(2). Improved magnifying means were next required for the viewing, and equally photographing, telescope. The chief feature necessary here was a large field with the increased magnifying power, and was given to a considerable extent by a grand Barlow-achromatic concave lens placed inside the usual telescope tube, by Messrs. T. Cooke & Sons, of York.

For mere magnifying, however, wherever the part of the spectrum under examination permits it without other addition, I have since then fully made up my mind that the second order of Professor Rowland's later and unprecedently fine Gratings from his new ruling engine, give sharper magnifying to the spectrum than any lens I have experimented with.

But they give it in a different way—*i. e.*, the second orders of Grating's spectra do; for they magnify only in one direction—that of separation—while a lens magnifies in a direction at right angles to that also. That feature is no doubt so much the worse for the lens, because it weakens the intensity of a continuous spectrum operated upon by it. But then there is another feature which is bad for the second, or any subsequently still more magnified spectrum-order of a Grating—viz., that they admit the red light of a previous order in the middle of their own violet; unless some possibly very absorptive liquid be employed to stop such red light where it is not wanted.

Now Messrs. Cooke's Barlow concave lens wants no help of that kind, for it was constructed to magnify the first order of spectrum only, and that has no red light of any other order intruding into its own ultra-violet, or requiring some chemical liquid to dull its potency. Hence I have actually found that I have been able to carry Messrs. Cooke's lenticular magnifying of the first order of a Grating's spectrum four plates further into the invisible than I was able to do with the second order of the very same Grating's spectra, assisted in various chromatic modes. As an illustration of which I beg to append a list of spectrum photographs so obtained last autumn.

(3). Lastly, my attention was kindly and earnestly directed by Professor Liveing to keep on the look-out for possible changes in some part or parts of the solar spectrum, depending on time and date only, especially if their origin should appear to be in the Sun.

Now it did so happen one morning that one of the glass negatives of the H and K region of the solar spectrum did show a very strange and anomalous difference from all the others, so different indeed that my first impression was to throw it away as irretrievably spoilt by some accident. But on considering what such an accident could be, or how it could be reproduced if desired, I was still more confounded and nonplussed. Having, moreover, Professor Liveing's letter still before me, the most respectful course seemed to be, on second thoughts, to describe publicly how the anomaly brought itself forward so far as I knew, and to leave gentlemen with more experience than myself to form their own opinions, either for or against its being anything important.

Now the main point of the anomaly is, that the whole space between H and K is bright, whilst that outside them is dark, even very dark. To understand which feature thoroughly and in the terms worked in by Nature, it was necessary that there should be several plates employed, and each of them should show, not only the whole space between those giant lines or bands, but at least as much more on either side.

Moreover, a good definition does not continue to hold all along even so small a plate of glass as a quarter size, but has to be set and reset several times in its course, while the appearance of the lines alters almost radically on account of the mere curvature of the field. I enclose in an album case, in the first place, thirteen ordinary photographs of the H and K lines, taken at successive foci all across the field, and then three various impressions from one and the same anomalous photograph, No. 14; following that by Nos. 15 and 16, ordinary, but focussed to the right, views: the whole eighteen now exhibited being enlarged on paper to six times the size of the glasses, for convenience of examination. And I should, perhaps, duly forewarn all and sundry that "date" plays no part in the arrangement of this bundle of repetitions of the H and K lines—only the continual progress from left to right of the place of sharpest definition.

Occultation of Mars, Sept. 3, 1892.—The occultation of Mars on Sept. 3 was observed at Allegheny with the 13-inch refractor, which I had employed earlier in the evening in making drawings of the markings on the planet. Times were recorded on a chronograph by a Frodsham sidereal clock. At the first contact the limb of Mars was undulating considerably, and the observation was therefore somewhat uncertain. Reduced to Eastern Standard Time the observations are as follows:

First contact	13^h	21^m	$24^s.1$
Estimated bisection of disc	13	21	47 .9
Second contact	13	22	16 .8

At emersion the Moon was too low for observation. J. E. KEELER.

CURRENT CELESTIAL PHENOMENA.

PLANET NOTES FOR DECEMBER.

H. C. WILSON.

Mercury will be at inferior conjunction with the Sun Dec. 11 at 10^h 48^m A. M. The planet will then be nearly 2° north of the Sun's center. On the last day of December, Mercury will be at greatest elongation, about 23° west from the Sun, and will be visible to the naked eye in the morning.

Venus is still "morning star" and will be visible in the east in the morning during December.

Mars will be at quadrature, 90° east from the Sun, Dec. 9. He will be in good position for observation early each evening during the month. His apparent diameter decreases from 10″ Dec. 1 to 8″ Dec. 31.

Jupiter is at his best now, crossing the meridian at a high altitude a little after 10 P. M. During December he will be in excellent position for early evening observations. There are three very conspicuous belts this season and large telescopes show as many more. The great red spot still retains its outline of an ellipse with each end drawn out to a point. The central part is covered with a white cloud so that it is not quite as conspicuous as during last year. It is reported that Mr. Reed, Professor Young's assistant at Princeton, has been able to see the fifth satellite of Jupiter, with the 23-inch telescope. With this exception, so far as reported, it has not been seen with any other than the great Lick telescope.

Saturn may be seen in the morning. He is near the center of the constellation Virgo. The rings will now be quite plainly seen, as the elevation of the Earth above their plane is about 8°.

Uranus is too near the Sun yet to be well seen.

Neptune comes to opposition to the Sun on the morning of Dec. 1. It is therefore in position to be observed all night long. We hope next month to give a photograph of the region immediately about Neptune showing the faint stars.

Date. 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Dec. 5	17 50.1	− 23 45	8 28 A. M.	12 50.0 P. M.	5 12 P. M.
15	16 56.9	− 20 08	6 42 "	11 21.6 A. M.	4 01 "
25	16 48.9	− 19 45	5 49 "	10 30.2 "	3 12 "
			VENUS.		
Dec. 5	14 28.4	− 12 36	4 16 A. M.	9 28.8 A. M.	2 42 P. M.
15	15 16.8	− 16 20	4 41 "	9 37.8 "	2 34 "
25	16 07.1	− 19 23	5 06 "	9 48.8 "	2 32 "
			MARS.		
Dec. 5	23 09.6	− 6 21	12 30 P. M.	6 08.5 P. M.	11 47 P. M.
15	23 32.5	− 3 36	12 03 "	5 52.1 "	11 41 "
25	23 55.8	− 0 48	11 36 A. M.	5 36.0 "	11 36 "
			JUPITER.		
Dec. 5	0 57.5	+ 4 36	1 35 P. M.	7 56.1 P. M.	2 18 A. M.
15	0 57.6	+ 4 40	12 55 "	7 16.9 "	1 39 "
25	0 59.0	+ 4 52	12 16 "	6 39.0 "	1 02 "
			SATURN.		
Dec. 5	12 43.6	− 2 13	1 50 A. M.	7 44.5 A. M.	1 39 P. M.
15	12 46.2	− 2 27	1 14 "	7 07.8 "	1 02 "
25	12 48.5	− 2 38	12 37 "	6 30.5 "	12 25 "
			URANUS.		
Dec. 5	14 25.5	− 13 58	4 19 A. M.	9 26.1 A. M.	2 33 P. M.
15	14 27.5	− 14 08	3 42 "	8 48.8 "	1 55 "
25	14 29.4	− 14 16	3 05 "	8 11.3 "	1 17 "
			NEPTUNE.		
Dec. 5	4 33.5	+ 20 21	4 02 P. M.	11 31.5 P. M.	7 01 A. M.
15	4 32.3	+ 20 18	3 22 "	10 51.1 "	6 20 "
25	4 31.2	+ 20 16	2 42 "	10 10.6 "	5 39 "
			THE SUN.		
Dec. 5	16 51.1	− 22 31	7 22 A. M.	11 51.1 A. M.	4 20 P. M.
15	17 35.2	− 23 20	7 30 "	11 55.7 "	4 22 "
25	18 19.6	− 23 23	7 36 "	12 00.7 P. M.	4 25 "

Occultations Visible at Washington.

Date 1892.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	IMMERSION Angle f'm N pt. °	EMERSION Washington M. T. h m	EMERSION Angle f'm N pt. °	Duration. h m
Dec. 2	B.A.C. 1143	6	7 38	87	8 38	215	1 00
2	32 Tauri	6	14 42	28	15 25	306	0 43
5	47 Geminorum	6	11 34	129	12 34	231	1 00
7	B.A.C. 3138	6	11 28	98	12 38	290	1 10
8	η Leonis	3	12 02	87	12 54	334	0 52
28	29 Arietis	6	14 19	70	11 15	255	0 52
30	62 Tauri	6	10 43	11	11 20	315	0 37

Phases and Aspects of the Moon.

		d	h	m	
Perigee	Dec.	2	10	18	P. M.
Full Moon	“	3	8	17	“
Last Quarter	“	10	8	30	“
Apogee	“	15	7	18	A. M.
New Moon	“	19	2	13	“
First Quarter	“	26	3	22	P. M.
Perigee	“	31	6	06	A. M.

Phenomena of Jupiter's Satellites.

		h	m			
Dec.	1	9	26	P. M.	I	Oc. Dis.
	2	12	44	A. M.	I	Ec. Re.
		6	35	P. M.	I	Tr. In.
		7	44	“	I	Sh. In.
		8	49	“	I	Tr. Eg.
		9	54	“	II	Tr. In.
		9	57	“	I	Sh. Eg.
	3	12	10	A. M.	II	Sh. In.
		12	26	“	II	Tr. Eg.
		7	13	P. M.	I	Ec. Re.
	4	4	11	“	II	Oc. Dis
		4	25	“	I	Sh. Eg.
		8	55	“	II	Ec. Re.
		11	21	“	III	Tr. In.
	8	6	08	“	III	Ec. Dis.
		8	03	“	III	Ec. Re.
		11	16	“	I	Oc. Dis.
	9	8	26	“	I	Tr. In.
		9	39	“	I	Sh. In.
		10	40	“	I	Tr. Eg.
		11	52	“	I	Sh. Eg.
	10	12	22	A. M.	II	Tr. In.
		5	44	P. M.	I	Oc. Dis.
		9	08	“	I	Ec. Re.
	11	5	07	“	I	Tr. Eg.
		6	21	“	I	Sh. Eg.
		6	37	“	II	Oc. Dis.
		11	31	“	II	Ec. Re.
	13	6	37	“	II	Sh. Eg.
	15	4	48	“	III	Oc. Dis.
		7	13	“	III	Oc. Re.
		10	11	“	III	Ec. Dis.
Dec.	16	12	04	A. M.	III	Ec. Re.
		10	17	P. M.	I	Tr. In.
		11	34	“	I	Sh. In.
	17	12	31	A. M.	I	Tr. Eg.
		7	36	P. M.	I	Oc. Dis.
		11	04	“	I	Ec. Re.
	18	4	45	“	I	Tr. In.
		6	03	“	I	Sh. In.
		6	59	“	I	Tr. Eg.
		8	16	“	I	Sh. Eg.
		9	06	“	II	Oc. Dis.
	19	5	33	“	I	Ec. Re.
	20	6	43	“	II	Tr. Eg.
		6	46	“	II	Sh. In.
		9	14	“	II	Sh. Eg.
	22	8	38	“	III	Oc. Dis.
		11	05	“	III	Oc. Re.
	24	9	30	“	I	Oc. Dis.
	25	6	38	“	I	Tr. In.
		7	58	“	I	Sh. In.
		8	52	“	I	Tr. Eg.
		10	11	“	I	Sh. Eg.
		11	38	“	II	Oc. Dis.
	26	6	20	“	III	Sh. Eg.
		7	29	“	I	Ec. Re.
	27	4	40	“	I	Sh. Eg.
		6	43	“	II	Tr. In.
		9	17	“	II	Tr. Eg.
		9	25	“	II	Sh. In.
		11	53	“	II	Sh. Eg.
	29	6	02	“	II	Ec. Re.

Approximate Central Times when the Great Red Spot will pass the Center of Jupiter's Disk.

		h	m	
Dec.	1	4	40	P. M.
	2	2	36	A. M.
	2	10	28	P. M.
	3	6	19	“
	5	12	06	A. M.
	5	7	58	P. M.
	7	1	45	A. M.
	7	9	36	P. M.
	8	7	32	A. M.
	8	5	28	P. M.
	9	11	15	“
	10	7	06	“
Dec.	12	12	54	A. M.
	12	8	45	P. M.
	13	6	41	A. M.
	13	4	36	P. M.
	14	10	24	“
	15	6	15	“
	17	12	02	A. M.
	17	7	54	P. M.
	19	1	41	A. M.
	19	9	33	P. M.
	20	7	28	A. M.
	20	5	24	P. M.
Dec.	21	11	12	P. M.
	22	7	03	“
	24	12	50	A. M.
	24	8	42	P. M.
	25	6	38	A. M.
	25	4	33	P. M.
	26	10	21	“
	27	6	12	“
	28	12	00	midn.
	29	7	51	P. M.
	31	1	38	A. M.
	31	9	30	P. M.

Configuration of Jupiter's Satellites at 8^h p. m. Central Time.

Dec.		Dec.		Dec.	
1	4 1 ○ 3 2	11	1 ○ 3 4 ●	21	4 3 2 ○ 1
2	♃ 4 ○ 2 3	12	3 ○ 1 2 4	22	4 1 ○ 2 ●
3	4 2 ○ 1 3	13	3 1 2 ○ 4	23	○ 4 1 2 3
4	4 1 ○ 2 3	14	3 2 ○ 4 1	24	2 1 ○ 4 3
5	3 4 ○ 1 2	15	4 ○ 1 2 3	25	♃ 2 ○ 3 4
6	3 1 2 4 ○	16	4 1 2 ○ 3	26	3 1 ○ 2 4
7	3 2 ○ 1 4	17	4 2 ○ 3 ●	27	♃ 3 1 ○ 4
8	1 ○ 3 2 4	18	4 1 2 ○ 3	28	3 2 ○ 1 4
9	○ 1 2 3 4	19	4 3 ○ 1 2	29	1 3 ○ 2 4
10	2 ○ 1 3 4	20	4 3 1 2 ○	30	○ 1 2 3 4
				31	2 1 ○ 4 3

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A................$0^h\ 52^m\ 32^s$
Decl.................+ 81° 17′
Period............2*d* $11^h\ 50^m$

Dec.	2	3 A. M.
	7	3 "
	12	3 "
	17	2 "
	22	2 "
	27	2 "

ALGOL.

R. A................$3^h\ 01^m\ 01^s$
Decl................ + 40° 32′
Period............2*d* $20^h\ 49^m$

Dec.	8	4 A. M.
	11	1 "
	13	9 P. M.
	16	6 "
	19	3 "
	28	5 A. M.
	31	2 "

λ TAURI.

R. A................ $3^h\ 54^m\ 35^s$
Decl................ + 12° 11′
Period............3*d* $22^h\ 52^m$

Dec.	2	1 A. M.
	5	midn.
	9	11 P. M.
	13	10 "
	17	8 "
	21	7 "
	25	6 "
	29	5 "

R CANIS MAJORIS.

R. A................ $7^h\ 14^m\ 30^s$
Decl................ − 16° 11′
Period............1*d* $03^h\ 16^m$

Dec.	4	8 P. M.

R. CANIS MAJ., CONT.

Dec.	5	11 P. M.
	7	2 A. M.
	8	5 "
	12	6 P. M.
	13	9 "
	14	midn.
	16	4 A. M.
	20	5 P. M.
	21	8 "
	22	midn.
	24	3 A. M.
	29	7 P. M.
	30	11 "

S CANCRI.

R. A................ $8^h\ 37^m\ 39^s$
Decl................ + 19° 26′
Period............9*d* $11^h\ 38^m$

Dec.	15	7 P. M.

S ANTLIÆ.

R. A................ $9^h\ 27^m\ 30^s$
Decl................ − 28° 09′
Period............0*d* $07^h\ 47^m$

Dec.	1	6 A. M.
	2	6 "
	3	5 "
	4	4 "
	5	4 "
	6	3 "
	7	2 "
	8	2 "
	9	1 "
	10	1 "
	10	midn.
	11	11 P. M.

S. ANTLIÆ, CONT.

Dec.	12	11 P. M.
	13	5 A. M.
	14	5 "
	15	4 A. M.
	16	4 "
	17	3 "
	18	2 "
	19	2 "
	20	1 "
	21	1 "
	21	midn.
	22	midn.
	23	11 P. M.
	24	6 A. M.
	25	6 "
	26	5 "
	27	5 "
	28	4 "
	29	3 "
	30	3 "
	31	2 "

Y CYGNI.

R. A...............$20^h\ 47^m\ 40^s$
Decl............... + 34° 15′
Period.......... 1*d* $11^h\ 56^m$

Dec.	1	10 P. M.
	4	10 "
	7	10 "
	10	10 "
	13	10 "
	16	10 "
	19	10 "
	22	10 "
	25	10 "
	28	9 "
	31	9 "

A Total Eclipse of the Moon, Nov. 4, 1892.—This will be invisible in the United States. The beginning is visible generally in the northwest part of North America, the Pacific Ocean, Asia, and the easterly portions of Europe. The end is visible in the northwest Pacific Ocean, Australia, Asia, Europe (except England and Spain) and the east portions of Africa. It begins at $7^h\ 10^m$ A. M. and ends at $12^h\ 20^m$ P. M. central standard time.

COMET NOTES.

New Comet Discovered by Photography, (*e* 1892, Barnard Oct. 12).—A very faint comet was discovered photographically by Barnard, Oct. 12. Oct. 13.638 it was observed in R. A. $18^h\ 53^m\ 56^s$; Decl. + 12° 53′. Daily motion $+\ 6^m\ 44^s$; — 37′. The following elements and ephemeris by Mr. Campbell were received by telegram Oct. 20.

Elements of Comet e 1892.

T = Aug. 26.14, 1892 Gr. M. T.

$$\left.\begin{array}{ll} \omega & = 114^\circ\ 02' \\ \Omega & = 184\ \ \ 13 \\ i & = \ \ 43\ \ \ 07 \end{array}\right\}\ 1892.0$$

q = 1.9904

Ephemeris.

Gr. Midn.	R. A. h m s	Decl. ° ′	Light
Oct. 18	19 44 36	+ 10 42	0.85
22	19 53 32	9 17	
26	20 02 28	7 56	
30	20 11 24	+ 6 41	0.69

The comet was observed at Goodsell Observatory, Oct. 20 and found very near the ephemeris place. It is very faint, barely visible in the five-inch finder, but easily observed with the 16-inch. It is in the constellation Delphinus, the Dolphin, and moving southeast.

Five Comets Now Visible.—On the same night, Oct. 20, we looked up the other four comets which are now visible. Swift's is in the constellation Andromeda, between the head and right hand, moving slowly southward. It is yet visible in a five-inch and will continue to be within reach of large telescopes for some time yet. Winnecke's comet is in Cetus a few degrees southeast of the star β and is moving slowly northward. It is not visible in small telescopes and is rather difficult to observe with a 16-inch. Denning's comet is still fainter than Winnecke's. It will, during November, traverse the lower left corner of the constellation Orion. Brook's comet (*d* 1892) is the brightest of the five now visible. It is an easy object with a small telescope and will perhaps be visible to the naked eye. It is now in the fore paws of Leo, the Lion, and moving southeast.

New Elements of Comet *d* 1892 (Brooks.)—The following elements and ephemeris were computed by Mr. A. G. Sivaslian, student at Goodsell Observatory, from observations at Northfield, Sept. 4 and Sept. 28, and one at Copenhagen Sept. 16.

T = Dec. 28.04941, 1892, Gr. M. T.

$$\left.\begin{array}{llll} \omega & = 253^\circ & 04' & 42''.0 \\ \Omega & = 264 & 27 & 49\ .9 \\ i & = \ \ 24 & 51 & 46\ .3 \end{array}\right\}\ 1892.0$$

$\log q$ = 9.986592 q = 0.96960

The representation of the middle place, $d\lambda \cos \beta = +\ 1.8''$; $d\beta = -\ 8.0''$, shows that the orbit is very nearly parabolic.

Ephemeris of Comet *d* 1892 (Brooks).

Gr. M. T.		App. R. A.			App. Decl.			log Δ	log *r*	Br.
		h	m	s	°	′	″			
Nov.	4.5	9	29	15.9	+ 8	57	15	0.0191	0.1230	12.9
	5.5		33	21.4	8	09	25			
	6.5		37	29.2	7	20	30			
	7.5		41	39.5	6	30	32			
	8.5		45	52.3	5	39	30	9.9998	0.1086	14.7
	9.5		50	07.7	4	47	26			
	10.5		54	25.5	3	54	22			
	11.5	9	58	45.9	3	00	20			
	12.5	10	03	08.9	2	05	20	9.9826	0.0943	17.0
	13.5		07	34.5	1	09	26			
	14.5		12	02.7	+ 0	12	41			
	15.5		16	33.5	− 0	44	54			
	16.5		21	06.9	1	43	14	9.9678	0.0801	19.5
	17.5		25	43.0	2	42	16			
	18.5		30	21.8	3	41	56			
	19.5		35	03.2	4	42	11			
	20.5		39	47.3	5	42	55	9.9560	0.0661	21.9
	21.5		44	34.1	6	44	05			
	22.5		49	23.6	7	45	35			
	23.5		54	15.7	8	47	20			
	24.5	10	59	10.5	9	49	16	9.9475	0.0526	24.3
	25.5	11	04	07.9	10	51	17			
	26.5		09	08.0	11	53	17			
	27.5		14	10.8	12	55	11			
	28.5		19	16.2	13	56	53	9.9427	0.0397	26.3
	29.5		24	24.1	14	58	18			
	30.5		29	34.5	15	59	20			
Dec.	1.5		34	47.5	16	59	53			
	2.5		40	02.9	17	59	52	9.9416	0.0277	28.0
	3.5		45	20.7	18	59	13			
	4.5		50	40.9	19	57	48			
	5.5	11	56	03.3	20	55	35			
	6.5	12	01	27.8	21	52	28	9.9440	0.0167	29.1
	7.5		06	54.4	22	48	22			
	8.5		12	23.0	23	43	13			
	9.5		17	53.6	24	36	58			
	10.5		23	26.0	25	29	32	9.9496	0.0071	29.6
	11.5		29	00.0	26	20	53			
	12.5		34	35.6	27	10	56			
	13.5		40	12.6	27	59	40			
	14.5	12	45	51.0	− 28	47	02	9.9580	9.9991	29.6

Ephemeris of Comet *a* 1892 (Swift.)

[Computed by Geo. A. Law, student in Goodsell Observatory, from elements by Miss Gertrude Wentworth, *Astr. Jour.* No. 273].

Gr. M. T.		App. R. A.			App. Decl.		log. *r*	log. Δ	Br.
		h	m	s	°				
Nov.	5.5	23	44	09.8	+ 37	14.3	0.5060	0.3859	.027
	6.5		44	6.7	36	57.7			
	7.5		44	5.1	36	41.3			
	8.5		44	4.9	36	25.1			
	9.5		44	6.1	36	09.1	0.5121	0.3980	.025
	10.5		44	8.7	35	53.2			
	11.5		44	12.7	35	37.5			
	12.5		44	18.6	35	22.0			
	13.5		44	24.8	35	06.7	0.5180	0.4104	.023
	14.5		44	32.8	34	51.6			
	15.5		44	42.1	34	36.6			
	16.5		44	52.7	34	22.0			

Gr. M. T.		App. R. A.			App. Decl.		log. *r*	log. *Δ*	Br.
		h	m	s	°	′			
Nov.	17.5	23	45	4.6	+ 34	07.2	0.5238	0.4231	.021
	18.5		45	17.7	33	52.8			
	19.5		45	32.0	33	48.7			
	20.5		45	47.5	33	34.8			
	21.5		46	04.1	33	11.1	0.5295	0.4359	.019
	22.5		46	21.9	32	57.6			
	23.5		46	40.7	32	34.3			
	24.5		47	00.6	32	21.3			
	25.5		47	21.6	32	18.4	0.5351	0.4488	.018
	26.5		47	43.7	32	05.8			
	27.5		48	06.8	31	53.4			
	28.5		48	30.9	31	41.2			
	29.5		48	55.9	31	29.3	0.5406	0.4610	.016
	30.5		49	21.9	31	17.6			
Dec.	1.5		49	48.8	31	06.1			
	2.5		50	16.6	30	54.8			
	3.5		50	45.4	30	43.8	0.5461	0.4747	.015
	4.5		51	15.1	30	33.0			
	5.5		51	45.5	30	22.4			
	6.5		52	16.8	30	12.1			
	7.5		52	48.8	30	01.8	0.5514	0.4877	.014
	8.5		53	21.6	29	51.8			
	9.5		53	55.2	29	42.2			
	10.5		54	29.6	29	32.8			
	11.5		55	04.5	29	23.5	0.5567	0.5005	.013
	12.5		55	40.1	29	14.3			
	13.5		56	16.4	29	05.4			
	14.5		56	53.4	28	56.7			
	15.5	23	57	31.0	+ 28	48.1	0.5619	0.5132	.012

Ephemeris of Comet 1892 (Winnecke).

(From *Astr. Nach.* No. 3112).

Berlin Midn.		App. R. A.			App. Decl.			log *r*	log *Δ*	Br.
		h	m	s	°	′	″			
1892 Nov.	16	0	49	17.7	− 19	19	17			
	17		49	20.5	19	03	26	0.3101	0.1196	0.138
	18		49	25.2	18	47	37			
	19		49	31.5	18	31	51			
	20		49	39.5	18	16	08			
	21		49	49.2	18	00	28	0.3180	0.1426	0.120
	22		50	00.4	17	44	51			
	23		50	13.2	17	29	17			
	24		50	27.6	17	13	46			
	25		50	43.4	16	58	19	0.3258	0.1651	0.104
	26		51	00.7	16	42	55			
	27		51	19.4	16	27	34			
	28		51	39.5	16	12	18			
	29		52	01.0	15	57	05	0.3333	0.1870	0.691
	30		52	23.7	15	41	56			
Dec.	1		52	47.7	15	26	52			
	2		53	12.9	15	11	51			
	3		53	39.3	14	56	54	0.3407	0.2083	0.080
	4		54	06.9	14	42	01			
	5		54	35.7	14	27	12			
	6		55	05.5	14	12	28			
	7		55	36.5	13	57	47	0.3479	0.2290	0.071
	8		56	08.6	13	43	10			
	9		56	41.6	13	28	38			
	10		57	15.8	13	14	10			
	11		57	50.9	12	59	45	0.3549	0.2492	0.062
	12	0	58	27.0	− 12	45	25			

		App. R. A.			App. Decl.			log *r*	log *Δ*	Br.
		h	m	s	°	′	″			
Dec,	13	0	59	04.0	− 12	31	08			
	14	0	59	42.0	12	16	56			
	15	1	00	20.9	12	02	48	0.3618	0.2687	0.055
	16		01	00.7	11	48	43			
	17		01	41.4	11	34	43			
	18		02	22.9	11	20	47			
	19		03	05.3	11	06	54	0.3684	0.2876	0.049
	20		03	48.4	10	53	06			
	21		04	32.4	10	39	22			
	22		05	17.2	10	25	42			
	23		06	02.7	10	12	06	0.3750	0.3059	0.044
	24		06	48.9	9	58	33			
	25		07	35.9	9	45	05			
	26		08	23.5	9	31	41			
	27		09	11.9	9	18	22	0.3814	0.3236	0.039
	28		10	00.9	9	05	06			
	29		10	50.6	8	51	54			
	30		11	40.9	8	38	46			
	31	1	12	31.8	− 8	25	42	0.3876	0.3408	0.035

New Minor Planets.—Seven planetoids have been discovered since Sept. 1. All were discovered by means of photography, two being found on the same plate in two instances. The following are the dates and positions of discovery:

Planetoid.	Date.	R. A.		Decl.		Mag.	Photograph by	Place.
		h	m	°	′			
1892 B	Sept. 1	23	44.7	− 3	00	12	Staus	Heidelberg.
C	Sept. 1	23	55.4	− 4	11	11	Staus	"
D	Sept. 19	0	30.5	+11	32	12	Charlois	Nice.
E	Sept. 22-23	0	48.1	+ 8	35	11.5	Charlois	"
F	Sept. 25-26	0	41.7	+14	18	12	Charlois	"
G	Sept. 25	0	36.6	+ 0	21	12	Wolf	Heidelberg.
H	Sept. 25	0	37.6	+ 1	02	12	Wolf	"

The designation B, C, D, etc., is given temporarily. At the end of the year those which have not been identified with asteroids already known, and whose orbits are well determined will receive permanent numbers as heretofore. 1892 B is found to be identical with (163) Erigone. 1892 D was found on the same plate with (137) Melibœa and hence is not identical with it. G and H were found on the same plate with (34) Circe and (184) Dejopeja and are probably new.

The Partial Eclipse of the Sun, Oct. 20.—Clouds prevented observations of much value at Northfield. Both contacts were partially obscured. The first glimpse of the Moon's image notching the solar disk was caught by Miss C. R. Willard, observing with a 4-inch refractor by projection, at $10^h\ 41^m\ 36^s$ central standard time. Professor Payne observing with the same instrument, thought he saw the notch 20^s earlier, but it was immediately covered by a cloud so that he was uncertain. Professor Wilson using the 5-inch finder saw the notch at $10^h\ 42^m\ 20^s$ and estimated contact to have occurred about 5^s earlier. The clouds were so dense all the morning that we did not have time to adjust the helioscope on the 16-inch and so decided to use the finder.

Last contact was also very cloudy; the last glimpse of the black notch was seen by Professor Wilson, using the 16-inch telescope and helioscope, at $1^h\ 25^m\ 22^s$ central standard time. This was estimated to be about 5^s early. Three photographs of the eclipse were taken between clouds.

Observations of the Eclipse at Providence, R. I.—The partial solar eclipse was observed here at our Observatory yesterday under favorable conditions. The sky was nearly clear from first to last contact. The first contact occurred at $0^h\ 07^m\ 28.5^s$ eastern standard time, and the last contact at $3^h\ 08^m\ 08.0^s$. Professor Johnson observed with a three-inch telescope stationed in the open air, and I observed with a four-inch telescope.

FRANK E. SEAGRAVE.

Providence, Oct. 21, 1892.

The Eclipse at Alta, Iowa.—The partial eclipse of the Sun was quite satisfactorily observed here on 20th inst. Heavy clouds covered the sky from early morning until about 10 A. M., when they suddenly broke away and only five minutes before the computed time of first contact the sky in the vicinity of the Sun was clear. First contact was noted at $10^h\ 23^m\ 10^s$ Alta mean time. Light haze now covered the sky for about an hour, but at time of ending of eclipse the sky was cloudless. Last contact occurred at $1^h\ 1^m\ 10^s$, Alta M. T. The observed times differ from my computed results by $1^m\ 20^s$ earlier and $1^m\ 16^s$ later for beginning and ending respectively, due I suppose to only approximate latitude and longitude of the station. Time was compared with fine regulator and noon signals at R. R. station. Telescope used, 3-inch Jena glass, full aperture employed.

DAVID E. HADDEN.

Alta, Ia., Lat. + 42° 40′; Long. 95° 15′ W. from Greenwich.

The Eclipse at Wilmington, N. C.—Mr. E. S. Martin writes that he observed the eclipse, under very favorable atmospheric conditions, with a 5-inch Clark refractor. He caught the first glimpse of the Moon at $12^h\ 08^m$, eastern standard time, a little after first contact. At $1^h\ 24^m$ the limb of the Moon occulted a conspicuous spot near the center of the Sun's disc. This spot reappeared at $2^h\ 30^m$ P. M. Last contact was not observed.

The Eclipse at Baltimore, Md.—I observed the partial eclipse as follows, using chronometer and chronograph:

	75 Meridian Time.			Position Angle from north point.
	h	m	s	°
First Contact......................	12	05	12	21 west
Last Contact......................	3	05	45	105 east

J. STAHR.

NEWS AND NOTES.

New Director of the Paris Observatory.—M. F. Tisserand has been elected Director of the Observatory of Paris, in place of the late Admiral Mouchez. The election, in accordance with rules recently adopted by the Academy of Sciences and the Council of the Observatory, is for five years.

M. Tisserand is an eminent astronomer and mathematician, having published many memoirs in the scientific journals, which indicate his ability in scientific research. He is spoken of by the French papers as the real successor of Le Verrier. He is 47 years of age, has held several positions of responsibility and honor, and is well fitted to discharge the duties of the important office to which he has been called.

Note from Professor Keeler.—As my name has been mentioned in various articles commenting on recent changes in the Lick Observatory staff, I desire to say that I resigned more than a year ago for private reasons which were in no way connected with the administration of observatory affairs, and that I left Mount Hamilton with the good will of the regents and on the best of terms with the Director and all my associates. JAMES E. KEELER.

Allegheny Observatory, Sept. 24, 1892.

Letter from Professor Young.—I have the pleasure of reporting that my assistant, Mr. Reed, has succeeded in finding and observing the new satellite of Jupiter with the 23-inch equatorial of the Halsted Observatory. It had been looked for on every opportunity for the last three weeks, but unsuccessfully until Oct. 10th. During the earlier portion of the time, when the elongations occurred between 2 and 3 A. M., we were baffled by fogs which repeatedly gathered about that time;and later we were misled by bringing forward the time of elongation with the erroneous period of $11^h\ 50^m$. On Oct. 10th the *Western* Elongation should have been occurring, (reckoning on this basis) at the time, 12:40 A. M., Eastern Standard, when the satellite was actually found at the *Eastern* one.

The night of Oct. 10th was very fine, and Mr. Reed reports the satellite as *easily* seen,—certainly less difficult than Ariel. The elongation occurred at 12:40 as nearly as he could estimate, but the error of estimation might be as much as 10 minutes.

Two micrometer measures, which he obtained with much difficulty, at 1:09 and 1:49 A. M., gave the distance of the satellite from the planet's centre as 61″.8 and 56″.6 respectively.

On the 11th the satellite was seen again, and was judged to pass its elongation at 12:30 A. M. The air was not so clear as on the 10th, and no micrometer measures could be made.

I have not been able to participate in the observations myself, on account of an attack of rheumatism

A comparison of these two elongation-times with Mr. Barnard's early observations, given in the *Astronomical Journal*, and with another made on Sept. 23d and kindly communicated to me in a letter, gives the periodic time $11^h\ 57^m.0$, which I think must be correct within 10^s or so. In the computation the correc, tions for the planet's change of longitude and distance during the interval covered by the observations were duly applied, and the observed times of elongation are all satisfied without any error as great as four minutes. If as, I hope, we are able to get two or three more determinations of the time of elongation soon the probable error of the period can easily be brought down to a single second.

Assuming the mass of Jupiter as one, one thousand forty eighth of the Sun's, its mean distance as 483,300,000 miles, and its period 43,326 days, and taking the period of the satellite at $11^h\ 57^m.0$, we find its distance from the centre of the planet to be 112,500 miles, using the formula $r^3 = \frac{K^3 t^2}{m.T^2}$

I may add that Mr. Reed considers the satellite bright enough to be seen (under favorable conditions of course) by any telescope exceeding 15 or 16 inches in diameter, but I should be disposed myself to doubt whether it could be reached by any object-glass much under 20 inches.

C. A. YOUNG.

Princeton, N. J., Oct. 13, 1892.

An Aerolite in Court.—A most interesting case, regarding the ownership of an aerolite, has just been decided by the Supreme Court of Iowa, in the case of Goddard *v.* Winchell. The facts are briefly as follows:

On the second day of May, 1890, an aerolite, weighing sixty-six pounds, fell on the land of one Mr. Goddard, imbedding itself in the soil to the depth of about three feet. One Mr. Hoagland, living on an adjoining farm, whose wife saw this aerolite fall, went upon the land the next day, with spade and pickaxe, dug up the aerolite, and took it to his own house, claiming it to be his own property, upon the ground that it could belong to no one else, except those who first found it and took it into their possession. A few days later Mr. Hoagland sold the stone to Mr. Winchell, whereupon the owner of the fee replevied the same, and hence arose the issue, as to the ownership of an aerolite. The question, plainly stated, was this: Does the stone belong to the man who owns the land upon which it fell, or does it belong to the first fortunate finder upon the ground that it formerly belonged to nobody, and hence would belong, when found, to the first person who should take it into his possession?

This is the first case of the kind which has ever been carried to a final decision, either in this or any other country. It is of interest to the scientific world in that it decides squarely of whom the scientist must purchase these messengers from abroad. Similar cases have been before the courts of limited jurisdiction, but never before has one been carried to the court of last resort. The questions placed before the Supreme Court of Iowa were as follows:

1. Does an aerolite belong to the owner of the fee, upon the ground "that whatever is affixed to the soil belongs to the soil?" or

2. Does it belong to the first finder, upon the ground "that the aerolite belongs to the great mass of unowned things and hence becomes the property of the first finder?"

If the first ancient rule of law is to be applied in this case, the stone must be long to the fee-holder. If the second principle is applied, then the finder will be the owner of the aerolite. The question of trespass in going onto the land of another to get property which fell there was not raised in this case, but the issue came up in the form above stated. The case was argued in the Supreme Court of Iowa by W. E. Bradford, of Britt, Iowa, and by Hon. W. S. Pattee of Minneapolis, the former appearing for the fee-holder, and the latter for Mr. Winchell, who purchased from the finder. The case was very thoroughly investigated, and elaborately argued upon both sides, and the Court finds the following, which stands as the syllabus of the reported case:

1. "An aerolite, weighing sixty-six pounds, which falls from the sky and is imbedded in the soil to the depth of three feet, is the property of the owner of the land on which it falls, rather than of the first person who finds it and digs it up."

2. "The rule that the finder of lost goods is entitled thereto, except as against the true owner, is not applicable to such case."

The main points of the Court's argument may be seen from the following extract from the Court's decision:

> As conclusions of law, the district court found that the aerolite became a part of the soil on which it fell; that the plaintiff was the owner thereof; and that the act of Hoagland in removing it was wrongful. It is insisted by appellant that the conclusions of law are erroneous; that the enlightened demands of the time in which we live call for, if not a modification, a liberal construction, of the ancient rule, "that whatever is affixed to the soil belongs to the soil," or, the more modern statement of the rule, "that a permanent annexation to the soil, of a thing in itself personal, makes it a part of the realty." In behalf of appellant is invoked a rule alike ancient and of undoubted merit, "that of title by occupancy;" and we

are cited to the language of Blackstone, as follows: "Occupancy is the taking possession of those things which before belonged to nobody;" and "whatever movables are found upon the surface of the earth, or in the sea, and are unclaimed by any owner, are supposed to be abandoned by the last proprietor, and as such are returned into the common stock and mass of things; and therefore they belong, as in a state of nature, to the first occupant or finder." In determining which of these rules is to govern in this case, it will be well for us to keep in mind the controlling facts giving rise to the different rules, and note, if at all, wherein the facts of this case should distinguish it. The rule sought to be avoided has alone reference to what becomes a part of the soil, and hence belongs to the owner thereof, because attached or added thereto. It has no reference whatever to an independent acquisition of title; that is, to an acquisition of property existing independent of other property. The rule invoked has reference only to property of this independent character, for it speaks of movables "found upon the surface of the earth or in the sea." The term "movables" must not be construed to mean that which can be moved, for, if so, it would include much known to be realty; but it means such things as are not naturally parts of earth or sea, but are on the one or in the other. Animals exist on the earth and in the sea, but they are not, in a proper sense, parts of either. If we look to the natural formation of the earth and sea, it is not difficult to understand what is meant by "movables," within the spirit of the rule cited. To take from the earth what nature has placed there in its formation, whether at the creation or through the natural processes of the acquisition and depletion of its particular parts, as we witness it in our daily observations, whether it be the soil proper or some natural deposit as of mineral or vegetable matter, is to take a part of the earth, and not movables.

If, from what we have said, we have in mind the facts giving rise to the rules cited, we may well look to the facts of this case to properly distinguish it. The subject of the dispute is an aerolite, of about 66 pounds weight, that "fell from the heavens" on the land of the plaintiff, and was found three feet below the surface. It came to its position in the earth through natural causes. It was one of nature's deposits, with nothing in its material composition to make it foreign or unnatural to the soil. It was not a movable thing "on the earth." It was in the earth, and in a very significant sense immovable; that is, it was only movable as parts of earth are made movable by the hand of man. Except for the peculiar manner in which it came, its relation to the soil would be beyond dispute. It was in its substance, as we understand, a stone. It was not of a character to be thought of as "unclaimed by any owner," and, because unclaimed, "supposed to be abandoned by the last proprietor," as should be the case under the rule invoked by appellant. In fact, it has none of the characteristics of the property contemplated by such a rule.

We may properly note some of the particular claims of appellant. His argument deals with the rules of the common law for acquiring real property, as by escheat, occupancy, prescription, forfeiture, and alienation, which it is claimed were all the methods known, barring inheritance. We need not question the correctness of the statement, assuming that it has reference to original acquisition, as distinct from acquisitions to soil already owned, by accretion or natural causes. The general rules of the law, by which the owners of riparian titles are made to lose or gain by the doctrine of accretions, are quite familiar. These rules are not, however, of exclusive application to such owners. Through the action of the elements, wind and water, the soil of one man is taken and deposited in the field of another; and thus all over the country, we may say, changes are constantly going on. By these natural causes the owners of the soil are giving and taking as the wisdom of the controlling forces shall determine. By these operations one may be affected with a substantial gain, and another by a similar loss. These gains are of accretion, and the deposit becomes the property of the owner of the soil on which it is made.

A scientist of note has said that from six to seven hundred of these stones fall to our earth annually. If they are, as indicated in argument, departures from other planets, and if among the planets of the solar system there is this interchange, bearing evidence of their material composition, upon what principle of reason or authority can we say that a deposit thus made shall not be of that class of property that it would be if originally of this planet and in the same situation? If these exchanges have been going on through the countless ages of our planetary system, who shall attempt to determine what part of the rocks and formations of especial value to the scientist, resting in and upon the earth, are of meteoric acquisition, and a part of that class of property designated in argument as "unowned things," to be the property of the fortunate finder instead of the owner of the soil, if the rule contended for is to obtain? It is not easy to understand why stones or balls of metallic iron, deposited as this was, should be governed by a different rule than obtains from the deposit of boulders, stones, and dirt upon our prairies by glacier action; and who would contend that these deposits from floating bodies of ice belong, not to the owner of the soil, but to the finder? Their origin or source may be less mysterious, but they, too, are "tell-tale messengers" from far-off lands, and have value for historic and scientific investigation.

It is said that the aerolite is without adaptation to the soil, and only valuable for scientific purposes. Nothing in the facts of the case will warrant us in saying that it was not as well adapted for use by the owner of the soil as any stone, or, as appellant is pleased to denominate it, "ball of metallic iron." That it may be of greater value for scientific or other purposes may be admitted, but that fact has little weight in determining who should be its owner. We cannot say that the owner of the soil is not as interested in, and would not as readily contribute to, the great cause of scientific advancement, as the finder, by chance or otherwise, of these silent messengers. This aerolite is of the value of $101, and this fact, if no other, would remove it from uses where other and much less valuable materials would answer an equally good purpose, and place it in the sphere of its greater usefulness.

The rule is cited, with cases for its support, that the finder of lost articles, even where they are found on the property, in the building, or with the personal effects of third persons, is the owner thereof against all the world except the true owner. The correctness of the rule may be conceded, but its application to the case at bar is very doubtful. The subject of this controversy was never lost or abandoned. Whence it came is not known, but, under the natural law of its government, it became a part of this earth, and, we think, should be treated as such. It is said by appellant that this case is unique; that no exact precedent can be found; and that the conclusion must be based largely upon new considerations. No similar question has, to our knowledge, been determined in a court of last resort. In the American and English Encylopedia of Law (volume 15, p. 388) is the following language: "An aerolite is the property of the owner of the fee upon which it falls. Hence a pedestrian on the highway, who is first to discover such a stone, is not the owner of it; the highway being a mere easement for travel." It cites the case of Maas v. Amana Soc., 16 Alb. Law J. 76, and 13 Ir. Law T. 381, each of which periodicals contains an editorial notice of such a case having been decided in Illinois, but no reported case is to be found. Anderson's Law Dictionary states the same rule of law, with the same references, under the subject of "accretions." In 20 Alb. Law J. 299, is a letter to the editor from a correspondent, calling attention to a case determined in France, where an aerolite found by a peasant was held not to be the property of the "proprietor of the field," but that of the finder. These references are entitled, of course, to slight, if any, consideration; the information as to them being too meager to indicate the trend of legal thought. Our conclusions are announced with some doubts as to their correctness, but they arise, not so much from the application of known rules of law to proper facts, as from the absence of defined rules for these particular cases. The interest manifested has induced us to give the case careful thought. Our conclusions seem to us nearest analogous to the general accepted rules of law bearing on kindred questions, and to subserve the ends of substantial justice. The question we have discussed is controlling in the case, and we need not consider others.

The judgment of the district court is affirmed.

The Photo-Electric Effect of Star-Light.—I forward to you an account of Professor Minchin's Photo-Electric Cells and the results obtained by Professor Dixon of St. John's, New Brunswick, who was residing next door to me during the time. The weather was on the whole very unfavorable. My telescope is a 7½-inch refractor by Alvan Clark (made for the late Rev. W. R. Dawes). It is excellent instrument of its kind but accuracy of definition is unimportant for the purposes we had in view. In fact, I think we succeeded rather better when the cells were placed farther out than the focus so as to spread the light of the star over a wider circle. When the light is contracted almost to a point it is difficult to insure its falling on the sensitive plate. The cell, if used outside the tube, should, of course, be cut off from diffused light as far as possible. I am not sure that we attended sufficiently to this requirement. The fault, however, I think, chiefly rested with the electrometer (Clyton's form of Thomson's). Besides oscillating considerably, the zero-point appeared to be gradually shifting on some occasions, while on others the electrometer would not hold any considerable charge. I am not a practical electrician but I think those who are so will agree with me in this. We failed to obtain any *certain* results from the fixed stars owing, as I believe, to these causes. With a larger telescope and a steadier and less leaky electrometer, I think a good deal could be effected with Professor Minchin's cells. The effects obtained from the moon by Professor Dixon were of a striking character and on one occasion, at least, he obtained results from bright patches in the clouds near, but I think not precisely in front of, the moon. Professor Fitzgerald had previously obtained well marked effects from the moon. W. H. S. MONCK.

The Photo-Electric Effect of Star-Light.—Mr. Monck has asked me to give a short account of some preliminary experiments with Professor Minchin's photo-electric cells, in which he was good enough to ask me to assist. The experiments were made in Mr. Monck's Observatory in Earlsford Terrace, Dublin. The following arrangement was made at Professor Minchin's suggestion and by his assistance. The cell or battery of cells was placed on a small slide which was fitted to the tube of the telescope when the eye-piece was removed. This slide was so arranged that the sensitive part of plate in the cell could be placed in the focus of the telescope. By placing the eye behind the cell it was easy to see when the image of the star or planet fell on the sensitive plate, then the telescope was clamped and clock work set going. The sensitive plate was connected with a quadrant electrometer and the other plate with earth. The light from the planet could be cut off by a screen so that its effect on the cell could thus be determined by the deflection of the electrometer needle. The following results from a battery of two cells were obtained on the morning of the 28th of August: When an E M F of .85 volt gave a deflection of 21 cm. on the electrometer scale the effect of Jupiter's light on the battery produced a deflection of 4 mm.; and when the E M F of .85 volt gave a deflection of 10.5 cm. the light of Venus caused a deflection of 5 mm. STEPHEN M. DIXON.

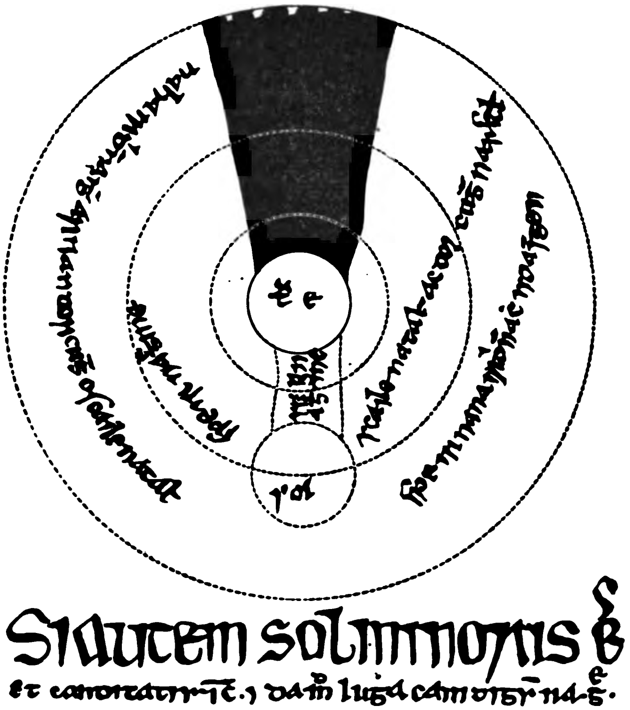
August 30, 1892.

A Curious Old Astronomical Chart.—We are indebted to Dr. William H. Grainger, East Boston, Mass., for a photographic copy taken from a facsimile of a curious astronomical chart, preserved in Trinity College, Dublin, bearing date A. D., 1400. The text is written in Celtic character and is somewhat faint, owing to the light brown color of the plate from which it was taken. The translation kindly furnished by Dr. Grainger is as follows:

"*Si Autem sol Minores eset Canditates,*" *etc.*—If the magnitude of the Sun were smaller than the magnitude of the Earth, everything unsustainable, unpermissible, we have said, and move along with them, they should fall in it; for the shadow of the Earth would be continually growing and leaping from the Earth out to the sphere of the high stars, and it would darken the greater part of them;

and an eclipse would happen to the planets in every month; and the eclipse of the Moon would hold during the night, as he says. Well then, as we have never seen the like of this, and as we nave not heard, and as we have not found it written it must be that the magnitude of the Sun is not smaller than the magnitude of the Earth; and what I say is manifest from this figure down here.

(G.G) MS. IN ROY. IR. ACAD. ASTRONOM: TRACT; CIRCA A. D. 1400.


Si autem sol minoris

Professor O'Curry says: "This remarkable astronomical tract does not appear to have been yet investigated by scientific scholars. A specimen has therefore been selected such as to show one of the many diagrams with which it is illustrated. It is a beautiful vellum manuscript of eight pages, in the finest style of handwriting."

Manuscript in R. I. A. (Circa 14th century).

The diagram contains the following words: (Translation).

1. The high stars on being darkened by the shadow of the Earth.
2. The Sun's sphere.
3. The Sun's sphere.
4. The shadow of the Earth darkening the Moon.
5. The sphere of the fixed stars.
6. The Sun.
7. The Earth.

Astronomical and Physical Society of Toronto.—The regular meeting of the Astronomical and Physical society of Toronto held Oct. 4, was one of lively interest to its members and visitors. Some of the topics considered were a permanent place for the books, apparatus and meetings of the society, arrangements for observing the Leonids, November 13 and 14; reports of auroræ for September, of large meteor by L. W. Smith; of Sun-spots; of occultation of Mars by the Moon, by Mr. Ridout; of the Barnard discovery of Jupiter's fifth satellite and of Jupiters opposition and the position of the shadows of satellites on the Jovian disc. Announcements of interesting phenomena for future observation were made and the promised work planned for somewhat in detail. This young society is doing useful work and engaging deserved public attention.

Chicago Academy of Sciences.—The regular meeting of the Section of Mathematics and Astronomy of the Chicago Academy of Sciences was held at the Dearborn Observatory, Evanston, on Tuesday evening, Oct. 4, 1892.

Professor G. W. Hough was in the chair.

The minutes of the last meeting were read and approved.

Mr. S. W. Burnham made some remarks on the new satellite of Jupiter. Mr. Barnard's discovery is by no means to be regarded as an accident, as Jupiter has been watched by this observer for many years. Up to June of the present year Mr. Barnard has been using the 12-inch telescope of the Lick Observatory in the examination of Jupiter's surface markings and the phenomena of the satellites. In July he was able for the first time to employ the 36-inch telescope for this work, and a very careful search was made for possible satellites. On Sept. 19 a very small star was seen close to the planet, and, as it was at once suspected to be a new satellite, its position with reference to the third Satellite was measured. On the two following nights it was re-observed and no doubt remained as to its true nature. It is described as a much more difficult object than the satellites of Mars, and therefore can probably be seen with only the largest instruments. The period is very nearly 11^h 59^m, and the distance from the planet's center about 112,000 miles.

Professor Hough spoke of the importance of the discovery, and of its relation to Galileo's discovery of the first four satellites.

Mr. Burnham added that the claims of the various observers with small telescopes as to their pretended discovery of the satellite were evidently not to be considered for a moment.

The next paper, "On the New Star in Auriga," was read by Dr. Henry Crew of Northwestern University. The discovery and earlier observations of the Nova were described, and the various remarkable features of the Nova and its spectrum were pointed out. Professor Crew's observations were made with the 36-inch telescope of the Lick Observatory. With a single prism the spectrum was very brilliant, but it was very faint with a grating. Attention was called to the peculiar way in which the lines faded away as the star declined in magnitude. Two lines in the red which were very faint when the Nova was brightest became brighter as the magnitude decreased, and finally surpassed even C itself. Dr. Crew considers the reappearance of the Nova as a nebula as distinctly opposed to Mr. Lockyer's meteoritic theory. The various other theories were reviewed and commented upon.

Mr. Burnham remarked, in answer to a question as to the position of the Nova, that Mr. Barnard had found by a series of measures that not the slightest change had occurred since the disappearance in the spring. He considers the mode of discovery as offering great encouragement to amateurs having small instruments. An observer with a large telescope depends so exclusively upon the circles in setting that he loses his familiarity with the sky. The amateur observer's constant use of star charts makes it much more likely that he will notice new objects, though many probably escape attention.

Dr. Crew exhibited Professor Campbell's new map of the Nova's spectrum, and pointed out the chief nebular line.

In speaking of Mr. Barnard's observations of an extremely faint nebulosity now surrounding the Nova, Mr. Burnham expressed his perfect confidence in Mr. Barnard's ability as an observer by stating that he would rather trust Mr. Barnard's observations of a very difficult object than believe in the testimony of his own eye.

Professor George E. Hale, of the Kenwood Observatory described an automatic spectroheliograph recently devised by him. When once adjusted and set in operation the instrument will take photographs of the Sun showing spots, faculæ and prominences, at any desired interval throughout the day. It is expected that such an instrument will soon be in daily use at the Kenwood Observatory.

Professor Hale also presented some remarks on a recent communication by M. Deslandres to the Paris Academy of Sciences. In his paper M. Deslandres suggests a method for determining the velocity of the axial rotation of stars. The method depends upon M. Deslandres' statement that the solar faculæ are sometimes sufficiently bright to show the H and K lines reversed in the solar spectrum as photographed with an integrating spectroscope. Professor Hale criticised M. Deslandres' method, and proposed a means of testing its applicability which will shortly be presented to the Paris Academy of Sciences.

Dr. Crew remarked that he considered M. Deslandres' method disposed of by Professor Hale's criticism, and thought it hardly necessary that the test be applied.

Professor Hough made a few remarks on the present appearance of Jupiter and the Red Spot, which is now very faint, and may completely disappear. He considers it identical with the spot seen by Cassini to appear and reappear every six years.

The meeting then adjourned, and the remainder of the evening was spent by the members in observing Jupiter and other objects with the 18½ inch equatorial of Dearborn Observatory. GEORGE E. HALE, Recorder.

BOOK NOTICES.

Cosmical Evolution. A New Theory of the Mechanism of Nature. By Evan McLennon. Messrs. Donohue, Henneberry & Co., Publishers, Chicago. 1890. pp. 399.

This book offers a new system of cosmical evolution which embraces the entire range of natural phenomena, although only the elementary conceptions of it are yet published. The introduction contains a statement of various legends of creation and primitive ideas and the successive theories of astronomical science from the Ptolemaic system to the Nebular Hypothesis. The body of the work is divided into three parts: An introduction to the theory, objections to the theory and finally the new theory itself. In the first part, we find the essential principle of the new theory, the sole characteristic of it, stated in these words:—"*Every known heavenly body is connected with its neighboring heavenly bod-*

ies by means of real, material bonds, and that every phenomenon of the universe, without exception, is due solely to the action of bodies upon one another through, and by means of, these bonds that join them together." It is the purpose of the book to prove this proposition, or, at least, to make it more probable than existing theories incompatible with it. The idea of force as commonly used by physicists is abandoned, and all argument is made to turn on the "all-sufficiency of matter and motion," in one grand chain of causation. The gist of the theory, stripped of all verbage, is simply this: What are these "real, material bonds" that constitute the solid "connections" of the different parts of the universe? Physicists say the union is sustained by force, but no scholar attempts to give a complete definition of force, because no one knows what it is. Now, it seems to us that the new theory does not help us any in the place of real difficulty, for what are these "real, material bonds?" What has been added to our knowledge of cause or effect by this discussion? We are free to say that the author has, in the main, stated well real objections to existing theories, but, on the other hand, we fail to see how he has given aid at the point where it is needed. We have been interested in the range of fact presented, and often the good popular statement given to difficult and unsettled questions of science. The book is an honest attempt to do real service in studying hard and knotty problems in physical science.

Questions and Answers about Electricity. A First Book for Beginners. Edited by E. T. Bubier 2d. By D. Van Nostrand Co., New York, 1892. pp. 100. Price 50 cents.

This is a very suggestive little book in the form of questions and answers with illustrations of electrical instruments where needed to give more definite ideas of principles or methods in the science. The Van Nostrand Company is doing science excellent service in publishing so many good books in cheap monograph form.

PUBLISHER'S NOTICES.

The subscription price to ASTRONOMY AND ASTRO-PHYSICS in the United States and Canada is $4.00 per year, in advance. For foreign countries it is $4.40 per year which is the uniform price. Messrs. Wesley & Son, 28 Essex Street, Strand, London, are authorized to receive subscriptions. Payment should be made in postal notes or orders or bank drafts. Personal checks for subscribers in the United States may be used.

Currency should *always* be sent by registered letter.

Foreign post-office orders should *always* be drawn on the post-office in Northfield, Minnesota, U. S. A.

All communications pertaining to Astro-Physics or kindred branches of Physics should be sent to George E. Hale, Kenwood Observatory, of the University of Chicago, Chicago, Ill.

All matter or correspondence relating to General Astronomy, remittances, subscriptions and advertising should be sent to Wm. W. Payne, Publisher of ASTRONOMY AND ASTRO-PHYSICS, Goodsell Observatory of Carleton College, Northfield, Minn.

Manuscript for publication should be written on one side of the paper only and *special care should be taken to write proper names and all foreign names plainly*. All drawings for publication should be *smoothly* and *carefully* made, in *India ink* with lettering well done, because such figures are copied exactly by the process of engraving now used. If drawings are made about double the size intended for the printed page, better effect will be secured in engraving than if the copy is less in size. As a rule the publishers have had to re-draw the figures sent during the last year at considerable expense. We hope to avoid this in the future. It is requested that manuscript in French or German be type-written. If requested by the authors when articles are sent for publication, *twenty-five* reprint copies, in covers, will be furnished free of charge. A greater number of reprints of articles can be had if desired, at reasonable rates.

Rates for advertising and rates to news agents can be had on application to the publisher of this magazine.

Astronomy and Astro-Physics.

NEW SERIES No. 10. DECEMBER, 1892. WHOLE No. 110

GENERAL ASTRONOMY.

MARS.*

WILLIAM H. PICKERING.

Now that the opposition of 1892 has passed into history, it may be well to give a brief summary of the observations made at Arequipa this year, preparatory to a more complete publication elsewhere. With one exception, the planet has been observed every night continuously, from July 9 until September 24, when the lens of the telescope was reversed, for photographic work, and the regular observations came to an end. Since the beginning of the year Mr. Douglass and myself have made 373 drawings of different features of the planet, thirteen of them being colored. Numerous micrometric measurements of the equatorial, polar, and phase diameters have been made. A large number of measurements of the snow, and other observations for correcting the physical ephemeris of the planet have been collected. Ninety-two stations have been located upon the planet micrometrically, many of them having been observed upon several different dates. Besides these, measurements of the clouds, and the breadths of the lakes, canals, and minor features have been obtained. Considerable data has thus been collected at this opposition for future discussion.

Turning now to what we may call the definite conclusions to be derived from our observations, we may say:—

(1st). That the polar caps are clearly distinct in appearance from the cloud formations, and are not to be confounded with them.

(2d). That clouds undoubtedly exist upon the planet, differing however, in some respects from those upon the Earth, chiefly as regards their density and whiteness.

(3d). There are two permanently dark regions upon the planet, which under favorable circumstances appear blue, and are presumably due to water.

---

* Communicated by the author.

(4th). Certain other portions of the surface of the planet are undoubtedly subject to gradual changes of color, not to be explained by clouds.

(5th). Excepting the two very dark regions referred to above, all of the shaded regions upon the planet have at times a greenish tint. At other times they appear absolutely colorless. Clearly marked green regions are sometimes seen near the poles.

(6th). Numerous so-called canals exist upon the planet, substantially as drawn by Professor Schiaparelli. Some of them are only a few miles in breadth. No striking instances of duplication have been seen at this opposition.

(7th). Through the shaded regions run certain curved branching dark lines. They are too wide for rivers, but may indicate their courses.

(8th). Scattered over the surface of the planet, chiefly on the side opposite to the two seas, we have found a large number of minute black points. They occur almost without exception at the junctions of the canals with one another, and with the shaded portions of the planet. They range from thirty to one hundred miles in diameter, and in some cases are smaller than the canals in which they are situated. Over forty of them have been discovered, and for convenience we have termed them lakes.

No repetition of the phenomena connected with the melting snow, which occurred in July has been observed. The Y mark has assumed its customary appearance, so that the narrowing of the southern branch seems to have been a temporary phenomenon, and was probably due to clouds. The central branch is now continuously visible, but its southern extremity which connected it with the snow has disappeared. The southern branch of the Y also seems to be gradually fading out.

Clouds have on several occasions been observed to project beyond the terminator, and also beyond the limb, thus confirming the observations made at the Lick Observatory. The height of these clouds has been measured, and it appears that some of them attained an altitude of at least twenty miles,—a height considerably greater than that attained by terrestrial clouds. This is a result naturally to be expected from the small mass of the planet. No direct measures have been possible of the density of the atmosphere at the planet's surface, but indirect observations lead us to conclude that it is less than that at the surface of the Earth, but probably not as much as ten times less.

A curious feature of the observations has been the distinct flattening at the planet's poles, amounting to at least $\frac{1}{70}$. From theoretical considerations, unless we assume a rather improbable internal structure, it cannot exceed $\frac{1}{200}$, and that is approximately the figure which Professor Young derived from his measurements. Herschel made $\frac{1}{16}$, Arago $\frac{1}{30}$, and other observers have obtained various results, in general greater than ours. The above figure must not be considered by any means final, but merely as an approximate minimum, since our computations have not as yet been completed. That the flattening at opposition was considerable was very evident. As no such conspicuous discrepancies among different observers occur in the case of the other planets, I am inclined to think that the variations may be real, and due perhaps to an equatorial cloud formation. Clouds are certainly very frequent upon the sunrise terminator, particularly towards the equator. In any case this is an interesting matter for investigation at future oppositions.

As the snow in melting receded towards the pole, there was a narrow, nearly straight region upon which it lingered longer than elsewhere. At present the snow is divided into two sections one long and narrow, the other of irregular shape, and somewhat mottled. The appearance is such as might be produced by a mountain range and an area of irregular elevation, with a valley lying between them. It was from this supposed valley that the dark line issued in July connecting it with the Northern Sea.

Upon August 5, in the region just to the north of Solis Lacus, latitude — 20°, a small but conspicuous white spot appeared. It was conspicuous from being brighter than any other spot upon the planet save the southern snow cap, which it exactly resembled in color.

A similar but much smaller spot was also noticed further to the southwest. Both spots had disappeared by August 7, but careful measurements upon two nights, and several drawings, had already accurately located their positions. The larger of these spots measured about 60 miles in length by perhaps 40 in width, and was much brighter than any cloud that I have ever seen upon the planet. I am inclined to attribute both of these spots to snow. We have frequently seen small white points lying along the line which bounds the shaded regions upon the north. Early in August the whole northern sphere of the Equatorial Sea was bounded by a narrow white line, while later a similar line bounded the Northern Sea upon the west. These lines were apparently due to cloud, and were not as bright as the spots of snow referred to above. Although nearly a thousand miles long, they could hardly have exceeded thirty miles in breadth.

Although Mars has been nearer the Earth at this past opposition than it will be again for fifteen years, I am quite inclined to believe that it will be better seen in 1894 than it has been this year. My reasons for this statement are as follows:—In the first place, its distance from the Earth will not be very much greater than it has been this year, and indeed for part of the time it will be less remote than it was when many of our most interesting observations were secured. Secondly, it will be much farther north, where the great northern telescopes can be used upon it to much greater advantage. Thirdly, following the melting of the southern snow, the Arean atmosphere was filled with clouds, and these did not clear away satisfactorily until the very end of August, or long after the opposition was over. It was only after the clouds began to clear, that the Arean lakes, which have proved such an interesting feature of this opposition, began to show to their full advantage. Owing to the change of seasons upon Mars, little of this latter difficulty should be experienced at the next opposition, and it is thought that many lakes and other delicate features still remain undiscovered, which may reveal themselves at that time. Could the great 40-inch telescope of Southern California then be completed, undoubtedly the best views of the planet would be obtained at that point, but if it is not, the Lick telescope can certainly be used to greater advantage, and the Arequipa telescope to no less advantage, than was the case this year.

AREQUIPA, PERU, September 28, 1892.

SILVERING GLASS MIRRORS.

A. A. COMMON.

The importance of a good reflecting surface in such instruments as the modern silver-on-glass reflecting telescope and the equatorial coudé is obvious. As a rule the silver surface if fairly protected from dust and damp will last many years with but slight loss of light, but must be renewed frequently if the best results are to be obtained. Many different processes and methods of silvering have been from time to time published by different people, and it becomes of some interest to examine these with a view of finding out the particular one that suits certain cases.

Having used reflecting telescopes for many years I have had occasion to try a great number of experiments with a view of getting a good process. It would be tedious to give these in detail, but it may be useful to give some few instances where satisfactory results have been obtained.

The process of depositing the metallic silver on a glass surface is an empirical one; the conditions affecting the reactions are so various that hard-and-fast rules cannot be laid down. The temperature in which the process is carried on seems perhaps the most important thing to be considered, ranging as it may from 35° or 40° to 104° F. according to the reducing agent employed.

I have had occasion to look up the processes published from time to time; some of these are of sufficient interest to be given briefly.

Baron Liebig found in 1835 that on heating aldehyde with an ammoniacal solution of nitrate of silver in a glass vessel a brilliant deposit of metallic silver was deposited on the surface of the glass. To this observation is due the modern process of silvering glass.

The next important step seems to have been taken by Cimeg, who, in 1861, patented a process for silvering mirrors (where of course only the surface against the glass is used) by what has since been known as the Rochelle-salt process. This patent is No. 619, 1861. After cleaning the glass in the usual way he washes the surface with Rochelle-salt solution 1 in 200. For 1 sq. yard of glass he takes 20 grammes of nitrate of silver in solution and adding it to ammonia of commerce till a brown precipitate commences to be produced; to this is added a solution of 14 grammes of Rochelle salts. Using the mixture in this proportion when it becomes turbid he pours it over the glass plate, which has an inclination of 1 in 40, for 30 minutes at a temperature of 68°.

In 1862 Cimeg has another process patented (No. 2314). He uses 20 grammes of Rochelle salts in 300 grammes of water, 20 grammes of nitrate of silver in 15 grammes of water with ammonia to clear; but in place of using a weak solution of Rochelle salts on the surface of the glass before silvering he rubs on the juice of apples, currants, sorbs, or other berries before silvering.

In 1873 Woerther uses glucose as the reducing agent.

In 1876 Pratt patents a process (No. 1259) in which before silvering he treats the glass with 1 part of protochloride of tin in 100 parts water. For large plates he uses 1 part protochloride of tin, 3 drachms of oxalate of ammonia, ½ lb. putty powder, 4 pints distilled water; this is rubbed on and allowed to dry; he then uses a solution of 2 parts oxalate of ammonia, 4 parts grape-sugar, 1 part lime, 1 part potassic cyanide, in 1000 parts water. In silvering he uses tartaric acid, but does not give details.

There are a few more patents for silvering since the last date of no importance.

In 1881 Piazzi Smyth gives, in 'British Journal of Photography Almanac,' Martin's process in full. This is a pretty well-known process, and in some hands has worked very well. Many other processes, in which the chief variation is the reducing agent employed, have from time to time appeared in the various scientific journals—the most important being that published by Mr. J. A. Brashear in the 'English Mechanic,' vol. 31, p. 327. This is a most excellent process and for ordinary work, when the glass can be put in face downwards, the best I know. This I give further on as I use it.

In the 'Encyclopædia Britannica,' vol. 16, p. 500, two processes, hot and cold are given; these, though mainly relating to the silvering of ordinary looking-glasses, have a bearing on the process as used for silvering mirrors.

"In the former method there is employed a horizontal double-bottomed metallic table which is heated with steam from 35° to 40° C. The glass to be silvered is cleaned thoroughly with wet whiting, then washed with distilled water and prepared for the silver with a sensitizing solution of tin, which is well rinsed off before it is removed to the silvering table. The table being raised to the proper temperature the glass is laid and the silvering solution at once poured over it, before the heat of the table has time to dry any part of the surface of the glass. The solution used is prepared as follows:—In half a litre of distilled water 100 grammes of nitrate of silver are dissolved; to this is added of liquid ammonia (sp. gr. 0.880) 62 grammes; the mixture is filtered and made up to 8 litres with distilled water, and 7.5 grammes of tartaric acid dissolved in 30 grammes of water are mixed with the solution: about 2.5 litres are poured over the glass for each superficial metre to be silvered. The metal immediately begins to deposit on the glass, which is maintained at about 40° C. (104° F.), and in little more than half an hour a continuous coating of silver is formed. The surface of silver is then cleaned by very carefully wiping with a very soft chamois leather and treated a second time with a solution like the first, but containing a double quantity of tartaric acid. The solution is applied in two portions, and thereafter the glass is once more carefully cleaned of all unattached silver and refuse and removed to a side room for backing up."

"In silvering by the cold process advantage is taken of the power of inverted sugar to reduce the nitrate of silver. This process has been adopted for the silvering of mirrors of astronomical telescopes, notably of Leverrier's great telescope in the Paris Observatory. For ordinary mirror silvering the following is the process recommended by H. E. Benrath:—Two solutions are prepared the first of which contains the silver salt, the second the sugar preparation. For the silver solution 800 gammes of nitrate of silver and 1,200 grammes of nitrate of ammonium are dissolved in 10 litres of water and 1.3 kilos of pure caustic soda in 10 litres of water, and of each of these solutions 1 litre is added to 8 litres of water, which is allowed to rest till the sediment forms and then decanted. The second solution—inverted sugar—is prepared by dissolving 150 grammes of loaf-sugar with 15 grammes of vinegar in 0.5 litre of water, and boiling the solution for half an hour. After cooling it is made up with water to 4,200 cubic centimetres. The silvering is done on horizontal tables in a well-lighted and moderately heated apartment, and the glass is cleaned with scrupulous care. For each square centimetre of glass operated on 15 cubic centimetres of the silver solution above described are measured out, and from 7 to 10 per cent of the solution of inverted sugar is added, both being quickly stirred together and poured rapidly and evenly over the glass. The reduction immediately begins and the solution exhibits tints passing through rose, violet, and black, till in about seven minutes it again becomes transparent and the deposit of metal is complete. This first deposit is extremely thin and allows the transmission of bluish rays. The exhausted solution with floating and unattached dust-like particles of silver is carefully wiped off, the silvered surface washed with distilled water, and again treated with the mixed solutions to the extent of half the quantity used in the first application. The finished surface is wiped and washed in the most thorough manner—for the least trace of caustic soda left would destroy the mirror. The further processes are the same in both methods of silvering."

In Brashear's process, already mentioned, the most important thing is the sugar solution forming the reducing agent. This greatly improves by keeping—a solution that has been made some months being much more effective than a newly made one. I find it convenient to have always some Winchester quarts of it in stock ready for use. I have for convenience varied his proportions slightly and thus give them as I have found them work so well. For the sugar solution I add to a 10% solution of loaf-sugar, in distilled water, 10% of alcohol and ½% of nitric acid. Solutions of 10% of nitrate of silver and of caustic potash are separately prepared, the latter one as wanted. These, with sufficient ammonia and a very dilute solution of nitrate of silver, and also a similar very dilute one of ammonia, are prepared, the latter in order to obtain that pale brown color of the ammoniated solution of nitrate of silver that it is absolutely necessary to have before adding the reducing agent.

Having selected a suitable dish to contain the liquid, in which the mirror can be placed face downwards with about ½ or ¾ inch of liquid underneath, find on the basis of 1 of silver-nitrate solution to 4 of the total required liquid the amount of silver solution needed; to this add ammonia till the first formed precipitate is dissolved, then add one-half of this quantity of the potash solution (this is a variation from Mr. Brashear's formula that I have found works well), and again add ammonia till the mixed solution is quite clear, taking care to put in only sufficient ammonia for that purpose; then add the weak solution of nitrate of silver till a clear brown color is obtained; should this become a dark brown some of the weak solution of ammonia will bring it to a pale brown color, which must persist if the solution is left standing some time.

The mirror, previously cleaned with nitric acid and distilled water, and suspended in the dish in distilled water of sufficient amount to make up on the addition of the solutions the total liquid required, is lifted out and the prepared solutions mixed with the distilled water and an amount of the reducing solution equal to about one-half that of the nitrate of silver solution more or less as the temperature is under or over 60°; as soon as all is intimately mixed the mirror is immersed with one movement, beginning by dipping the edge first and lowering so as to prevent any air bubbles forming under the glass. In from three to five minutes the silver begins to form on the mirror, the solution changing from pink to dark brown and black, the film thickens quickly and in from twenty-five to thirty minutes sufficient silver is deposited. The mirror can then be washed and put to soak in distilled water for a few hours, then taken out and dried and polished in the usual way, that is with a soft pad of clean chamois, and going all over the mirror with light strokes till the bloom is all removed and a fair polish is obtained, finishing with a very little of the finest washed rouge, quite dry, lightly dusted on the pad; it is very important to well consolidate the film of silver by the unrouged pad before using any polishing powder.

It is a very good plan for any one who is not in the habit of silvering, or to whom the process is strange, to try the proportions of the solutions on some small pieces of glass till a satisfactory proportion for the temperature (for that is the chief factor in varying the amount of reducing solution necessary) of the room in which he is working. The most important thing (after the solutions) is the proper cleansing of the glass, for on the proper preparation of the surface of the glass a very great deal depends.

As already stated, this process is used when the glass to be silvered can be suspended in the liquid; it is not suitable when we attempt to silver surfaces face upwards. The mud formed settles down and prevents any proper deposition of silver; this was a source of considerable trouble when it was required to silver the three-foot mirror, and a pneumatic arrangement was eventually made to hold the mirror by the back, so that it could be silvered face downwards, and up to that size the silvering could be managed.

The great size of the five-foot mirror and its enormous weight (over half a ton without the cell) made it dangerous to suspend it, and the question of silvering became a serious one. In making experiments in order to get rid of the mud formed in the process last mentioned, it was found that by leaving out the potash the silver was deposited from a nearly clear liquid and no mud was formed and the first five-foot mirror was very successfully silvered in this manner. The solutions of silver and sugar are used in the same proportions without potash, but it is found advisible to use a stronger total mixture. For subsequent silvering of the five-foot mirror the Rochelle-salt process has been used, and this for the deposition of the silver on a surface face up seems to be the best, using, if necessary, two or more applications.

In preparing a large mirror for silvering in this manner it is necessary to form it into a dish by using a band of paraffined brown paper round the edge, standing up an inch or more all round, and mounting the mirror on a swinging support, so that it can be tipped up to throw off the water or spent solutions; in the case of the five-foot mirror, when mounted on the machine this tipping up could be done by the same arrangement used for placing the mirror vertical for testing.

The proportions of solutions used for the five-foot were for each application; 3000 cubic centimetres of silver solution as before ammoniated as already described, and 500 c. c. of Rochelle-salt solution, with about 29,000 c. c. of distilled water; this remained on the mirror 28 minutes; another simllar application was left on for 30 minutes; after thorough washing, distilled water was left on for some hours and the film dried and polished.

A very fine film of silver was deposited on a five-foot mirror, using one application only of 4,000 c. c. of silver solution and 750 c. c. of Rochelle-salt solution; this after one year was found to be in a very good state indeed; this was on the first mirror which, from some defect in the glass, could not be made into a good mirror. The disk of glass was returned to the makers to be replaced by another. I took this opportunity of removing and collecting the whole of the silver by dissolving it in nitric acid. The assay of the deposit gave a total weight of 26.5 grains of silver on a surface of 2,800 square inches, equal to a thickness of $\frac{1}{280000}$ inch, almost exactly; in actual weight somewhat between that of a threepenny and a fourpenny piece, not a large amount of the 400 grammes of nitrate of silver used in depositing the film. The actual waste need not be very much, as the chloride of silver can be easily deposited by the addition of common salt to the spent solutions and the silver thus recovered.

It will be seen that the various processes all have the ammoniated solution of nitrate of silver, and differ only in the reducing agent. The preparation of this solution, in order to get the pale brown color already spoken of, demands some care. If the solution is too strong, on the addition of ammonia a very flocculent deposit is formed, difficult of redissolution. If after the solution is cleared by the addition of ammonia a strong solution of silver nitrate is added to get this color, this flocculent deposit occurs; but if the weak solution advised be used, there is not any difficulty in getting the proper color free from any deposit. This is important. A word of caution may not be out of place concerning the production sometimes of a fulminate of silver, recognized by its dark grey metallic lustre. This is extremely liable to explode with great violence on the contact of almost anything; a few drops of water once sufficed to explode some in a beaker and blow it to fragments. By using moderately diluted solutions this danger is obviated. My own experience is not singular in this respect, for Mr. Brashear relates a similar occurrence.

The silver film is not always of the same quality, and experiments are needed to get more information as to what determines the greater density and coherence of some films over others. I have had surfaces of glass silvered experimentally where the film would not wash off with any amount of wet rubbing, these mostly on surfaces that had been silvered many times. Probably the glass in this case was in the best state to receive the new deposit; certainly the condition of the surface does affect the coherence of the silver as well as the amount of the deposit, as judged by the way in which certain parts on a mirror that has been incompletely cleaned show that the deposition has begun long before other parts, necessarily resulting in an unequal thickness of film. With the most careful cleaning of a mirror I have often found that the first application did not succeed, but the second on the surface just cleaned off with nitric acid was all right. The nature of the liquid other than distilled water last in contact with the surface of the mirror seems to be the determining thing. —*Observatory*, October, 1892.

REQUEST FOR OBSERVATIONS OF NIGHT CLOUDS.*

W. FOERSTER AND O. JESSE.

Since the year 1885 a very remarkable phenomenon has been noticed in the sky in our latitude, which is of a nature to greatly excite the interest of astronomers and geophysicists. The essential substance of what has been learned so far through observations regarding the phenomenon of the so-called *luminous night-clouds* is in brief the following:

For the latitude of Berlin the phenomenon is visible only during a comparatively short portion of the year, namely from the 23d of May until the 11th of August. While in the first years it was seen quite frequently, and before midnight, during the last four years, it has appeared in nearly every instance after midnight only. The phenomenon shows itself in the form of cirrus-clouds which stand out bright against the twilight sky. This especially distinguishes them from the ordinary cirrus-clouds which with the depression of the Sun at which the luminous clouds are seen at present, appear dark on the light twilight sky. The color of the phenomenon is generally a bluish white which becomes yellowish and reddish in the close proximity of the horizon.

Frequent photographs which have been taken simultaneously at various points in the neighborhood of Berlin, show that the altitude of the luminous clouds, is constant and exceedingly great, namely equal to 82 kilometres. In consequence of this great altitude they receive light from the Sun when it is *below* the horizon, which makes them appear light on the twilight sky. They are visible only so long as the Sun shines on them; as soon

---

* Communicated by the authors. Scientific Journals are asked to give notices of this article.

as the shadow of the Earth passes over them, they become invisible. As a rule they commence in the morning shortly before the twilight begins, and they disappear as soon as the Sun is less than 8° to 10° below the horizon.

Of late years these clouds have been seldom seen. Within the period above stated, they have occured only about ten times, while in the first year they were quite frequent. Their appearance is subject to great changes. While they frequently consist of only a few little luminous streaks or patches, at times they appear of greater extent and with a more intense light. Especially in the last days of the period from the 2d until the 6th of August their light seems to be considerable in our latitudes. They are generally observed in the vicinity of the horizon, and over that part below which the Sun is.

Judging from the frequent observations regarding the movements of the phenomenon, which after midnight, are always from the direction NE ± 40°, it is most probable *that the movements are caused principally by a resisting medium of the inter-planetary space.* In accordance with this is the fact that in the half year after its appearance in this country the phenomenon has been observed repeatedly in the southern latitude of 53°, viz., by the meteorological observer Mr. Stubenrauch in Gunta Armas as well as several times by ship captains.

Other observations also confirm the assumption of such an annual movement, for instance at Grahamtown in 33° south latitude the phenomenon was observed on the 27th of October 1890,* and at Haverford in 40° north latitude, according to written information, it was observed on the 17th of May 1892. These times are so related that from them in connection with the time of the appearance in this country, the conclusion may be directly drawn that there is a movement of the phenomenon from north to south and back.

The luminous night clouds decrease year after year in respect to the frequency of their appearance as well as to their extent and to their intensity of light. Although, according to this, the phenomenon will have entirely disappeared within a few years, it seems, that during the next year observations will still be possible, which may give us information regarding several questions of extraordinary importance.

For this, measurements, especially of the apparent altitude of the upper limits of the luminous clouds, mainly at the time in which the upper limit of the twilight segment has the compara-

---

* Compare *Astron. Nach.* No. 3008.

tively small altitude of say 1° to 10°, would be of great value. The measurements will serve to decide the question whether the altitude of the clouds varies in different geographical latitudes; providing that the estimates always refer to points which lie within the upper limits of the clouds, produced by the shadow of the Earth.

Since the last year the whole of the twilight segment is comparatively seldom filled out by the luminous night clouds, and it may therefore frequently be doubtful whether the highest point of the phenomenon really lies at the limit of the Earth's shadow. In order, therefore, to make sure that the measurements will answer the said purpose, it is necessary to repeat them as often as possible at intervals of a few minutes. In the evening, besides this, this limit is generally found by the fact that within it parts of the phenomenon disappear from above, while towards morning new parts always become visible at this limit as it moves upwards. The distance of the zeniths from the upper limit of the luminous clouds in the vertical of the Sun, for the latitude of Berlin, presuming that the phenomenon now stretches over the whole of the twilight segment, may be seen from the following statement:

Depression of the Sun Below the Horizon.	Zenith Distance of the uppermost Limit.
°	°
12.0	80
12.5	83
13.0	85
13.5	86
14.0	87

Moreover, as by means of a telescope the upper limit of the phenomenon is generally seen a little higher than with the naked eye, the more so the stronger light gathering power of the telescope is, it is desirable that the telescope should always be adjusted to the limit line seen with the naked eye. A comparison of the appearance seen with the naked eye, and the one seen in the telescope, will help in easily finding the line corresponding with the one seen with the naked eye. The exactitude of these measurements must be within about 3′ to 6′ in azimuth and altitude, while the time should be exact within 2 to 4 seconds.

The employment of photographic apparatus is of advantage for the indication of the place as well as of the movements of the phenomenon. But only such apparatus is suitable of which the proportion of the diameter of the aperture to the focal distance is at least 1 : 4 or greater. If the proportion were smaller, the duration of exposure would have to be too long, and consequently, on account of the rapid changes of the phenomenon, the details would be lost. With an apparatus of which the proportion of the aperture to focal distance is 1 : 3, the duration of exposure for the various depressions of the Sun below the horizon, under the condition that the phenomenon is bright in some degree, is as follows:

Depression of the Sun Below the Horizon.	Duration of Exposure.
°	s
9	16
10	21
11	27
12	35
13	48
14	72
15	122

Generally at the same time stars become visible on the photographic plate, through which together with the time of exposure, the direction of adjustment of the apparatus is ascertained; (that is to say: the position of the axis of the apparatus is ascertained).

With regard to the equator region, it is of great value to carefully observe the time when the luminous night-clouds pass through these regions. According to the observations made up to the present, the passage across the equator may take place between the beginning of September and the end of October, and the return, between the beginning of March and the end of April. In 20° south latitude the passage will take place from the middle of September to the middle of November, and from the middle of February to the middle of April, and in 20° north latitude, from about the middle of March to the middle of May, and from the middle of August to the middle of October. Besides, in consequence of the daily rotation of the Earth on its axis, together with the distinct movements of the Earth's atmosphere, it may be, that the passage across the equator does not take place in the simple manner here described. It does not seem to be unlikely, that the periods are not limited as exactly as stated.

Moreover, it is probable that the luminous night-clouds consist of a kind of gas, which is condensed in consequence of the lower temperature prevailing at the altitude of 82 kilometres. Upon the question regarding the kind of this gas, several other cosmical questions depend; for instance, with respect to the temperature of the air of the inter-planetary space, and the temperature of the atmosphere in the altitude of 82 kilometres, which will be answered through comparing experiments in the laboratory. For this purpose, photographs of the spectrum of sunlight at low altitudes of the Sun, in the season in which the phenomenon of the luminous night-clouds is seen, are of great value. Such spectrum photographs should be taken in the evening, shortly before sunset, and in the morning, shortly after sunrise.

It appears, that in the northern regions of the Earth, at about 70° latititude, during the period from the middle of June, until the middle of July, an extra great accumulation of clouds takes place, which, however, because of the Sun, is constantly *above* the horizon during this time, will be hardly visible. It will therefore be of special advantage, for this region, to take spectrum photographs of sunlight at low altitudes.

The above short remarks, regarding the importance of the phenomenon, in relation to cosmical problems, will show sufficiently, that the observations necessary for the investigation of the same essentially belong in the sphere of work of astronomers and geophysicists. There can be no doubt, that the observations necessary for the solution of these problems, far exceed the province of a single institution. The request is therefore issued to all those observers who take interest in the furtherance of the questions indicated, to assist through one or the other kinds of observation indicated above, in the investigation of the luminous night-clouds.*

ROYAL OBSERVATORY, Berlin, September, 1892.

THE TOTAL ECLIPSE OF THE SUN, 1893.

JOHN KING.†

As I have been asked by some astronomers to give a description of the general appearance and climate of this part of Chile, in which a total eclipse of the sun occurs next year, I have drawn up for publication the following account:—

The eclipse takes place on April 16, 1893, at about 8.15 A. M., Chile local time, and will be seen to the greatest advantage in this part of the Province of Atacama.

At the sea coast the central line of total eclipse passes close to Chañaral 29° S. L. This is not the better known Chañaral, north of Caldera, but a small place equidistant from Coquimbo

---

* A publication "Die leuchtendem Nachtwolken" by O. Jesse, which may be expected within the next month, will contain details in full regarding the present state of this problem.

† British Vice Consul, Carrizal Bajo, and engineer of the Carrizal and Cerro Blanco railway.

and Carrizal Bajo. The southern limit of total eclipse is 29° 50′ S. L. just north of Coquimbo, and the northern limit 28° 10′, just south of Carrizal Bajo.

The band of total phase stretches between these two limits in a north-easterly direction, across the country, from the coast towards the rising sun. Along the central line of this band the sun will be hidden by the moon for nearly three minutes. The eclipse will be total everywhere within the limits given above, but the total phase will be shorter and shorter the nearer those limits are approached, and outside of them the eclipse will be partial.

On the accompanying map of the Carrizal and Cerro Blanco and Copiapo Railway systems I have marked the northern and southern limits, and the central line of totality.

It will be seen that the port of Carrizal Bajo, 28° 4′ S. L., is just outside the total band, but the railway connecting it with Yerba Buena intersects the central line of total eclipse 70 miles inland, and a branch to Merceditas, 60 miles inland, at an altitude sufficiently high to be above the damp and hazy atmosphere of the coast. At the points of intersection the climate is simply perfect for astronomical observations, and is also, during the month of April, delightful to live in.

The accompanying form was filled up, in compliance with a request from Amherst College Observatory, to show the cloud conditions in the inland region during the month of April this year as an indication of what might be expected during the same month next year.

I had two series of observations made, one at Mina Bronces by Mr. Martin, chemist to the works (the results of which are hereto appended), the other at Cerro Blanco by Señor Miranda, at his mine. Both reports are in every respect alike. The 10th and 27th were cloudy, all the other days absolutely clear. As the two stations are some twenty-five miles apart, these reports show that there is no local weather, and that it is only when a general atmospheric disturbance, originating in the Cordillera de los Andes, occurs that the weather is affected at these high stations.

It will be seen that there was only one day—the 27th—out of twenty-one days of observation on which the sun was not visible at eight o'clock in the morning, for on the other cloudy day—the 10th—the sun was bright at intervals.

Cloud Observations at "Mina Bronces," Chile, 1892.

Day.	Local time.			Remarks.
	7:45 A. M.	8:15 A. M.	8:45 A. M.	
April 10	2	2	2	Clouds were light, allowing a slight shadow to be cast. Bright Sun at intervals.
" 11	2	0	0	Clouds were on the horizon, so that the Sun rose above them at 8 o'clock.
" 12	0	0	0	Perfectly clear sky.
" 13	0	0	0	Perfectly clear sky. Sun rose at 6:22 A. M.
" 14	0	0	0	Sun rose at 6:22 A. M.
" 15	0	0	0	Fresh wind. Sun rose at 6:23 A. M.
" 16	0	0	0	Sun rose at 6:24 A. M.
" 17	0	0	0	
" 18	0	0	0	Slight haze at sunrise. Sun rose at 6:25 A. M.
" 19	2	0	0	Bank of clouds near north-east horizon, which the Sun rose above at 8.05.
" 20	0	0	0	Sun rose at 6:26 A. M.
" 21	0	0	0	" " 6:27 "
" 22	0	0	0	" " 6:28 " Strong wind.
" 23	0	0	0	" " 6:29 " " "
" 24	0	0	0	
" 25	0	0	0	
" 26	0	0	0	
" 27	4	3	3	Haze thick at 8:15 A. M., but light at 8:45 A. M.
" 28	0	0	0	Sky got cloudy at midday.
" 29	0	0	0	
" 30	0	0	0	

KEY.

0 = "Sun entirely clear from clouds."
1 = "Clouds generally scattered."
2 = "Clouds massed about the Sun."
3 = "Sun in haze or fog.
4 = "Sun invisible in thick clouds."

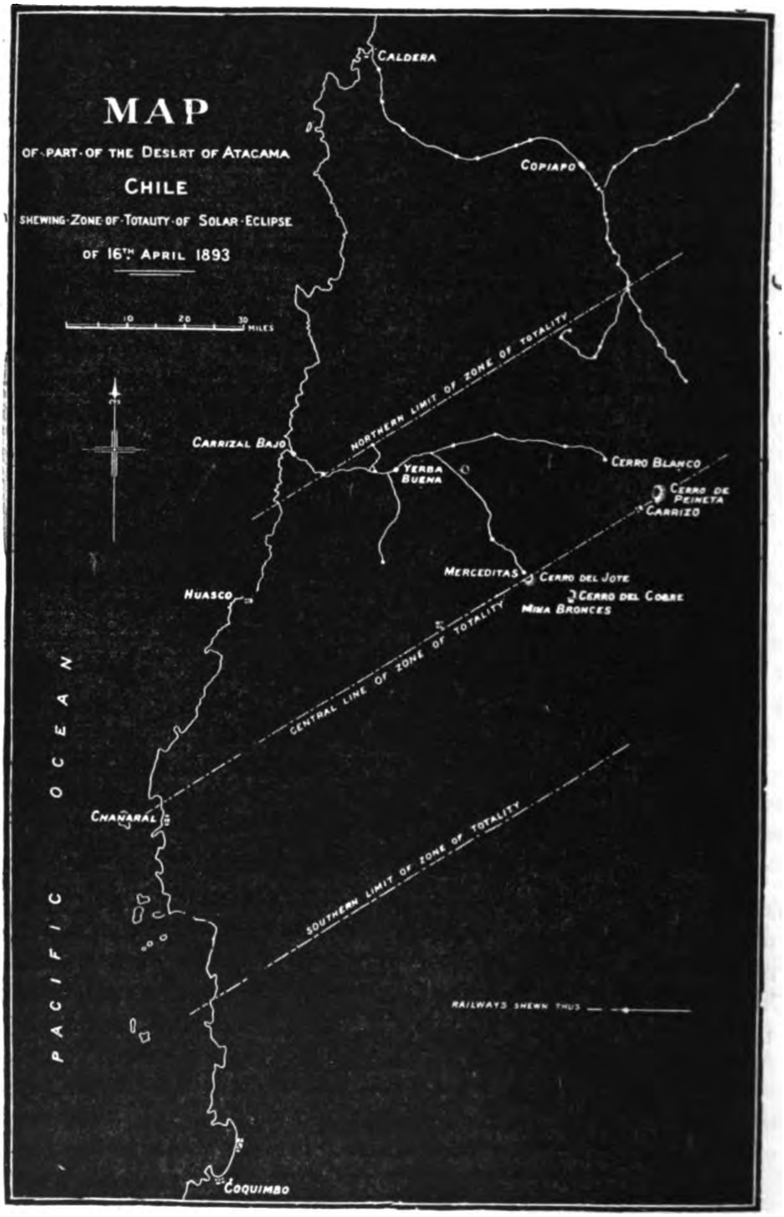
Observatory Stations.

I have marked on the map, along the central line of totality, several stations that I think suitable for observatories; the positions are only approximately correct, for I have no means of determining them accurately, but the errors, if any, cannot be great.

Undernoted are heights above sea level of some places shown on the map:—

Yerba Buena railway terminus	3,867 feet
Cerro Blanco, north hill	10,000 "
" south, Peineta	8,000 "
Carrizo, in the valley, a small farm	5,000 "
Merceditas railway station	2,900 "
Cerro del Jote	6,000 "
Cerro del Cobre	8,000 "
Lay observatory	4,000 "

Cerro de Peineta is part of Cerro Blanco; this Cerro Blanco is not part of the Andes, but a detached hill with low ground all


MAP
OF PART OF THE DESERT OF ATACAMA
CHILE
SHEWING ZONE OF TOTALITY OF SOLAR ECLIPSE
OF 16TH APRIL 1893
10
20
30
MILES
CALDERA
COPIAPO
NORTHERN LIMIT OF ZONE OF TOTALITY
CARRIZAL BAJO
YERBA BUENA
CERRO BLANCO
CERRO DE PEINETA
CARRIZO
MERCEDITAS
CERRO DEL JOTE
CERRO DEL COBRE
MINA BRONCES
HUASCO
CENTRAL LINE OF ZONE OF TOTALITY
PACIFIC OCEAN
CHAÑARAL
SOUTHERN LIMIT OF ZONE OF TOTALITY
RAILWAYS SHEWN THUS
COQUIMBO

round, and a clear view to the north-east. It is easily ascended by pack-mules.

Carrizo is not a hill, but a small farm or large garden, irrigated by a mountain stream. The advantages of this station are: nearness to the railway, a good road, and plenty of small hills of easy ascent to select from.

Cerro del Cobre is a good hill, but probably too far south. However, there are hills all the way from Merceditas that might be selected (see Mr. Martin's letter).

Serra del Jote, near Merceditas, is accessible to pack-mules half-way up, higher than which it would not be necessary to go. Moreover, it is said that the rest of the ascent is difficult. The three hills, Cerro de Peineta, Cerro del Cobre, and Cerro del Jote, can all be seen from one another.

Lay Observatory. On April 15 I went to Merceditas and stayed overnight, as I wished to find near the railway station a hill on which the sun shone at an early hour on the morning of the 16th, through some opening among the surrounding hills, and which would be suitable for ordinary lay observers who had no expensive apparatus, but who wished to see the eclipse well through a smoked or colored glass. To the south of the railway station I found a range of hills eminently suited to the purpose; at a height of 4000 feet above the sea the sun shone over a dent in the Jote at 6.40 A. M. The hill is much higher than 4000 feet, but I did not go higher. This is an excellent, well-sheltered spot, and would do well as a station for professional astronomers. I went up on horseback in forty minutes, but the ascent, from the railway station, could be easily made on foot in an hour. As I could not find any local name for this hill, I called it the Lay Observatory.

Climate.—At two o'clock in the afternoon of April 15 the temperature at Merceditas was 78° F.; this was the hottest time of the day, and it was a warmer day than usual, and at 8 P. M. the temperature was 62° F. Next morning, the 16th, I got up at two o'clock to see the comet then visible, and found the temperature was 58°; at 5 A. M. it was 56°.

Everywhere on the coast of Chile, north of Coquimbo, the sun, in the morning, is almost always obscured by a thick haze which makes the sky of a dull lead color. This haze is sometimes driven away by the sun during the forenoon, but just as often it remains all day, especially during the months of March, April and May.

The hazy morning atmosphere extends inland for a distance of about forty miles, and up to an elevation above the sea of about 2,500 feet; beyond this distance and height the sky is almost always clear and the air dry. Standing in the early morning, on a mountain of 3,000 to 4,000 feet or higher, you looked down on a great white sea of mist covered with whiter ridges like motionless waves, and studded here and there with islands which are the mountain tops piercing through. This haze is usually gone by nine o'clock, except within about five miles of the sea.

Accommodation on the Hills.—Tents can be quickly and cheaply made with the "esteros de totora," that is, mats made of reeds. All the more temporary houses of miners and prospectors and of railway track repairers are made of these mats which are seven feet square, and may be rolled up and carried from place to place. They form an article of commerce, and cost eighteen pence each, or from eighty to ninety cents of Chile paper currency. During the month of April and part of May it is quite safe to trust to this kind of tent, but not later than the middle of May, for rain or snow sometimes falls in the end of that month.

There are no venomous reptiles in Chile, nor are there mosquitoes on these hills, and fleas cannot live at an altitude of 4,000 feet—no slight advantage.

Rain.—On the Chilian side of the Andes, in the province of Atacama, rain generally falls twice in the year: the first rain is expected in June, the next in July, each rain usually lasting two days, and always accompanied with wind from the north. As soon as the wind changes to its prevailing quarter, the south, there is beautifully clear but cold weather. From two to three inches of rain fall in the year, but sometimes less than one inch. On Cerro Blanco it usually freezes every night from July till the end of August, and some snow lies on the mountain till September. On the hillsides there are plenty of bushes and small trees for firewood, and excellent water is found in all the higher valleys.

I have heard one objection to this district for observing the eclipse, which is that as the eclipse takes place in the morning, and the sun is not high in the sky, it would be better to go farther east. This objection has no weight, on account of the extreme dryness of the atmosphere. At the mines on Cerro Blanco and the other hills everything gets dried up; Huasco raisins grow hard and rattle on one's plate like nuts; agricultural produce, such as wheat, beans and barley, brought from Southern Chile as food for man and beast at the mines, loses two per cent of its weight every month for several months, office ink bottles have to be kept tightly corked or the ink very soon dries up, chairs and tables fall to pieces, veneer peels off, and a piano soon loses its tone. The sky is dark blue, and the sun rises white and dazzling without a trace of any other color. The hills, the rocks, and the bushes cast dark shadows, and even every pebble the size of a hazel nut casts its shadow, so that in the early morning the gravelly ground seems half wetted with a shower; one side of every pebble is in bright light, the opposite in deep shadow.

Although the eclipse would be the object of greatest interest to visitors, a few weeks might be profitably spent among the copper mines, and if any one wished to become a mine owner, plenty of mines are to be had for the asking. All the mines belong to the State. You have only to take up a mine, pay a nominal license to the government annually, and the mine is yours as long as you pay the license. There are no royalties, no surface rents and no export duties. The next thing to do is to make the mine pay, and this is sometimes done.

There is no sport in April, but after snow falls on the Cordillera, huanacos and immense flights of turtle-doves come down to feed on the lower slopes. Life, however, is never wanting. The region from Cerro Blanco southward as far as Coquimbo is the home of the fur chinchilla. It feeds on the nut of the carbon tree, *Cordia decandra* (Hook. et Arn.), and on the pea of the algarrobillo, *Balsamocarpon brevifolium* (Clos.). This bush which produces the tannin pod of commerce, thrives best far inland, on sunny, almost rainless slopes, but it must have one shower in June or July, otherwise it bears no fruit. If there be no rain for three or four years—as sometimes happens—the bushes do not die—they just wait. The same thing happens with all the other bushes; sometimes for several successive years, they are without leaves, and though the soil seems as dry as dust, whenever rain comes they show themselves full of life.

British astronomers—professional and amateur—ought not to lose the opportunity of observing under such favorable circumstances this great eclipse. I doubt if better conditions were ever offered before. The distance to come is long, but the expense is not very great, and can be exactly counted beforehand. An expedition might leave Liverpool in February by Straits of Magellan steamer, and be home again in June. Or, after the eclipse go by steamer to San Francisco or Vancouver, and thence by rail to the World's Fair at Chicago, and instead of encountering hardship and danger in some unhealthy climate, have a pleasant trip all the way.

Though horses and mules can be got here everyone should bring a saddle and bridle.

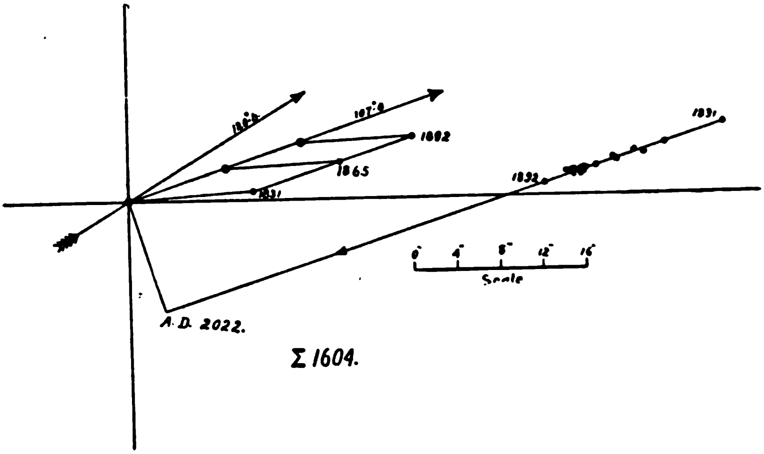
In conclusion I would impress on the members of every expedition that may come out, the importance of selecting as observing stations, places at a distance of at least 60 or 70 miles from the sea. On the other hand, the advantages of going further inland are doubtful, and as the railways go no farther, traveling would be more difficult.

Carrizal Bajo, Province of Atacama, Chile, May, 1892.

ON PROPER MOTION OF Σ 1604.

S. W. BURNHAM.

This is one of the wide triples of Struve's Catalogue. The more distant of the two companions is now much nearer the primary than it was at the time of the first measures by Struve; while the change in the other has been very small. It is well known that the apparent motion of C is rectilinear, and due to the proper motion of A. The other companion has practically the same proper motion as A, the entire change of distance in sixty years being but little more than 1″. The proper motion of the principal star as given by Stumpe is 0″.354 in the direction of 120°.6. This is probably based upon meridian observations. The micrometer measures of C give a somewhat different result.



Σ 1604.

It might be said that C may have some proper motion of its own, and that therefore the other value is not necessarily in error. While this may be the fact, it seems impropable for the reason that the difference between the two values is not a large error in meridian positions of stars to which attention has not been specially directed. The measures of C, assuming that star to be fixed, give an annual proper motion for A of 0″.289 in the direction of 107°.8. If, however, the other value given for the movement of this star is correct, then C has a motion of its own of about 0″.1 per year in the direction of 160°. This question can be best settled by connecting A with some other star.

The following is a complete list of the measures of both companions, including my recent observations with the 12-inch refractor at Mt. Hamilton:

A and B.

	°	″		
1831.95	93.3	11.98	Struve	3n
1835.40	89.9	12 ±	Herschel II	1n
1844.34	94.8	11.01	Madler	1n
1856.40	92.8	11.75	Secchi	1n
1863.31	94.6	11.38	Hall	1n
1865.63	92.5	11.21	Dembouski	7n
1869.85	91.6	11.37	Duner	2n
1877.40	91.5	11.60	Flammarion	1n
1879.33	91.1	11.32	Burnham	1n
1879.35	89.7	11.46	Cincinnati	1n
1880.30	91.1	11.44	Pritchett	2n
1881.36	90.7	11.20	Bigourdan	1n
1883.15	91.8	11.13	Englemann	6n
1884.58	91.4	11.40	Wilson	2n
1890.35	90.3	10.37	Glasenapp	2n
1892.37	91.5	10.70	Burnham	3n

A and C.

	°	″		
1831.95	96.9	58.00	Struve	3n
1835.40	93.0	60 ±	Herschel II	1n
1856.40	95.2	50.38	Secchi	1n
1863.31	94.6	48.51	Hall	1n
1864.70	94.8	47.68	Dembouski	6n
1869.85	94.0	45.96	Duner	2n
1871.17	94.1	45.64	Dembouski	1n
1877.37	93.5	43.95	Schiaparelli	2n
1877.40	93.1	41.92	Flammarion	1n
1879.33	93.3	42.92	Burnham	1n
1879.33	93.1	43 21	Schiaparelli	1n
1879.35	93.5	43.97	Cincinnati	1n
1880.30	92.9	42.62	Pritchett	2n
1881.34	92.7	42.68	Schiaparelli	1n
1881.36	92.9	42.88	Bigourdan	1n
1882.38	93.2	42.06	Schiaparelli	1n
1883.37	93.1	41.69	Schiaparelli	1n
1883.53	92.6	41.85	Engelmann	5n
1884.37	93.0	41.53	Schiaparelli	5n
1884.58	92.3	42.00	Wilson	3n
1885.40	93.0	41.27	Schiaparelli	1n
1890.35	91.9	39.23	Glasenapp	2n
1892.37	91.9	39.19	Burnham	3n

The magnitudes of A, B and C in Struve are respectively 6.5, 9.0 and 7.8. The principal star is Virginis 59 (= Lalande 22798), and the bright companion to Lalande 22803. The three stars are found in the Argentine General Catalogue, the magnitudes being 7, 8½ and 8. Herschel called B "very ruddy." The nearest approach of C will be about the year 2022, when its distance from A will be about the same as the present distance of B.

CHICAGO, Nov. 10, 1892.

A FREE ESCAPEMENT WITH A PERFECTLY INDEPENDENT BALANCE OR PENDULUM.*

D. APPEL, CLEVELAND, O.

In the early part of the year 1884, while occupied with a study on free escapements, I was on March 10 of the same year led to the discovery of a new principle for a free escapement with a perfectly independent balance or pendulum with unlimited oscillations.

In common practice the transmission of power to the balance is effected directly through the escapement, whereas in the new principle the balance derives its impulse through the hair spring. This is accomplished by having the free end of the hair spring arranged to be movable. The performance of the wheel train consists in moving to and fro, at the proper moment, the free end of the hair spring at each vibration of the balance. This may be done in several ways according to the application of the escapement to chronometers, pendulum clocks or watches, or to instruments which require to be driven with precision under variable resistance, such as a heliostat or, as in the present case, to a small equatorial in which the new escapement is subject to the most severe test. For the latter purpose the new escapement is so constructed that it will easily control a considerable surplus of power without affecting its function as an excellent time-piece. This has been successfully demonstrated on a 4-inch equatorial of Warner & Swasey in June, 1890, with the partially illustrated driving clock provided with the new escapement regulated to sidereal time.

During the trial of the new escapement the 4-inch telescope, an equatorial star near the meridian could be carried bisected by the vertical wire for some time with a hardly perceptible variation of light on either side of the wire. These tests I repeated on several evenings in June, 1890, with the same results.

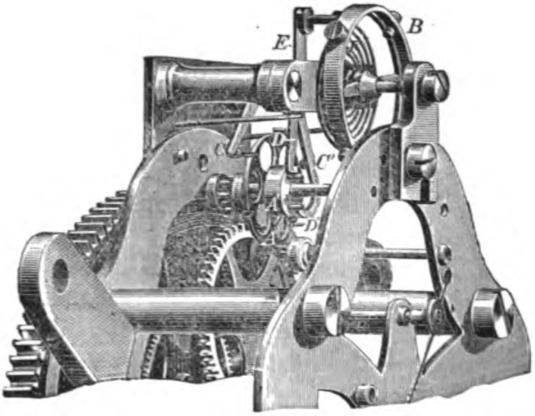
The driving clock, connected to the lower end of the polar axis, has been an ordinary eight-day Seth Thomas lever clock, the

---

* Communicated by the author.

wheel train of which was modified for an increase of power, and a wheel of forty-eight teeth was added to correct the error effected through the new escape wheel having only six instead of fifteen teeth.

The escapement shown in the illustration is constructed after one of my models of 1887 in which the escape wheel consists of a large locking wheel, A, with 6 teeth (3 on each side), and a small lifting pinion, A′, with 3 teeth, of which only 2 can be seen in the cut. The axis of the anchor (not visible) which may be considered a continuation of the balance axis, carries two rigidly connected anchors of which CC′ effects the unlocking of the wheel A, while the other anchor, DD′ during the rotation of the escapewheel through the lifting pinion, A′, increases the tension of the hairspring, the free end of which is fastened to an extension, E, of the lifting anchor, DD′.



The illustration shows the escapement at the moment in which the balance B moves in the direction of a clock hand, having just passed her rest position, the increasing tension of the hair spring F effects a moment later the release of the locking wheel A, through the anchor arm C, at this moment the longer arm D′ of the lifting anchor is moved to the right by the lower pin of the lifting pinion A′ through the rotation of the escape wheel, increasing the tension of the hairspring. Meanwhile the balance completes her motion, and effects after passing her resting point in an opposite direction, in the same way, the releasing of the locking wheel A through the partially shown anchor arm C′ and causes the upper pin of the lifting pinion A′ to move the shorter anchor arm D to the left. The escapement is now again in the position shown in the illustration, and as soon as the balance returns from her journey to the left, and has passed her point of rest, we have again arrived at our starting point. The same performance repeats itself at each double oscillation, without the balance being influenced by the wheel train or disturbed by the escapement during her oscillations.

THE PROPER MOTION OF THE STARS.*

W. H. S. MONCK.

In comparing the proper motions of different stars it occurred to me that it would be desirable to refer them to a common standard. When the magnitude of the star had been ascertained photometrically this was easily done on the assumption that no light is lost in transmission. The proper motion being expressed in seconds (of an arc) by multiplying it by the number whose logarithm is one-fifth of the magnitude on the photometric scale, we obtain in all instances what the motion would be if the star was brought near enough to us to appear as one magnitude brighter than the first (or of magnitude 0 on the photometric scale). I compared Herz and Strobl's revision of Auwers' Catalogue with the Harvard Photometry for this purpose and obtained the photometric magnitudes and proper motions of nearly 600 stars. The proper motions in right ascension, however, were given in seconds of time and it would have taken some labor to reduce them to seconds of an arc; and as my object was to deal with classes of stars I thought it sufficient to compare the motions in N.P.D., believing that the averages were likely to be the same in right ascension as in declination. I further extracted from the *Draper Catalogue* the spectra of all the stars which I was able to identify. In a few cases my identifications are doubtful. In many others the spectrum is marked as doubtful in the *Draper Catalogue.* I thought it best to follow its classification without regarding the notes of interrogation. The first step was to ascertain the average proper motion of the 600 stars when referred to the standard in question. Here I found that in taking an arithmetical mean the result would be much influenced by a few stars with great proper motion. Thus 61 Cygni had on my scale a proper motion of 34 seconds annually in N.P.D. which when distributed among 600 stars would raise the general average by about 0″.060. Instead of an arithmetical mean I therefore thought it better to ascertain the point at which the stars with greater and less proper motion would be equal in number, and I found that for the entire number of the stars examined the average thus obtained was about 0″.225 annually. I may here remark that supposing the average velocity of a star towards or from the north pole to be 10 miles per second (being the average velocity in the line of sight according to Vogel) the average parallax of these 600 stars, if brought near enough to us to appear one magnitude brighter than the first, would be only about 0″.067. The arithmetical mean would be considerably greater than 0″.225, but I did not think it necessary to determine it precisely.

When, however, I examined the means for stars of different magnitudes the results were remarkable. Of 8 stars ranked in the *Harvard Photometry* as above the first magnitude only two (Rigel and Betelgeuse) have a standard motion of less than 0″.225. The average determined for the eight in the above manner is 0″.537, the arithmetical average being 0″.618. But the 15 stars between magnitudes 1 and 2 (including Aldebaran rated at 1″.00) include 13 with a motion less than 0″.225 and only two with greater motion. The average for these 15 stars determined as above is only 0″.066, and the arithmetical average 0″.103. The average standard motion of these fifteen stars in N.P.D. is consequently not more than one-sixth of that of the foregoing eight. The stars between the 2d and 3d magnitude are also far below the mean, though their motions average a little more than that of their immediate predecessors. The average determined as above is about 0″.1, or arithmetically 0″.2. In 16 cases the motion is greater than 0″.225 and in 43 less. Between the 3rd and 4th magnitudes, however, the mean is nearly realized, 89 stars according to my count being above 0″.225 and 98 below it. From the 4th to the 5th magnitudes the figures are almost identical with the foregoing, the standard motions of 87 stars being above 0″.225 and those of 97 below it. The arithmetical average for the stars of magnitude 3 to 4 is indeed greater than for magnitude 4 to 5, 27 stars giving a standard motion of over 1″ in the former case against 19 in the latter. Between the 5th and 6th magnitudes I found 74 stars above the mean against 50 below it; but probably a good many of these fainter stars owe their introduction into Auwers' Catalogue to their considerable proper motions, so that a fuller examination of the proper motions of all stars between the 5th and 6th magnitudes might lead to a different result. The same remark applies more strongly to the small number of stars below the 6th magnitude which the catalogue contains. It will be seen, at all events, that there are two exceptions to the steady increase of (standard) motion as the stars become fainter. One is afforded by the eight brightest stars in the catalogue and the other by the stars comprised between the 4th and 5th magnitudes. I may add that in considering the quantities of proper motion only and disregarding their directions, it seems to me that errors of observation or computation will necessarily increase the average motions of very faint or rather very distant stars. Such errors will assign small motions of approach or recession where the motion is really insensible, and these small motions may be considerably increased by multiplying them by the number whose logarithm is one-fifth of the photometric magnitude as already explained. I may remark that taking the average standard proper motion in N.P.D. of a second magnitude star at 0″.100 the average parallax on the assumption of an average velocity of 10 miles per second would be only 0″.03; but this being the parallax on the assumption that the star was brought near enough to appear two magnitudes brighter than it is, the actual average would be only 0″.012. The recently published Oxford observations give an average parallax nearly 5 times as great as this; according to which the average velocity of a second magnitude star to or from the north pole is only about 2 miles per second. The average velocity in the line of sight differs from this in rather a startling manner.

My main object, however, was to compare the standard motions of stars with different types of spectra. The result of this comparison can be best presented in a tabular form, but I have omitted spectra which occur so rarely that the results are unreliable.

Spectrum (Draper Catalogue).	Standard Motions.						
	over 1″.0	0″.5 to 1″.0	0″.3 to 0″.5	0″.2 to 0″.3	0″.1 to 0″.2	under 0″.1	Total.
A	9	28	48	32	40	77	234
B	0	1	0	1	9	17	28
F	29	10	10	2	12	12	75
G	5	1	1	1	2	9	19
H	11	8	8	5	6	15	53
I	10	7	6	5	11	6	45
K	10	10	15	9	19	31	94
M	0	8	6	5	6	6	31

It is evident at a glance that the standard motions of the solar stars (spectra F, G, H, I and K) are far in excess of those of the Sirians (spectra A and B). But the subdivisions show other remarkable differences. The standard motions of stars with spectrum B fall far short of those with spectrum A. In fact, the average motion for stars of this type, determined in the way already indicated, is only 0″.052, the arithmetical average being 0″.098. The corresponding averages for spectrum A are between three and four times as great as this. Again, the stars with spectrum F (with which the small number of stars with spectrum E should probably be classed) have, on the average, much greater proper motion than the other stars of the solar type. In more than one-half of them, the standard motion exceeds half a second annually, in which respect they stand alone, and nearly three times as many of them have a standard motion of over one second annually as of the more numerous class of solar stars with the spectrum K. I have elsewhere proposed to call stars with the former type of spectrum Capellan, from the brightest star which possesses it, and to call stars of the latter type Arcturian for a similar reason. Stars with the spectra G, H and I appear to agree better with the Arcturian than with the Capellan class. Only four stars in the Catalogue have spectra of the type E and of these, two have standard motions of more than one second annually, thus agreeing with the Capellan stars. Stars with spectra of the third type (M) hold an intermediate position between the Sirians and Solars as regards proper motion. The average is not very different from that for the class K. No Sirian star has a standard proper motion of more than 2″ in N. P. D. and only 4 stars of the type K attain that figure, but it is attained by no less than 23 stars with the spectrum F. I think I am justified in concluding that the Capellan type (which I believe approaches most nearly to that of the Sun) is the predominant one among our nearest neighbors. Otherwise, stars with this type of spectrum must move through space with much greater velocity than the others. This latter theory is rendered improbable by the extent to which the motions of these stars appear to be affected by the Sun's motion in space. Thus, of the 29 Capellan stars with standard motion of more than one second, 19 are approaching the North Pole and only 10 receding from it. This proportion agrees pretty well with the other stars whose motion exceeds the same limit, but for the total number of stars in the Catalogue the preponderance is considerably less. The motions of the same stars in right ascension points to a similar result. Assuming the right ascension of the Sun's goal to be 18^h the effect of the Sun's motion will be to diminish the Right Ascension of stars between 6^h and 18^h' and to increase it between 18^h and 6^h. I find that the former interval contains 17 and the latter 12 of the 29 stars under consideration. The latter 12 are divided equally as regards increasing or diminishing R. A., but 13 of the 17 in the other interval have motions in diminishing R. A. A closer agreement would have been obtained by taking the R. A. of the Sun's goal at 17^h 30^m. My conclusion is further confirmed by the large proportion of Capellan stars among binaries for which orbits have been computed; for in this case if we reject the explanation by greater nearness, our alternative is not greater velocity but greater mass. Further investigation with more extensive Catalogues is no doubt requisite, but I think I have made out a fair case for my conclusion that, great as the distances between the components may be, the Sun forms one of a group or cluster of stars in which the predominating type of spectrum is similar to its own. With regard to the recently published parallax researches at Oxford, they seem to me hardly to bear out the sanguine expectations formerly entertained as regards the photographic method. The results, however, are rather favorable to my conclusion. The average parallax of the 21 second-magnitude stars measured at Oxford is 0″.056. They consist of 12 Sirian stars, 8 solars and 1 with a peculiar spectrum. The average for the 8 solar stars taken separately is 0″.071, which is considerably in excess of that for the Sirians. It so happens, however, that of the 8 solar stars only one belongs to the Capellan type. Its parallax is 0″.0867. Only one of the 21 stars has a standard motion of more than one second. It has the largest parallax of any in the list, viz., 0″.128. Six of the solar stars have the spectrum K and one the spectrum L which may be also classed as Arcturian.

The nearness of the Capellan stars which seems to be thus established is a nearness relatively to stars of the same magnitude but with different types of spectrum. Researches on binary stars seem to establish that this is not due to smaller average mass, and it would therefore appear that these stars are of the dullest or least light-giving class—more so not only than the Arcturian stars but than those of the type of Antares or Betelgeux. The Sun as a Capellan star may therefore be expected to give a small amount of light relatively to its mass when compared with most of the fixed stars. The comparisons hitherto made point in this direction.

ROBERT GRANT.*

In Robert Grant, who at the ripe age of seventy-eight died at the place of his birth, Grantown-on-Spey, on October 24, 1892, science loses one of her ablest historians. His education was interrupted by a serious illness, which confined him to his bed from his fourteenth to his twentieth year. With surprising energy, however, on his recovery he set about the study of mathematics and the acquisition of ancient and modern languages. After studying for a time at King's College, Aberdeen, he went to London to collect materials for a history of physical astronomy. Thence he proceeded to Paris in 1845, where for two years he attended the lectures of Arago at the Observatory, and those of Leverrier and others at the Sorbonne. Returning to London, he lost little time in beginning the great work with which his name will always be associated. It was published in numbers, the first of which appeared in September, 1848, but it was not until March, 1852, that the whole work was issued. It bears the title "History of Physical Astronomy from the Earliest Ages to the Middle of the Nineteenth Century, comprehending a detailed account of the establishment of the Theory of Gravitation by Newton, and its development by his successors; with an exposi-

---

* *Nature*, Nov. 10, 1892.

tion of the progress of research in all the other subjects of Celestial Physics." Most completely do the contents of the volume fulfil every expectation raised by this comprehensive programme. The fame of its author was at once established. Four years later he received from the hands of the late Mr. Manuel J. Johnson, President of the Royal Astronomical Society, the gold medal, then for the first time awarded for literary service to astronomical science. One paragraph of the address delivered on that occasion may here be quoted as characterizing most justly the work as well as its author: "Throughout the book no one can fail to be struck with the rare skill, integrity, and discernment the author has displayed in tracing the successive stages of progress; or with the scrupulous care he has taken to assign to each of the great men whom he reviews their proper share in the common labor. Nowhere is this more conspicuous than in the discussion relative to the discovery of the planet Neptune. By a simple narration of facts he has placed the history of that great event in so clear and so true a light, that I believe I am not wrong in saying he has gained an author's highest praise under such circumstances—the approval of both the eminent persons concerned." Even now, forty years after its publication, the "History" has lost none of its value as a mine of information, and as a delightful guide to those who desire to make a closer acquaintance with the astronomers of the past as well as their works.

For some time Mr. Grant edited the "Monthly Notices" of the Royal Astronomical Society, and was a member of their Council. In conjunction with the late Admiral Smyth, he translated and edited Arago's "Popular Astronomy" (2 vols. 1855 and 1858). Meanwhile his health had so far improved that in 1858 he was able to go through a course of observational astronomy at Greenwich Observatory. In the following year, on the death of Professor J. Pringle Nichol, he was appointed Professor of Astronomy, and Director of the Observatory in the University of Glasgow.

As a member of the party that went to Spain in the troop ship *Himalaya*, to observe the total solar eclipse of July 18, 1860, Professor Grant from his station near Vittoria, had the satisfaction of seeing a portion of the chromosphere, the existence of which as a thin layer enveloping the photosphere he had abundantly demonstrated in the winter of 1850-51, from a discussion of all the observations extant ("History," pp. 395, 396). It can excite no surprise that Professor Grant assumed the red layer and also the prominences to shine by reflected light when it is recollected that the Sun's light and heat were then supposed to originate wholly in the photosphere, while the nucleus was thought to be so cool as possibly to be habitable. When Professor Grant took charge of the Glasgow Observatory the only useful instrument he found was the transit-circle by Ertel & Son of Munich, but through the liberality of a few friends, chiefly in Glasgow, a nine-inch Cooke equatorial was added to the Observatory some years afterwards. After thoroughly testing the transit-circle the new director commenced a series of observations of Mercury, Neptune, the minor planets, and a selection of stars from the British Association Catalogue. Gradually, however, his attention was concentrated entirely on the stars, the list being correspondingly expanded. The observations of planets were communicated from time to time to the *Astronomische Nachrichten* or to the *Monthly Notices.*

The stellar observations were published at the expense of her Majesty's government in 1883 in the well-known "Catalogue of 6415 Stars for the epoch 1870, deduced from observations made at the Glasgow University Observatory during the years 1860 to 1881, preceded by a synopsis of the Annual Results of each star arranged in the order of Right Ascension."

In the introduction will be found a discussion of the Proper Motions of 99 stars. A very complete and appreciative review of this work from the pen of Professor Auwers of Berlin appeared in the *Vierteljahrsschrift der Astronomischen Gesellschaft* (19 Jahrgang). The Glasgow star places were at once looked on with confidence by the numerous observers of comets and minor planets. One point connected with the Catalogue deserves special attention, viz., that, although the observations from which it is derived extend over a space of twenty-one years, the work appeared within two years of the close of the series. This promptitude excites the greater admiration when we learn that, exclusive of Professor Grant's personal share in the work, no less than thirteen young assistants at various times took part in the observations, and two others in the computations. Many of these personal changes, each of which brought its quota of extra work to Professor Grant were no doubt in some measure due to the smallness of the allowance provided for assistance, viz., £100 per annum. Professor Grant, however, was the last man to waste his energies in useless complaint, and dismisses this point with the remark that "in recent years the work of scrutinizing, reducing to a common epoch, and combining together the vast mass of the observations of the catalogue, extending over a period of more than twenty-one years, has pressed very heavily upon the slender resources of the observatory." The important time service of the City of Glasgow was originated by Professor Grant some thirty years ago, and continues in operation up to the present moment. In 1855 he received from the University of Aberdeen the degree of M. A., followed by that of the honorary LL. D. in 1865 in which latter year he was elected a Fellow of the Royal Society of London. For three years he presided over the Philosophical Society of Glasgow, to whose proceedings he made various contributions. It may also be noted that among his writings are two remarkable letters proving beyond a shadow of doubt the spurious character of the pretended Pascal correspondence. These letters were printed in the *Comptes Rendus* by special permission of the French Academy.

In manner Professor Grant was singularly vivacious, and to the last he greeted with the warmest enthusiasm every fresh discovery in the science to which is life was devoted. R. C.

ASTRO-PHYSICS.

THE MOTION OF NOVA AURIGÆ.*

W. W. CAMPBELL.

My observations of the position of the chief nebular line in Nova Aurigæ's spectrum show a progressive increase of wave-length after September 7. Satisfactory observations made the last two nights fully convince me that the variation is real. It is probably the result of orbital motion. The following measures have been made recently, in addition to those already published in ASTRONOMY AND ASTRO-PHYSICS:

	Oct. 19.	Nov. 2.	Nov. 3.
Grating, 1st order	5004.3	5004.32	5005.01
Grating, 2nd order	5004.3	5004.34	5004.39
Compound prism	5002.8	5004.49	5004.61
	5003.8	5004.38	5004.67

The measures of Oct. 19 were made with great difficulty, and are entitled to small weight. The results obtained with different dispersions are about equal in weight. The adjustments of the instrument for the Nov. 2 and 3 observations were tested by measuring the velocity of Venus. The observed velocity, using the second order grating, was + 7.7 miles per second. The computed velocity, from Nautical Almanac data, was + 7.4 miles.

The table below contains the wave-lengths of the chief nebular line resulting from the several nights' observations, together with the corresponding velocity of approach, in miles per second.

Date.	λ.	Velocity.
1892, Aug. 20	5003.6	— 128
21	3.7	125
22	3.7	125
23	3.1	147
30	2.4	173
Sept. 3	2.4	173
4	1.9	192
6	2.1	184
7	1.9	192
15	2.2	180
22	2.5	169
Oct. 12	3.6	128
19	3.8	121
Nov. 2	4.4	99
3	4.7	— 87

A few of the earliest measures were made with a dense 60° prism, and must be given smaller weight; however, tests made

---

* Communicated by the author.

by me upon known intervals in comparison spectra have shown that surprisingly accurate results can be obtained with that prism.

A photograph of the Nova's spectrum taken October 19 shows additional lines at λ 438, λ 426, λ 423 and λ 410, making eighteen thus far observed. On account of the wide slit employed the wave-lengths are reliable to three places only. The line at λ 438 exists also in the Orion Nebula spectrum. That at λ 410 is strong and is probably Hδ. A very faint trace at λ 397 is probably H. There were lines near all of these in the February spectrum of the new star.

MT. HAMILTON, 1892, Nov. 4.

NOTE ON THE REVIVAL OF NOVA AURIGÆ.*

WALTER SIDGREAVES.

Mr. Campbell's paper in the October number of ASTRONOMY AND ASTRO-PHYSICS has renewed our interest in the faded star that was new and bright in the first months of the year.

The searching analysis of its light, carried on at Mt. Hamilton in August and September, has enabled Mr. Campbell to give us a list of lines of what may be called the new spectrum of Nova Aurigæ. It is a valuable contribution to the history of the star; but it adds to our perplexity, and warns us against reading it wrongly rather than helps us to read it aright.

The three most prominent lines of the new spectrum are given at λλ 5003, 4953 and 4858, these figures being the means of 16; 6 and 7 measures respectively and their relative intensities are quoted at 10, 3 and 1. They have been identified as undoubtedly the three nebular lines, shifted five-tenth metres to the violet side.

In accepting these values as comparable with those obtained from the star in its greater brilliancy, we must make great allowance for the changed conditions of spectroscopic analysis. The supply of light from the star at the tenth magnitude cannot offer the same means for accurate measurement as were placed at our service by the more energetic radiation of its earlier life. But if the wave-lengths quoted by Mr. Campbell are the true positions of the lines on the spectrum band, they must be new lines; for their relative positions are not those of the green triplet of the earlier spectrum, or of any other three in this region. The wave-

---

* Communicated by the author.

length interval between the first and third, taken from Dr. Crew's measures on the 10th and 13th of February, is 155 $\mu\mu$, and the August measures give 145 $\mu\mu$ separation; while the middle line has no better representative on the first spectrum than a very faint line at 4970 observed by Mr. Campbell, or a possible broad line at 4956 noted on one of the Stonyhurst plates, but considered too uncertain to be admitted into the list of lines.

Wave-lengths of bright lines of Nova Aurigæ, 1892.

Stonyhurst February.		Lick August.			Stonyhurst February.		Lick August.		
No.	Wave-length	Wave-length	Intensity	No. of Obs.	No.	Wave-length	Wave-length	Intensity	No. of Obs.
1	5895				22	4529			
2	5734	5750	1	4	23	4517			
3	5676				24	4500			
4	5631				25	4487			
5	5612				26	4470	4466	0.1	1
6	5564	5570	0.2	1	27	4446			
7	5527				28	4417			
8	5369				29	4394			
9	5334				30	4380			
10	5310				31	4364	4358.8	0.8	6
11	5273	5268	0.3	1	32	4343	4335·9	0.1	1
12	5230				33	4312			
13	5196				34	4298			
14	5167				35	4271			
15	5016	5002.8	10	9	36	4245			
16	4922	4953·3	3	6	37	4232			
17	4861	4857·7	1	7	38	4177			
18	4664	4681.3	0.4	5	39	4135			
19	4626	4630.8	0.7	4	40	4101			
20	4583				41	3968			
21	4551								

In the foregoing table the lines of the new spectrum are placed opposite the nearest corresponding lines found on the Stonyhurst photographic plates of the earlier spectrum of February. The columns of *Intensity* and *Number of Observations* refer to the new spectrum of August. The Stonyhurst list of lines is taken from the last column of the table of wave-lengths as given in my paper for the Memoirs R. A. S., now at the press. The wave-lengths are quoted for the centres of the broad lines, each reading being the mean of the marginal measures of the line. They are independent of any shift of the spectrum due to radial velocity of the star, each line having its wave-length assigned with reference to the centre of the broad F line as the supposed true position of λ 4861 of the bright line star, and under the supposition that all the bright lines are given by the same star. This relation was secured, as described in the Memoir, by setting the plate on the micrometer stage with the centre of the line F adjusted to the scale division that corresponds to the wave-length 4861 of the interpolation curve. But the wave-lengths quoted in the table will be found to differ a little from those of the map of the spectrum in the same Memoir; the differences being according to a final correction there fully explained.

The figures give their own verdict upon the later spectrum of the star; viz., that its lines cannot all be revivals of the older ones. And the question then becomes: to what star do the new lines belong? The three chief nebular lines, as found at Mt. Hamilton, with a shift of 5 tenth metres to the violet side, cannot belong to the bright line star of February and March, which was rushing away from us at a velocity too high and too constant to admit of its wheeling round to come back in August at the speed of nearly 180 miles in the second. We cannot, on the other hand, suppose the dark line star to have changed its dress so far as to display the characteristic colors of a planetary nebula. And we are therefore driven either to admit the presence of a third rushing star, against the enormous improbability of such a gathering, or to fall back upon the local disturbances of one, for the origin of the complicated spectrum. Mr. Campbell's remark "that the relation of this spectrum (of August) to the earlier one of February is not apparent," is the truth. But we venture to add that his discovery strengthens the probability in favor of the one-star-origin of the spectrum.

STONYHURST OBSERVATORY, Lancashire, Oct. 25, 1892.

ON THE APPLICATION OF INTERFERENCE METHODS TO SPECTROSCOPIC MEASUREMENTS.*

ALBERT A. MICHELSON.

The theoretical investigation of the relation between the distribution of light in a source, as a function of the wave-length, and the resulting "visibility curve" has been given in a paper bearing

---

* *Philosophical Magazine*, Sept. 1892.

I take this opportunity of presenting my acknowledgments and thanks to the Smithsonian Institution for the funds necessary to carry out this research; to the Clark University for the facilities it has placed at my disposal; and especially to Mr. F. L. O. Wadsworth, Assistant in Physics of Clark University, for the valuable services he has rendered and his unflagging zeal in furthering this investigation.

the same title as the present one in the *Philosophical Magazine* for April 1891.

The physical definition of "visibility" there adopted is

$$V=\frac{I_1-I_2}{I_1+I_2},$$

in which I_1 is the intensity at the centre of a bright interference-band, and I_2 the intensity at the centre of the adjoining dark band. In order to interpret the actual curves obtained by observation of interference-fringes, it is first necessary to reduce the results of the eye-estimates of visibility, which may be designated by V_e, to their absolute values as above defined.

For this purpose two quartz lenses, one concave and the other convex, and of equal curvatures, were mounted with their crystalline axes at right angles to each other between two Nicols. Under these conditions a series of concentric interference-rings appeared. If α be the angle between the principal section of the polarizer and the axis of the first quartz, and ω the angle between the axis and the analyser, the intensity of the light transmitted will be

$$I=\cos^2(\omega-\alpha)-\sin 2\alpha\sin 2\omega\sin^2\pi\frac{\kappa(t_1-t_2)}{\lambda},$$

where t_1 is the thickness through the first quartz and t_2 that through the second. If the analyser and polarizer are parallel, $\omega=\alpha$, and

$$I=1-\sin^2 2\alpha\sin^2\pi\frac{\kappa(t_1-t_2)}{\lambda},$$

whence $I_1=1$, and $I_2=1-\sin^2 2\alpha$,

and $$V=\frac{I_1-I_2}{I_1+I_2}=\frac{1-\cos^2 2\alpha}{1+\cos^2 2\alpha}.$$

This curve, together with the mean of a number of eye-estimates, is given in fig. 2, Plate XLII. From these the following table of corrections may be obtained:—

V_e.	Cor.
.00	.00
.05	+ .03
.10	+ .04
.15	+ .03
.20	+ .02
.25	.00
.30	− .03
.35	− .05
.40	− .07
.45	− .08
.50	− .10
.55	− .12
.60	− .14
.65	− .15
.70	− .16
.75	− .16
.80	− .14
.85	− .13
.90	− .11
.95	− .08
1.00	.00

The curves show a general tendency to estimate the visibility

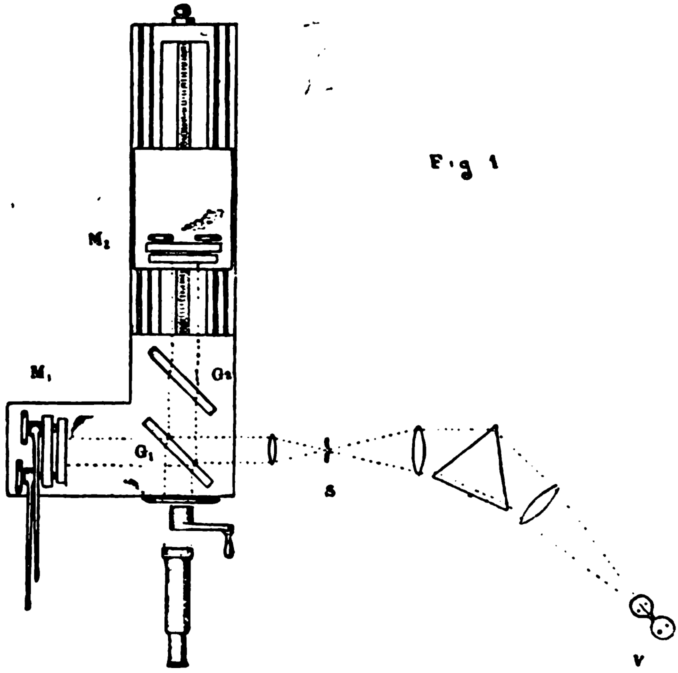


Fig 1

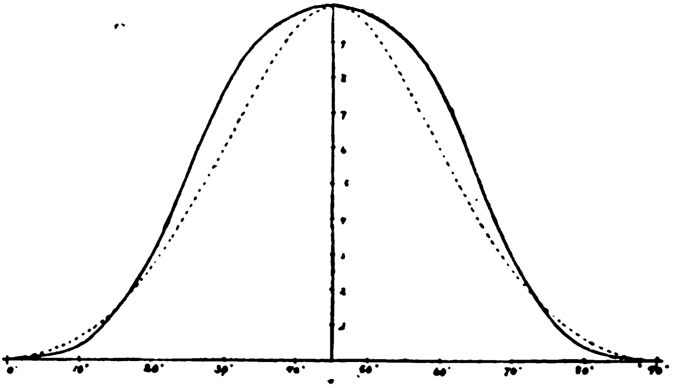


Fig 2

Equation Dot'd Curve :—

$V = \frac{1 - \cos^2 2a}{1 + \cos^2 2a}$.

Full. Curve -

Eye Estimates - V_e -

PLATE XLII.

too high when the interference-bands are clear, and too low when they are indistinct. This tendency may be modified by a number of circumstances: thus, it increases with the refrangibility of the light used; it is greater when the field contains a large number of bands than when there are but few; it is greater while the visibility-curve is falling than when it is rising; it does not seem to be greatly affected by the intensity of the light; finally, it varies on different occasions and with different observers. Notwithstanding these disturbing causes, the result, after applying the correction, will rarely be in error by more than one-tenth of its value, and ordinarily the approximation is much closer than this.*

As stated in Part I of this paper, the observations necessary to construct the visibility-curves, from which the distribution of

---

* The formula for visibility deduced in the preceding paper is

$$V^2 = \frac{C^2 + S^2}{P^2},$$

in which

$$C = \int \varphi(x) \cos kx dx,$$

$$S = \int \varphi(x) \sin kx dx,$$

$$P = \int \varphi(x) dx,$$

$$k = 2\pi D,$$

$$D = \text{Difference in path},$$

and $\varphi(x)$ represents the distribution of light in the source.

In this expression no account was taken of the effect of extraneous light, and it was assumed that the two interfering pencils were of equal intensities. It can be shown that the error due to both these causes tends to lower the visibility; but in either case the correct values may be obtained by multiplying by a constant factor.

In the first case, let e be the intensity of the extraneous light, and V' the resulting visibility; then, by definition,

$$V' = \frac{(I_1 + e) - (I_2 + e)}{(I_1 + e) + (I_2 + e)} = \frac{I_1 - I_2}{I_1 + I_2 + 2e}; \text{ or if } \frac{2e}{I_1 + I_2} = r, \ V' = \frac{I_1 - I_2}{(I_1 + I_2)(1 + r)}$$

whence $V = (1 + r)V'$.

In the second case, let ρ be the ratio of intensities of the interfering pencils, then it can readily be shown that the resulting intensity is

$$I = (1 + \rho^2)P + 2\rho(C \cos \vartheta - S \sin \vartheta),$$

and hence the visibility is

$$V'' = \frac{2\rho}{1 + \rho^2} \frac{\sqrt{C^2 + S^2}}{\rho},$$

whence $V = \frac{1 + \rho^2}{2\rho} V''$.

If the interfering pencils differ by 25 per cent, the factor $\frac{1 + \rho^2}{2\rho}$ differs from unity by about 4 per cent: so that, in most cases, this cause of error may be neglected.

light in any approximately homogeneous source is to be deduced, may be made with any form of interference apparatus which allows a considerable alteration in the difference of path between the two interfering streams of light.

The apparatus actually employed for this purpose was designed for the comparison of wave-lengths, and while admirably adapted for the observation of visibility-curves, it contains many parts not necessary for this use. Fig.1. Plate LXII presents the plan of an arrangement which, while showing all the essential parts, is much less complicated. Starting from V, a vacuum-tube containing the substance whose radiations are to be examined (and which is usually enclosed in a metal box in order that it may be raised to any required temperature), the light is analysed by one or more prisms forming a spectrum, from which any required radiation may be separated from the rest by passing through the slit S.*

The light from S is rendered nearly parallel by a collimating lens, and then falls on a transparent film of silver, on the surface of the plane parallel plate G_1.† Here it divides, part being transmitted to the fixed plane mirror M_1 and part reflected to the movable mirror M_2. These mirrors return the light to the silvered surface, where the first part is reflected and the second transmitted; so that both pencils coincide on entering the observing-telescope.‡

A little consideration will show that this arrangement is, in all respects, equivalent to a film or plate of air between two plane surfaces. The interference phenomena are, therefore, the same as for such an air-plate.

The theory of these interference-bands has been given in an article entitled "Interference Phenomena in a new form of Refractometer," *Philosophical Magazine* for April, 1882. As is there

---

* In the case of close groups of lines, the image of the source is first thrown on a slit; otherwise the lines at S would overlap.

† The light entering the telescope is a maximum when the thickness of the silver film is such that the intensity of the transmitted light is equal to that of the reflected light. The silvering has another important advantage in diminishing the relative intensity of the light reflected from the other surface. Indeed, for this purpose it is advisable to make the film heavier; even so thick that the reflected light is twice as bright as the transmitted. This does not affect the ultimate ratio of intensities of the interfering pencils—for what is lost by transmission on entering the plate G_1 is made up by reflection on leaving it, the effect being simply to diminish somewhat the whole intensity. Another advantage of the thicker film is that it can be made uniform with far less difficulty than the thin film. It may be mentioned that with this form of instrument the interference-fringes in white light present a purity and gorgeousness of coloration that are surpassed only by the colors of the polariscope.

‡ The second plane parallel plate G_2 is made of the same thickness as the first, and is required to equalize the optical paths of the two pencils.

shown, the projections of the bands are, in general, conic sections, the position of maximum distinctness being given by the formula

$$P = \frac{t_0}{\tan\varphi}\tan i \cos^2\theta,$$

in which t_0 is the thickness of the equivalent air-plate, where it is cut by the axis of the telescope, φ, the inclination of the two surfaces, θ and i, the components of the angle of incidence parallel and perpendicular respectively to the intersection of the surfaces, and P, the distance of the plane of maximum distinctness from the surfaces. If θ be small the variations of P with θ may be neglected, and we have then

$$P = \frac{t_0}{\tan\varphi}\tan i,$$

or with sufficient accuracy,

$$P = \frac{t_0}{\varphi} i.$$

From this it will be seen that the focal plane varies very rapidly with i, so that, unless $\varphi = 0$, it is impossible to see all parts of the interference-bands in focus with equal distinctness. If, however, $\varphi = 0$, that is, if the two surfaces are strictly parallel, then $P = \infty$, and if the observing-telescope is focused for parallel rays, all parts of the bands are equally distinct. Under these circumstances the interference-fringes are concentric circles, whose angular diameter is given by

$$\cos\vartheta = \frac{\Delta}{2t_0}.$$

If for Δ we put $2t_0 - n\lambda$, and for $\cos\vartheta$ its approximate value $1 - \frac{\vartheta^2}{2}$, we have

$$\vartheta_n = \sqrt{\frac{n\lambda}{t_0}}.$$

In order to obtain an idea of the order of accuracy required in this adjustment, suppose the angle ϑ to be so small that its influence on the distinctness may be neglected. The intensity at the focus of the observing-telescope will be

$$I = \int\int \cos^2 \tfrac{1}{2}\kappa\Delta\, dx dy, \text{ where } \kappa = \frac{2\pi}{\lambda}.$$

If the aperture be a rectangle whose height is $2b$, and width $2a$,

$$I = 2b\int_{-a}^{+a} \cos^2 \tfrac{1}{2}\kappa\Delta\, dx.$$

But $$\Delta = 2(t_0 + \varphi x),$$

whence $$\mathrm{I} = 2b\left(a + \cos 2\kappa t_0 \frac{\sin 2\kappa\varphi a}{2\kappa\varphi}\right).$$

The maximum value of I is

$$2b\left(a + \frac{\sin 2\kappa\varphi a}{2\kappa\varphi}\right),$$

and the minimum value is

$$2b\left(a - \frac{\sin 2\kappa\varphi a}{2\kappa\varphi}\right),$$

whence $$\mathrm{V} = \frac{\sin 2\kappa\varphi a}{2\kappa\varphi a}.$$

In attempting to verify this formula by actual observation, one is met by the difficulty that all parts of the bands are not in focus at the same time, the right and left bands being more distinct than the central one, to which attention ought to be directed. Notwithstanding the rather rough character of the observations, the results agree fairly well with theory. If φ_0 is the ratio of the wave-length to the width of the rectangular aperture, the above formula becomes

$$\mathrm{V} = \frac{\sin 2\pi\varphi/\varphi_0}{2\pi\varphi/\varphi_0},$$

from which the second column in the following table was calculated:

φ/φ_0	V (calc.)	V (obs.)
0.0	1.00	1.00
.1	.94	.94
.2	.75	.73
.3	.50	.40
.4	.24	.13
.5	.00	.09
.6	.15	.10
.7	.22	.09
.8	.19	.07
.9	.15	.05
1.0	.00	.04

From this table it appears that if the visibility is to be estimated by observations with a telescope of 12 millim. aperture (or with a circular aperture about one-fourth greater), an error in the adjustment of the surfaces of a second of arc would produce a diminution of 4 or 5 per cent in the visibility. Accordingly, if the ways on which the mirror-carriage moves are not true to this degree, it is necessary to make the adjustment for every observation.

This can be done with very great accuracy by moving the beam of light from side to side and adjusting the mirror until there is no perceptible alteration in the size of the rings. Since the admissible error in adjustment is inversely proportional to the aperture, the observations may be facilitated by making this as small as possible if there be light to spare. This is all the more necessary for the same reasons, if the surfaces be not true. However, the error due to this source may be easily corrected (since all the observations are affected alike) by multiplying by a constant factor.

In order that the visibility-curve may extend as far as possible, it is necessary that the vapor should be very rare. Accordingly, in all but a few cases to be mentioned later, the substance to be investigated was enclosed in a vacuum-tube, which was previously heated to drive off any moisture or occluded gases.

The vapor was rendered luminous by the discharge from the secondary of a large induction-coil, whose primary current was interrupted by a rotary break attached to the armature of an electric motor, making about 20 to 30 breaks per second. The steadiness of the light thus obtained was far greater than with the ordinary Foucault interrupter. Probably it would have been still more satisfactory to use an alternating dynamo properly wound to give a strong current with comparatively few alternations.

The box surrounding the vacuum-tube was heated just sufficiently to give a steady bright light, and the temperature then kept as nearly uniform as possible. This temperature was usually taken to represent that of the vapor within the tube. This is, of course, only a rough approximation to the truth; and in some cases the estimate was much too low.

As it was not intended to include in the present work an elaborate study of the effect of temperature, this matter was not of great consequence. It may be suggested, however, that a very much closer approximation to the real temperature could be obtained by winding a platinum wire about the capillary portion of the tube, and deducing the temperature from the variation of its resistance. A preliminary experiment in which a platinum wire passing through the tube and heated by a current until the platinum spiral outside the tube was raised to fixed temperatures, would give a means of deducing, from the indications of the spiral, the true temperature within the tube.

These adjustments being effected, the screw of the "wave-comparer" was turned to zero; that is, till there was no difference of path between the interfering pencils. At this point the visibility should be as great as possible, and was accordingly marked 100. The screw (of 1 millim. pitch) was then turned through one turn, thus giving a difference of path of 2 millim., and the visibility again estimated, and so on. The curve was then drawn, giving the estimated visibility for each 2 millim. difference of path; and this was corrected for the personal equation, as before described.

Hydrogen.

The full curve in fig. 3 *b*, Pl. XLIII, represents such a curve for the red hydrogen line* at a pressure of about 1 millim. and a temperature of about 50° C.

The dotted curve represents

$$V = 2^{-X^2/19^2} \cos \cdot 7/30.\dagger$$

It follows that the visibility-curve is practically the same as that due to a double source, whose components have the intensity ratio 7 : 10, and in each of which the light is distributed according to the exponential law, expressed by the first term.

The formula for a double source, where the components are similar, is

$$\bar{V}^2 = \frac{1 + r^2 + 2r \cos 2\pi \frac{X}{D}}{1 + r^2 + 2r} V^2,$$

in which D, the period of the curve, is inversely proportional to the distance between the components.

But $D = N\lambda_1 = (N + 1)\lambda_2$, whence

$$\alpha = \lambda_1 - \lambda_2 = \frac{\lambda^2}{D}.$$

Hence, in the present instance we have for the distance between the components of the red hydrogen-line

$$1/30 \times (6.56 \times 10^{-4})^2 = 1.4 \times 10^{-8} \text{ millim.}$$

or 0.14 division of Rowland's scale.

Again, if δ be the "half-width" of the spectral line (the value of x when $\varphi(x) = \frac{1}{2}$), then

$$\varphi(x) = 2^{\frac{-x^2}{\delta^2}}, \text{ and } V = e^{-\frac{\pi^2 X^2 \delta^2}{l^2}}.$$

---

* The hydrogen was prepared by dropping distilled water upon sodium amalgam, and allowing the gas to pass through sulphuric acid into the vacuum-tube, which was repeatedly exhausted until the spectrum of hydrogen was nearly pure.

† As frequent use is to be made of the function

$$\sqrt{\frac{1 + r^2 + 2r \cos 2\pi \frac{X}{D}}{1 + r^2 + 2r}},$$

it will be abbreviated to the form cos r/D.

If Δ be the value of X for $V = \frac{1}{2}$, then $\delta = \frac{l2}{\pi}\frac{1}{\Delta}$, or, with sufficient accuracy, $\delta = \frac{.22}{\Delta}$.

Substituting the value of δ in the equation for V, we have $V = 2^{\frac{-X^2}{\Delta^2}}$. The value of Δ in the hydrogen curve is 19. Accordingly, after reducing to the same units as above, we have $\delta = 0.049$.

From these data fig. 3 *a*, Plate XLIII, was constructed, the full curve showing the distribution of light in the source.

Fig. 4 *b*, Plate XLIII, gives, in the full curve, the corrected values of the visibility of the blue hydrogen-line, at the same temperature and pressure as before. The dotted curve represents a double exponential, as before. The formula for this curve is

$$V = 2^{-X^2/24^2} \cos .7/28,$$

thus giving $\alpha = 0.08$ for the distance between the components, and $\delta = 0.057$ for the "half width" of each. These values give for the distribution of light in the blue hydrogen-line, the full curve in fig. 4 *a*.

Oxygen.

Fig. 5, Plate XLIII, represents the results obtained from oxygen prepared by heating a tube containing mercuric oxide, drying the gas by sulphuric acid, and exhausting and filling repeatedly till the spectrum was nearly pure. The lines are much less bright than those of hydrogen; and in order to obtain satisfactory results, the current had to be increased so far that the tube was frequently broken. Notwithstanding the somewhat uncertain character of the observations, it will be seen from fig. 5*a* that the curve for the orange-red line corresponds very well with that given by the formula

$$V = 2^{-X^2/34^2}[.36 + .32 \cos 2\pi X/2.69 + .16 \cos 2\pi X/4.85 \\ + .16 \cos 2\pi X/1.73]^{\frac{1}{2}}.$$

The agreement between the coefficient $2^{-X^2/34^2}$ and the general curve drawn through the maxima is also shown in fig. 5 *b*, Plate XLIII.

The interpretation of these results is that the orange-red oxygen line is a triple, whose components have intensities in the ratios 1 : 1 : 1/2, and whose distances apart are 1.51 and 0.84 respectively, and whose "half-width" is 0.027. This is shown in fig. 5 *c*.

Sodium.

The results obtained from metallic sodium in the vacuum-tube are so varied, the character of the lines being so considerably altered by temperature and pressure, that a complete study is at present impossible. This is especially true of the yellow lines; and the difficulty is considerably increased on account of the insufficiency of the dispersion used, which does not permit the separate examination of the lines. Some reference to the changes mentioned will be given at the close of this paper. At present it will suffice to take a particular case—the pressure being very low, and the temperature about 250°.[*]

The full curve in fig. 6 *b*, Plate XLIII, gives the experimental result for the visibility at the maxima for yellow sodium, corrected for the personal equation. The dotted curve corresponds to the formula

$$V = 2^{-X^2/156^2} \cos .7/50 \cos .1/140.$$

The complete equation, assuming that the two lines are alike is,

$$V = 2^{-X^2/156^2} \cos .8/0.58 \cos .7/50 \cos .1/140.$$

The interpretation of these results is that each of the sodium-lines is a close double, as shown in fig. 6 *a*.

The yellow-green sodium-line at λ = 5687 is a double whose components are about the same distance apart as the yellow pair. It was found to be far less variable than the yellow; and the full visibility-curve, neglecting slight irregularities, gives the experimental results corrected for personal equation. Fig. 7 *b*, Plate XLIII, shows that its components are single, and correspond in distribution of light fairly well with the exponential curve, fig. 7 *a*.

The same may be said of the orange-red double at 6156 also, except that this seems to have a companion of feeble intensity.

The doubles at 5150 and at 4982 were also examined, the curves showing nearly the same results as the red.

Zinc.

The temperature at which the radiations from metallic zinc could be conveniently observed was in the neighborhood of the melting-point of the glass of which the vacuum-tubes were made. But few observations were recorded, though these were quite consistent. The results of the observations, corrected for personal equation, are given in figs. 8 and 9, Plate XLIII. The

---

[*] The curve given above was obtained a year ago; and since then it has been impossible to reproduce it exactly.

former is the record obtained from the red line near 6360, and shows that this line is single, the distribution of light agreeing very well with a simple exponential curve, the "half-width" being 0.013. The latter shows the results of observation on the blue line near 4811. The dotted curve is the visibility-curve due to a distribution represented in fig. 9 *a*.

Cadmium.

Metallic cadmium in the vacuum-tube at a temperature of about 280° gives a number of very bright lines, widely separated, and varying very slightly with temperature or pressure. Fig. 10 *b*, Plate XLIV, shows the experimental visibility-curve of the red line near 6439, corrected for the personal equation, together with the simple exponential curve $V = 2^{-X^2/138^2}$. The remarkably close agreement leaves no doubt that the distribution of light in the source follows very nearly the exponential law giving the curve in fig. 10 *a*, in which the "half-width" of the source is 0.0065.

The result of a single set of observations on the green line at 5086 is given in fig. 11 *b*, Plate XLIV, the approximate agreement between the full line and the dotted curve (which corresponds to the equation $V = 2^{-X^2/120^2} \cos .2/115$) showing that the source is a close double, the intensity of whose components is in the ratio 5 : 1, and whose distance apart is .022, the "half-width" of each component being 0.0048.

The curve for the blue radiation at 4800 is given in fig. 12 *b*, Plate XLIV, and shows that the results may be approximately represented by $V = 2^{-X^2/64^2} \cos .1/32$, which corresponds to the distribution of intensity given in fig. 12 *a*.

Thallium.

The metal is not sufficiently volatile at the temperatures attainable, but the chloride answers admirably, giving a brilliant green light, the visibility-curve varying but little with temperature. This curve is given in fig. 13 *b*, Plate XLIV., together with the dotted curve representing the equation

$$V = \tfrac{1}{3} \cos .2/160 \sqrt{4V_1^2 + V_2^2 + 4V_1V_2 \cos 2\pi X/25.3},$$

in which $V_1 = 2^{-X^2/246^2}$ and $V_2 = 2^{-X^2/188^2}$.

This is the visibility-curve due to a double source, each of whose components is a close double, as shown in fig. 13 *a*.

Mercury.

Mercury in a vacuum-tube gives two yellow lines 5790 and 5770, a very brilliant green line at 5461, and a violet line at 4358.

The yellow lines are not very bright, and are so close together that it is somewhat difficult with the dispersion employed to prevent the light from overlapping. Notwithstanding these difficulties, the close agreement of a number of observations shows that the curve for the lower line, given in fig. 14 *b*, Plate XLIV., is a close approximation to the truth. Neglecting the effect of a line of feeble intensity at a distance of about .24 from the principal line, the distribution of light in the source is represented in fig. 14 *a*, which gives for the visibility curve

$$V = \tfrac{1}{4}\sqrt{3V_1^2 + V_2^2 + 6V_1V_2 \cos 2\pi X/28},$$

in which $V_1 = 2^{-X^2/200^2}$ and $V_2 = 2^{-X^2/260^2} \cos .5/280$.

Fig. 15 *b*, Plate XLIV, represents the results of observations on the upper yellow line, omitting some peculiarities due to the presence of one or more lines of feeble intensity. The curve agrees closely with the formula

$$V = \tfrac{1}{4}\sqrt{3V_1^2 + V_2^2 + 6V_1V_2 \cos 2\pi X/70},$$

in which $V_1 = 2^{-X^2/183^2}$ and $V_2 = 2^{-X^2/126^2}$, which represents the visibility-curve produced by two lines of intensities 1:3 and separated by 0.019 divisions as shown in fig. 15 *a*.

The green mercury-line is one of the most complex yet examined. The constituent lines are nevertheless so fine that the interference-bands are frequently visible when the difference o path is over four-tenths of a metre. The full curve in fig. 16 *b* Plate XLIV, gives the results of observations corrected for personal equation, while the dotted curve represents the equation

$$V = 2^{-X^2/230^2}\sqrt{.69V_1^2 + .03V_2^2 + .28V_1V_2 \cos 2\pi X/31.4},$$

in which $V_1 = .62 + .38 \cos 2\pi X/360$

and $V_2 = .77 + .23 \cos 2\pi X/110$.

This is the visibility-curve corresponding to the distributio represented in fig. 16 *a*. The components of the line, for simpli ity, have been assumed to be symmetrical, as figured; but t observations are not sufficiently accurate to determine whethe for instance, each component is a double or a triple line. In th case also, as in the preceding ones, it is impossible from the dat

Fig 14 Hgx

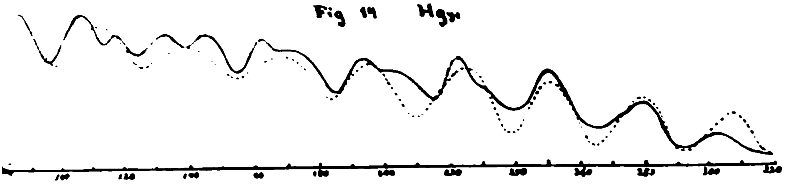
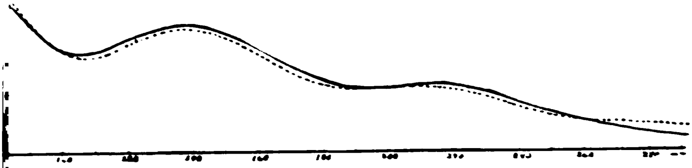


Fig 15 Hgo



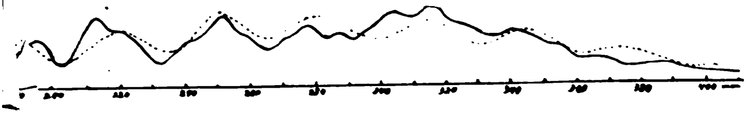


Fig 17 Hgv

Fig 14 Hgn

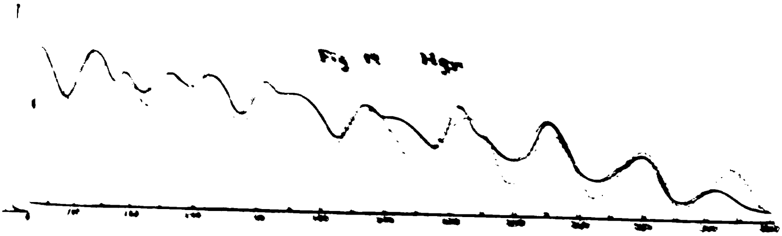


Fig 15 Hgn

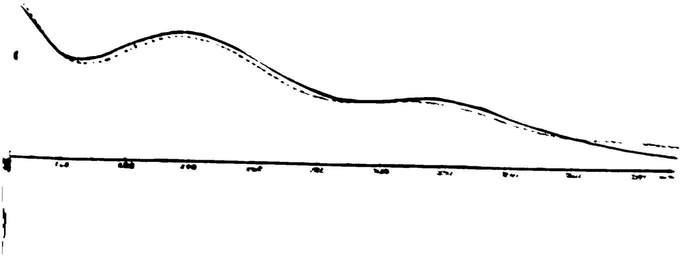


Fig 17 Hgv

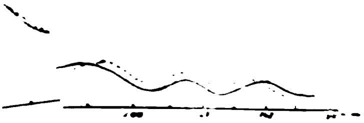


Fig [illegible] Hg

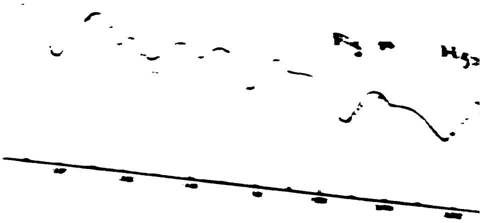
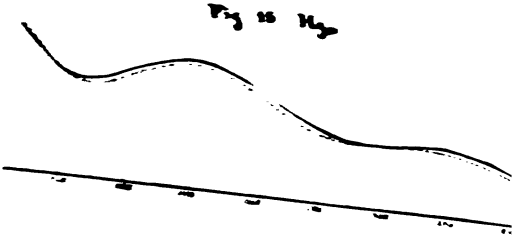


Fig 16 Hg



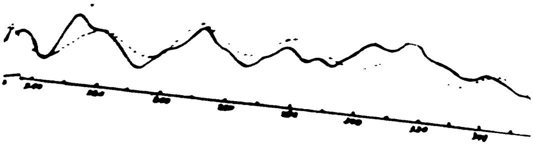


Fig 17 Hg

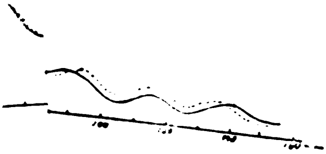
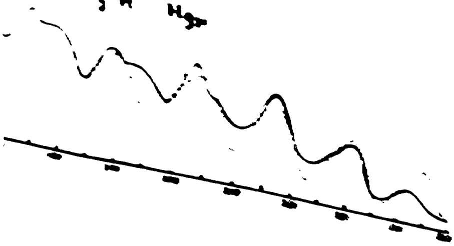
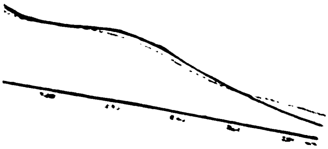


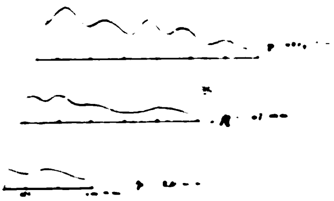
Fig [illegible] Hg



Hg



ig 22



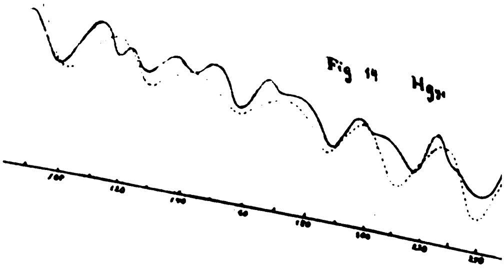


Fig 14 Hg_{31}

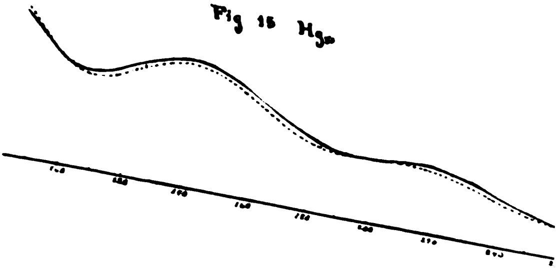


Fig 15 Hg_{20}

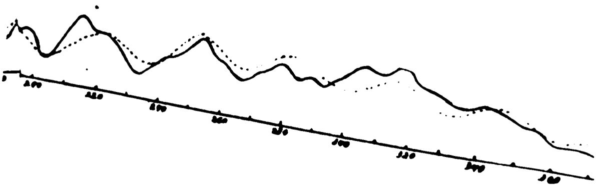
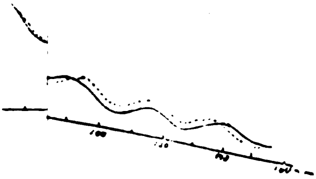
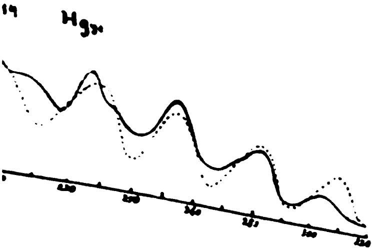


Fig 17 Hg_{v}



19



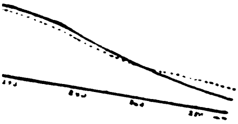
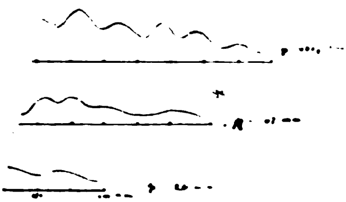
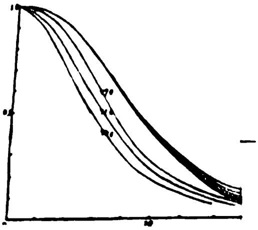


Fig 22





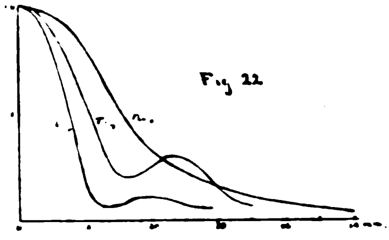
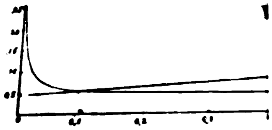
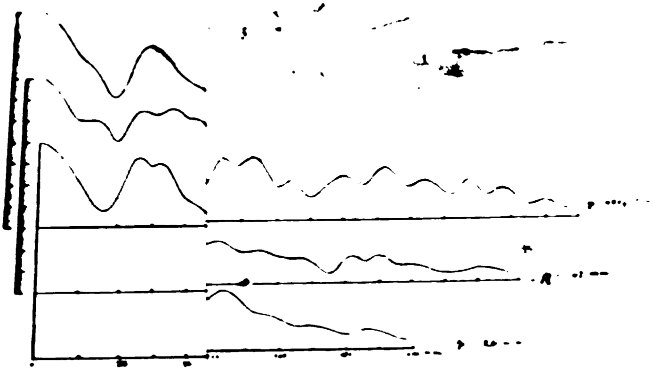


Fig 22





may be ignored, and it will be shown that in the case of hydrogen this is the case when the presure is one or two millimetres.

In most of the cases investigated the pressure was so low that the discharge passed with difficulty. Supposing, then, the effect of collisions to be insignificant, let it be proposed to find the effect due to the motion of the molecule in the line of sight. If v be the mean velocity of the molecule and V that of light, then the formula for the resulting visibility-curve, as given by Lord Rayleigh* is $h = (1 - a'')/(1 + a'')$.

If the definition of visibility as given above be taken, however, this becomes

$$V = a'' = \exp\left[-\pi\left(\frac{\pi X}{\lambda}\,\frac{v}{V}\right)^2\right].$$

If Δ be the difference of path at which the visibility is reduced to half its value at $X = 0$, then

$$\Delta = \frac{1}{\pi}\sqrt{\frac{l2}{\pi}} \cdot \frac{V}{v}\lambda,$$

or approximately,

$$\frac{\Delta}{\lambda} = .15\frac{V}{v}.$$

If we take for hydrogen $v = 2000$ metres per second, then $\frac{\Delta}{\lambda} = 22500$.

Again, if we ignore the difference in the temperature (about which there is considerable uncertainty), at which the other substances were examined, the velocities v would vary inversely as the square root of the atomic weight, and the number of waves in the difference of path at which the visibility is 0.5 is therefore $22500\sqrt{m}$.

Considering the difficulties and uncertainties of the problem, the following Table shows a remarkable agreement between the values actually found and the calculated results.†

---

* "On the Limit to Interference when Light is Radiated from Moving Molecules," Phil. Mag. April 1889.

† It should be stated that the value of Δ for the yellow sodium-line, if taken from the curve, would be much larger than that given. The latter was the mean of a number of observations taken within the past month. As has been stated before, this particular curve has not been obtained since last year. A few other substances, very difficult to examine, either because the lines are too feeble, or because the spectrum is so unstable, have given results not quite so consistent as the above, though all are of the same order of magnitude as that required by theory.

Substance.	At. Wt.	λ.	Δ.	$N = \frac{\Delta}{\lambda}$.	N. (Calc).
H_r	1	656	19.0	30000	22500
H_b	1	486	8.5	18000	22500
O	16	616	34.0	55000	80000
Na_r	23	616	66.0	107000	108000
Na_y	23	589	80.0	133000	108000
Na_{gy}	23	567	62.0	109000	108000
$Na_g{}'$	23	515	44.0	85000	108000
$Na_g{}''$	23	498	55.0	110000	108000
Zn_r	65.5	636	66.0	104000	182000
Zn_b	65.5	481	47.0	98000	182000
Cd_r	112.0	644	138.0	215000	238000
Cd_g	112.0	509	120.0	236000	238000
Cd_b	112.0	480	64.0	134000	238000
$Hg_y{}'$	200.0	579	230.0	400000	317000
$Hg_y{}''$	200.0	577	154.0	270000	317000
Hg_g	200.0	546	230.0	420000	317000
Hg_b	200.0	436	100.0	230000	317000
Tl	203.6	535	220.0	400000	322000

In order to show conclusively that the effect of density may be neglected in the foregoing observations, as well as to ascertain the law governing the broadening of spectral lines by pressure or density, a series of observations was made on the red hydrogen-line at varying pressures, with the results shown in fig. 19 *a*, Plate XLV.*

From these curves the following Table was calculated :—

Pressure in millim.	δ
90	.128
71	.116
47	.095
23	.071
13	.056
9	.053
3	.050
5	.048

In fig. 19 *b* the curved line gives the relation between δ and $\frac{1}{p}$, and shows clearly that when p is less than 5 millim. the effect of collisions has almost entirely ceased. If we take as variables δ and p, the results agree very closely with the straight line $\delta - \delta_0 = kp$, in which $\delta_0 = .047$ (the "half-width" of the line at zero pressure in the units adopted), $k = .00093$, and p is the pressure in millimetres.†

The same results were found for the blue hydrogen-line, though, as might be expected, these were not so consistent.

It thus appears that in the case of hydrogen—and probably in all other cases—the width of the spectral line diminishes towards

---

* The numbers against the curves denote pressure in millimetres.

† In the figure, the numbers representing values of the abscissæ for this line should be multiplied by 100.

a limit as the pressure diminishes, which depends upon the substance and its temperature; and that the excess of width over this limit is simply proportional to the pressure.

In general, it may be said that, under considerable ranges of temperature and pressure, the character of the visibility-curve remains the same; but it may be important to note that there are a number of exceptions to this rule, among which the green mercury-line and the yellow sodium-line may be especially mentioned.

Thus, fig. 20 *a*, Plate XLV, represents the visibility-curve usually observed for the green mercury-line, and fig. 20 *c* represents that obtained when the vacuum is so high that the discharge passes with difficulty, while fig. 20 *b* represents the intermediate stage. This last observation was obtained by placing the mercury in an atmosphere of hydrogen whose pressure could be measured by a McLeod gauge.

It might be objected that the presence of a foreign substance might of itself affect the distribution of light in the source, and therefore the form of the curve. In order to test this point, a series of observations of the red hydrogen-line was taken, while the tube contained liquid mercury, which was heated until the mercury-spectrum was at least ten times as bright as that of the hydrogen. The character of the visibility-curve was not perceptibly altered.

In the same series of experiments it was found that, provided the pressure of the hydrogen remained constant, the effect of a change in temperature from 75° to 140° had no appreciable effect on the result. In this connection it may be mentioned that the character of the curve for the green mercury line was not essentially altered when, in place of metallic mercury, the nitrate, iodide, or the chloride was substituted, the only important effect being a diminution in the visibility in the order named.

In the case of yellow sodium light, it has already been mentioned that the character of the curve is more variable than that of any other line thus far examined. This is illustrated by the curves in figs. 21 *a* and 21 *b*, Plate XLV. It has not been possible thus far to devote the attention which a systematic investigation demands. These changes are very puzzling to trace, but undoubtedly much of the difficulty is due to the fact that the dispersion employed was not sufficient to permit the separate examination of the components. Still, there can be no doubt that the width of the lines, their distances apart, and their relative intensities vary rapidly with changes in temperature and pressure.

In addition to the preceding investigations of visibility-curves for light emanating from a rare gas or vapor in a vacuum-tube, the curves for sodium, thallium, and lithium in the flame of a Bunsen-burner have been observed; and the results are given in fig. 22, Plate XLV. The thallium and lithium-lines are clearly double; the distance between the components of the former agreeing very well with the results obtained with the vacuum-tube.

These substances were brought into the flame in the ordinary way, and the results obtained were at least as good as when a finely divided solution was used according to the method of Gouy. It appears from these curves that the width of the line is about ten times as great as when the vacuum-tube is used. But if the temperature of the flame be taken at 1500° C. and that in the vacuum-tubes at 350° C., the lines should be only twice as broad in the former case as in the latter. It appears, then, that notwithstanding the small quantity of substance present (barely enough to color the flame), the real density must be comparable to that of the vapor of the substance boiling under atmospheric pressure.

The principal object of the foregoing work is to illustrate the advantages which may be expected from a study of the variations of clearness of interference-fringes with increase in difference of path. The fundamental principal by which the "structure" of a line or group of lines is determined by this method is not essentially different from that of spectrum-analysis by the grating, both depending, in fact, on interference phenomena; but in consequence of the almost complete freedom from errors arising from defects in optical or mechanical parts, the method has extraordinary advantages for this special work. A glance at fig. 18, Plate XLV., will give a fair idea of the "resolving-power" of the method as compared with that of the grating. In order that the comparison be quite fair, however, it would be necessary to take for a comparison-spectrum that of the substances here used, and under the same conditions. With the best instrumental appliances now in use, it is difficult to "resolve" lines as close together as the components of either of the yellow sodium-lines. It is evident, however, that by *Light-wave Analysis* (if I may venture so to call the foregoing method) a tenth of this distance is obviously within the limit; indeed, if the width of the lines themselves be less than their distance apart, there can be no limit.

SUPPLEMENT.

I. It has already been pointed out that in many cases it is difficult or impossible to decide between two or more distributions of lines which give very nearly the same visibility-curve; and when there are many lines in the source, the combinations of intensities and arrangement of these from which a type may be selected is enormously great. Indeed, even when the number of lines is greater than three, excepting perhaps the cases where the lines may be in pairs (as in the case of yellow sodium-light), the resulting visibility-curve becomes so complex that it is very difficult to analyse. Doubtless in many cases where the components are not too close, the grating will give the information necessary for the investigator to select the proper combination.

It may readily be shown that the formula

$$V^2 = \frac{C^2 + S^2}{P^2},$$

for the *visibility*-curve due to a distribution of light, $y = \varphi(x')$, is identical with that of the *intensity*-curve at the focus of a telescope provided with apertures which produce this distribution in the light passing through. Accordingly, if a telescope be provided with apertures adjustable in width, (or length) and distance apart, the diffraction image of a distant illuminated slit will give, at once, a representation of the whole visibility-curve; and by adjustment of intensities and distances any particular visibility-curve may be more or less accurately copied, thus furnishing a means of studying the relations between V and $\varphi(x)$, which, while giving perhaps only a rough approximation to the truth, may prove more convenient than analytical or graphical methods.

II. One of the purposes which led to these investigations was the search for a radiation of sufficient homogeneity to serve as an ultimate standard of length. It will appear from the curves of cadmium that there are three lines which may be used for this purpose. The red cadmium-line is almost ideally homogeneous, and will readily permit the estimation of a change of phase in the interference-fringes of one hundredth of a fringe in a total distance of 200 millimetres, or over 300,000 waves.

Both the green and the blue lines are fairly well adapted for the purpose, and will prove very valuable as checks. Each of these, however, has a small companion, and it is necessary to know the effect of this in altering the phase of the interference-bands.

If φ be the fraction of a wave by which the position of a minimum is shifted on account of the presence of the companion, α the number of "periods" in the difference of path, and r the ratio of the intensities, then

$$\tan 2\pi\varphi = -\frac{r \sin 2\pi\alpha}{1 + r \cos 2\pi\alpha}.$$ [*]

Thus, if $r = 1/4$, φ is a maximum when α is about $1/3$; and for this we have, approximately, $\varphi = -.04$.

This is the largest correction to be applied, and is negative if the brighter line has the greater wave-length. It is theoretically possible, by this means, to determine, in case of an unequal double, or a line unsymmetrically broadened, whether the brighter side is toward the blue or the red end of the spectrum.

III. It has been argued that, even if all practical difficulties in making large gratings could be removed, nothing further could be gained in resolution of groups of spectral lines, on account of the real width of the lines themselves, caused by the lack of homogeneity in the radiations which produce them. The results of the preceding investigations show that, while this is very far from being true with present gratings, such a limit undoubtedly exists. The accordance between the measured widths of eighteen lines shows, further, that this broadening of lines in a rare gas can be fully accounted for by the application of Döppler's principle to the motion of the vibrating atoms in the line of sight, and indeed furnishes what may be considered one of the most direct proofs of the kinetic theory of gases.

The form of the ultimate components of all the groups of lines thus far examined is found to agree fairly well with an exponential curve, $\varphi(x) = e^{-a^2x^2}$, which shows that the distribution of velocities cannot vary widely from that demanded by Maxwell's theory.

If the limit above mentioned were due solely to the motion of the molecule, and the radiating substance could be rendered luminous while its temperature was very low, it might be possible to observe interference-phenomena with difference of path of many metres. But it must be considered that, since every vibrating molecule is communicating its energy to the æther in the form of light-waves, its vibrations must diminish in amplitude; consequently the train of waves is no longer homogeneous even though the vibrations remain absolutely isochronous, and the result is a broadening of the line and limitation of the difference of path at which interference is visible.

---

[*] See Phil. Mag. April 1891, page 345. (The value of r is the reciprocal of that here used.)

ON THE NEW STAR IN THE CONSTELLATION AURIGA.*

H. SEELIGER.

The phenomena presented by the new star in Auriga were in the highest degree remarkable. Spectroscopic, as well as photometric observations, were much more numerous than in previous apparitions of this kind, and for this reason they have sufficed to show that a number of explanations which had been given of earlier new stars, with more or less plausibility, are in the present case untenable. On the other hand, it is very difficult to combine the details of all the published observations in a manner which is desirable for a satisfactory test of a definite hypothesis. It therefore seems to me appropriate to present a new attempt at explanation, in a hypothesis which appears to agree better than others with the principal results of observation, but the final test of which in all its details must be left to the future. Should difficulties be encountered in applying it to the present case, which I admit is possible, though scarcely probable, it nevertheless deserves a somewhat exhaustive discussion, since it deals with conditions which I believe to be entirely possible, and it is therefore a valid hypothesis for the appearance of certain new stars. I shall therefore, in more firmly establishing this hypothesis, confine myself to the conditions which are regarded by observers as proved by the results of their observations, an examination of the latter not coming within the scope of these lines. I may state that I gave the substance of the following remarks in a treatise published in March of the present year.†

The principal results of observation, which may be regarded as characteristic of the entire phenomenon, are the following:

(1.) According to Herr Lindemann,‡ the light curve of the Nova exhibited these peculiarities:

"From the 1st to the 3d of February the photometric curve rose rapidly to a brightness of $4^{\mathrm{m}}.7$, then sank gradually until Feb. 13th, and more rapidly until Feb. 16th, when the brightness was $5^{\mathrm{m}}.8$. On Feb. 18th it reached a second maximum of $5^{\mathrm{m}}.14$, had then on Feb. 23 a second minimum, likewise of $5^{\mathrm{m}}.8$, then a third maximum on March 2 again of $5^{\mathrm{m}}.4$, then sank, at first

---

* Translated from A. N. 3118. The unit of length adopted by Prof. Seeliger—the German geographical mile—has been retained in the translation, as the numerical results of the mathematical treatment are of no special importance. 1 German mile = 4.61 English miles.—Tr.

† Neber allgemeine Probleme der Mechanik des Himmels, S. 28. München, 1892.

‡ A. N. 3094.

slowly until March 6th, then quickly, in a straight line, reaching the 9^{m}.3 on March 22d. To this is to be added that the photographs taken at Harvard College show that the star began to be visible in the beginning of December, 1891, and had already reached a maximum of brightness on Dec. 20—22, which however did not quite equal the later one on Feb. 3d.

(2.) The spectrum of the new star was very remarkable. Herr Vogel says in regard to it, summing up the results obtained at Potsdam*: "The observations have led to the altogether interesting result, that the spectrum of the Nova consists of two superposed spectra, and that a number of lines, particularly those of hydrogen, which appear bright in one spectrum and dark in the other, have a strong relative displacement. This result can hardly be interpreted otherwise than as signifying the presence of two bodies having a very considerable motion in the line of sight. . . . . . . The two bodies were separating with a relative velocity which did not vary appreciably during the four weeks of observation (in February), and which was at least 120 (German) miles per second." To this should be added that a number of maxima of brightness appeared in the very broad bright lines, two of them being fairly distinct. *

To explain these facts it has been assumed that two bodies passed very close to each other, and that the changes which were thereby produced in their atmospheres caused the sudden outburst of light. As thus stated, the hypothesis is much too vague for detailed application. It is true that, following a suggestion by Klinkerfues, an attempt has been made to form a more definite conception of the phenomenon, by assuming the existence of a powerful tidal action between the two bodies; at places covered by the flood of the atmospheric tide there would be a darkening due to absorption, and at the places of the ebb the reduction in thickness of the atmospheric strata would cause an accession of brightness. To this the objection must be made that the static theory of the tides, which is used throughout, is quite incapable of giving a correct representation of the deformations which are doubtless produced by the close passage of the two bodies; for with very eccentric orbits (which it is necessary to assume on other grounds), the continually varying action would last for so short a time that one could scarcely expect to derive a trustworthy conclusion in regard to the actual circumstances from a consideration based on the forms which the bodies could assume

---

* Vierteljahrschrift der Astr. Gesellsch. Band 27, S. 141.

* A. N. 3079.

in equilibrium;—not taking into account the fact that such a consideration generally yields only approximate results, the accuracy of which it is impossible to estimate. In the case of Nova Aurigæ particularly, as will be shown farther on, the action of the two bodies on each other must be regarded as arising almost suddenly and then vanishing. It should further not be overlooked, that the atmosphere of an incandescent heavenly body must be regarded as the outer envelope of a series of denser strata, and that these also are distorted, although by a smaller amount. On this account it has generally been held that the distortion is accompanied by eruptions of gas from the interior of the body. This assumption contains truly nothing impossible, but without greater definiteness it is scarcely serviceable for purposes of discussion. At any rate, it would be necessary to make still further hypotheses to make this explanation hold when applied to special cases. Thus, in the case of Nova Aurigæ there would still remain unexplained, why one spectrum is in the main an absorption spectrum, the other a spectrum of incandescent gas. It is true that this difficulty could be obviated by means of special assumptions, but it is not very probable that our confidence in the validity of the hypothesis would be thereby increased.

In Nova Aurigæ still other facts present themselves, which do not speak in favor of the hypothesis. It is at least very surprising that just here we should meet with cosmical masses moving with velocities so enormous as to be almost unprecedented. The existence of such velocities must, therefore, be regarded as one of the facts to be explained. Formulæ are given farther below which up to a certain point allow the mechanical conditions of the close passage of two cosmical bodies to be followed mathematically. From these formulæ it follows that in Nova Aurigæ the two bodies could describe parabolas around each other, only in case their united masses were very much greater than 15,000 times the mass of the Sun. For a hyperbolic motion it is possible to arrive at materially smaller masses only by assuming that the observed great relative velocity of 120 miles per second has been produced in only a small degree by their attraction, and that it existed almost entirely in the beginning. We have, therefore, either to choose the assumption of extremely great masses, or renounce an explanation of the great relative velocity. Now neither assumption contains an actual impossibility, but I do not believe that unequivocal testimony for the correctness of the hypothesis can be recognized in either of them. In my mind they make the hypothesis very much less plausible.

The formulæ already mentioned show, as will be explained more fully below, that the supposed action of the two bodies in the present case must have passed off very rapidly, perhaps that it could have been brought into play for but a few hours. The action must necessarily have taken place at the first outburst of the star, in the beginning of December, 1891. Why, therefore, the Nova should have reached a second, and, to all appearances, greater maximum several weeks later (in the beginning of February, 1892), and further, why the light curve should have sunk slowly until the beginning of March and then have fallen off rapidly; seems to me to be scarcely, if at all, explicable, on the ground of the hypothesis above mentioned. The difficulty will at any rate exist until it is expressly obviated in all its details.

The difficulties which have been above briefly touched upon, disappear entirely in the light of the following considerations. The results obtained by astronomical photography, particularly the work of Herr Max Wolf, have left no doubt that space is filled with more or less extensive aggregations of thinly scattered matter. The physical constitution of these cosmical clouds will obviously differ greatly, and we may leave this question open, without investigating it further. Now, that a heavenly body should become involved in such a cosmical cloud is in itself not improbable, and at any rate it is much more probable than the close approach of another compact body required by the hypothesis which has been considered above. But as soon as a body enters such a cosmical cloud, its surface will begin to be heated, no matter what the constitution of the sparsely distributed material may be. In consequence of the superficial heating, vaporized products will form around the body, which will in part become detached from it and quickly assume the velocity of the neighboring parts of the cloud.

It will be appropriate to compare such an occurrence with the well known and quite similar one of shooting-stars or meteors. In this case, also, a compact body, moving with a certain velocity, penetrates a mass of very tenuous matter (the upper strata of the atmosphere); it is heated and partially vaporized, and its path is marked by a luminous train, which is often visible for a long time after the sudden appearance of the meteor. The separated particles quickly lose their velocity relatively to the air, for they scarcely seem to follow the motion of the meteor.

If the star thus made incandescent by resistance should be examined with a spectroscope, two superposed spectra would obviously be seen. One would in general be continuous, with absorbtion lines due to the glowing gaseous envelope; the other would consist principally of bright lines. Both spectra would be displaced with respect to each other by an amount depending upon the relative velocity in the line of sight. Thus the whole appearance would be quite similar to that observed in Nova Aurigæ, and a complete agreement may be brought about by assuming, if necessary, that physical changes due to direct heating effect, friction of the separated particles, etc., would take place in the parts of the cloud next to the solid body. In view of our ignorance of the properties of the cloud material, this assumption does not seem to me to offer any difficulties. Whether it is in any case necessary I do not need to decide for the purposes of the present article.

Of very great importance, however, is the investigation of the question whether we can in this way arrive at a plausible explanation of the great relative velocity indicated by the two spectra. On the approach of the body, the cloud would evidently be lengthened in the direction of approach. This lengthening and likewise the relative velocity of the individual cloud-particles with respect to the body, would grow with the increasing proximity of the latter. Without some definite provision in regard to the structure of the cloud, it is difficult to give any detailed representation of the phenomenon that will ensue, and we must content ourselves with considering some special case which will allow of closer investigation. If we assume, for example, that the separate particles of the cloud are in general influenced only by the attraction of the body, they will describe hyperbolas around the latter with its center as focus. Their greatest relative velocity will diminish rapidly with the distance from the body, so that the neighborhood of the latter will be filled with particles having very different velocities. It is easy to see that no extravagant assumption is required to obtain very great velocities for the particles which pass close to the surface of the body,—velocities such as have been proved to exist in the case of Nova Aurigæ, and this even when the initial velocity of the particles is very small. It also follows, from what has been shown above, that the spectral lines of particles moving away from the body with such different velocities must be greatly widened; moreover, not only is not the slightest difficulty encountered in explaining the different brightness of various parts of these lines, but the existence of such maxima of brightness follows as a necessary consequence. This point does not seem to me to be unimportant, since it cannot be deduced from the hypothesis of the close passage of two compact masses, but leads to the very improbable assumption that there are several moving bodies of this kind.

As long as the body moves within the cosmical cloud, the appearances just described will be continually reproduced, and it follows that the characteristic features of the spectrum, apart from minor changes determined by all the circumstances of the case, must as a whole remain unchanged for a considerable time; a point which is not clear without further explanation on the ground of the first described hypothesis. It is also not surprising that during this time the brightness of the star should undergo little variation, but that it should fall off pretty rapidly after the emergence of the body from the cloud. This also agrees well with the observed light curve of the Nova. Finally, the periodic fluctuations of brightness are quite naturally explained. It is only necessary to remember the known fact, recently confirmed photographically by Herr Max Wolf, that the same phenomena are exhibited by meteors, and are explicable without difficulty.

We must in any case assume that the star entered the cosmical cloud in the beginning of December, and left it not long before the beginning of March. The question at once presents itself, how such a great relative velocity could exist for so long a time, notwithstanding a resitance sufficiently great to generate the heat required for the continuous incandescence of the body. We will decide this question by comparing the resisted motion of the star with that of a meteor in the upper layers of the atmosphere.

We may assume, with sufficient generality, that the rectilinear motion of the star is given by the equation

$$\frac{dv}{dt} = -\lambda v^n \qquad (1)$$

in which v is the velocity, n is a positive number > 1, and λ is a constant which is proportional to the surface of the spherical body and the density of the medium, and inversely proportional to the mass of the body. Let us now compare equation (1) with the equation for the motion of a meteor,

$$\frac{dv'}{dt'} = -\lambda' v'^n$$

in which the time t' is now reckoned by another suitably chosen unit. If we place

$$v' = \mu v; \quad t' = \nu t; \quad \lambda = \lambda' \nu \mu^{n-1}, \qquad (2)$$

the latter equation will be identical with (1); *i. e.*, the motion of the star will correspond at every point with the motion of the meteor if equation (2) is satisfied. If we now represent by m, O, r, δ, respectively the mass, surface, radius, and density of the star, by m', O', r', δ', the corresponding quantities for the meteor, and by D and D' respectively the densities of the cosmical cloud and atmospheric layer in question, we have

$$\frac{\lambda}{\lambda'} = \frac{DOm'}{D'O'm}; \quad \nu = \frac{1}{\mu^{n-1}} \cdot \frac{DOm'}{D'O'm}$$

or also

$$\nu = \frac{t'}{t} = \left(\frac{\mathrm{v}}{\mathrm{v}'}\right)^{n-1} \cdot \frac{r'\delta'D}{r\delta D'} \tag{3}$$

If we further place $r = k$ times the Sun's radius ($=$ 700 million metres) and $r' = r'$ metres, and in accordance with the observations of the new star, place $\mathrm{v} = 30$, (the unit being the Earth's orbital velocity), $t = 100$ days, and $\mathrm{v}' = 2$ (which corresponds to the velocity of a rather quickly moving meteor), and finally $n = 2$, then

$$\nu = \frac{15}{k} \cdot \frac{D\delta'}{D'\delta} \cdot \frac{r'}{700 \text{ mill.}}$$

and

$$t' = 0^s.185f; \quad f = \frac{r'\delta'D}{k\delta D'}$$

The motion of the star falls off in 100 days by the same relative amount as that of the meteor in 0.185 seconds, if we place $f = 1$. Since we are, moreover, free to assume that $\frac{D}{D'}$ is small, we can reduce the time to a very small part of a second, and as in a few hundredths of a second the motion in the highest regions of the atmosphere is not sensibly retarded, there will likewise be no sensible retardation in the motion of the star. We have evidently a parallel to this result in the fact that the motion of a small body is more affected by atmospheric resistance than that of a large one, and that the resistance of the air has a much smaller effect on the orbital relations of large meteors than on those of small ones.

But we must now show that in spite of this small retardation of the motion of the body, sufficient kinetic energy is transformed into heat to cause the *superficial* incandescence of the star, such a state of incandescence, at least, having occurred in the case of Nova Aurigæ. We must therefore compute the quantities of heat Q and Q' which are generated per second on a unit surface of the two bodies respectively. If we call P and P' the loss of kinetic energy during the times t and t', and v_0 and v_0' the velocities before entering the resisting medium, then

$$Q = \frac{P}{Ot}; \quad Q' = \frac{P'}{O't'}$$

and

$$P = m(v_0^2 - v^2); \quad P' = m'(v_0'^2 - v'^2)$$

and with the aid of the previously deduced formulæ,

$$\frac{Q}{Q'} = \frac{D}{D'}\left(\frac{v}{v'}\right)^{n+1}$$

with the same numerical values as before, $\frac{v}{v'} = 15$; $n = 2$,

$$\frac{Q}{Q'} = 3375\,\frac{D}{D'}$$

so that we can assume that the density of the cosmical medium is very small compared with that of the extremely tenuous air in which the meteor is brought to incandescence, and still obtain the necessary quantity of heat. It is worthy of remark that all the numerical values can be varied within very wide limits without danger of contradiction. We therefore conclude that from this point of view also, no difficulties are opposed to the hypothesis which has been advanced.

I have now to deduce formulæ, which have been already referred to, and which are in themselves of considerable interest.

If we represent by μ the sum of the masses of two bodies moving around each other in conic sections, by V the velocity, and in other respects follow the customary notation, we have for the parabola,

$$V^2 = k^2\mu\,\frac{2}{r}; \quad r = \frac{q}{\cos^2\frac{1}{2}v}$$

$$\tan\tfrac{1}{2}v + \tfrac{1}{3}\tan^3\tfrac{1}{2}v = \frac{k\sqrt{\mu}\,t}{q^{\frac{3}{2}}\sqrt{2}}$$

from which immediately follows:

$$\mu = \frac{V^3 t}{4k^2 \sin\frac{1}{2}v\left[1 - \frac{2}{3}\sin^2\frac{1}{2}v\right]}.$$

Let us call c the velocity of the Earth in its orbit with radius R, and place the mass of the Sun plus that of the Earth $= 1$, so that $k^2 = c^2R$. If we further consider that the expression

$$\sin\tfrac{1}{2}v\left[1 - \tfrac{2}{3}\sin^2\tfrac{1}{2}v\right]$$

can attain the maximum value $\frac{\sqrt{2}}{3}$, it follows that

$$\mu > \frac{3}{4\sqrt{2}}\left(\frac{V}{c}\right)^3 \cdot \frac{ct}{R}$$

or if c is expressed in days,

$$\mu > 0.009123 \left(\frac{V}{c}\right)^3 t \qquad (4).$$

In order to apply this to the Nova, we must note that $\frac{V}{c} > 15$, since the orbital velocity can be considerably greater than the velocity in the line of sight. Further, more than two months elapsed after the supposed passage of the two bodies, which must nearly coincide with the time of periastron, up to the time at which spectroscopic observations could still be made. t is therefore much greater than 60. The formula (4)

$$\mu > 14779 \text{ times the mass of the Sun}$$

gives therefore a limit in which the masses are far too small. In reality we can perhaps takedouble this value without danger of contradiction.

Similar, although less simple considerations apply to the case of hyperbolic motion.

If V_0 represents the velocity at an infinite distance, we have

$$V^2 - V_0^2 = \frac{2k^2\mu}{r}$$

and according to the Theoria Motus,

$$\frac{r}{a} = \frac{e - \cos F}{\cos F};$$

$$e \tan F - \log \tan (45^\circ + \tfrac{1}{2}F) = \frac{k\sqrt{\mu}t}{a^{\frac{3}{2}}},$$

from which we find at once,

$$\left.\begin{aligned} \mu &= \left(1 - \frac{V_0^2}{V^2}\right)^{\frac{3}{2}} \cdot \left(\frac{V}{c\sqrt{2}}\right)^3 \cdot \frac{cA}{R} X \\ X &= \left(\frac{e - \cos F}{\cos F}\right)^{\frac{3}{2}} \cdot \frac{1}{e \tan F - \log \tan (45^\circ + \frac{1}{2}F)} \end{aligned}\right\} (5).$$

As F increases from 0° to 90°, the expression for X first diminishes, reaches a minimum, and then increases up to infinity. The minimum value is readily determined from the condition

$$\frac{3}{4} \frac{e \sin 2F}{(e - \cos F)^2} [e \tan F - \log \tan (45^\circ + \tfrac{1}{2}F)] = 1.$$

This equation is easily solved for special values of e. For the purposes of the present investigation I have adopted another course, assigning various special values to e and computing the corresponding values of X, as shown in the following table:

	$e = 1.5$	2.0	4.0	6.0	8.0	10.0
$F = 4°$	10.207	14.393	24.882	32.111	37.988	43.071
8	5.224	7.302	12.554	16.182	19.135	21.689
12	3.614	4.987	8.494	10.930	12.913	14.630
16	2.852	3.866	6.505	8.348	9.853	11.156
20	2.429	3.226	5.345	6.838	8.059	9.118
24	2.178	2.827	4.603	5.866	6.902	7.802
28	2.027	2.569	4.343	5.204	6.112	6.902
32	1.941	2.400	3.753	4.740	5.555	6.265
36	1.900	2.293	3.510	4.411	5.158	5.810
40	1.892	2.234	3.345	4.181	4.877	5.486
44	1.911	2.211	3.240	4.029	4.688	5.266
48	1.953	2.220	3.187	3.941	4.574	5.131
52	2.017	2.257	3.179	3.911	4.528	5.072
56	2.101	2.323	3.217	3.936	4.547	5.086
60	2.208	2.420	3.301	4.020	4.633	5.175
64	2.341	2.552	3.438	4.170	4.797	5.351
68	2.510	2.729	3.644	4.404	5.056	5.635
72	2.728	2.968	3.944	4.754	5.451	6.070
76	3.026	3.307	4.390	5.286	6.055	6.739
80	3.477	3.830	5.108	6.152	7.048	7.843
84	4.308	4.802	6.480	7.824	8.972	9.991
88	6.991	7.938	10.960	13.320	15.321	17.091

For very large values of *e* the minimum of *X* occurs when

$$\sin F = \sqrt{\frac{2}{3}}$$

and the minimum value is

$$\text{Min } X = \sqrt{\frac{3^{\frac{3}{2}} e}{2}} = 1.612 \sqrt{e}. \qquad (6)$$

We shall make no appreciable error if we use (6) for values of *e* not very different from unity, as will be seen in the following table, where the minimum values taken from the preceding table and those computed from formula (6) are placed side by side.

E	Direct.	Formula.
1	1.5	1.6
1.5	1.9	2.0
2	2.2	2.3
4	3.2	3.2
6	3.9	3.9
8	4.5	4.6
10	5.1	5.1

We thus obtain:

$$\mu > 0.0104\left(1 - \frac{V_0^2}{V^2}\right)^{\frac{3}{2}}\left(\frac{V}{c}\right)^3 \sqrt{e}\,.\,t. \qquad (7)$$

For the assumption $t = 60$, $\frac{V}{c} = 30$, we get

$$\mu > 16800 \sqrt{e}\left(1 - \frac{V_0^2}{V^2}\right)^{\frac{3}{2}}$$

a formula which holds for values of *e* not quite equal to 1. In order to include the parabola also we may write

$$\mu > 15000\sqrt{e}\left(\frac{V^2 - V_0^2}{V^2}\right)^{\frac{3}{2}} \qquad (7a)$$

Therefore in this case also we either arrive at masses which are extremely great, and therefore not very probable, or else we must assume that $\frac{V_0}{V}$ is very nearly $= 1$. Even for $\frac{V_0}{V} = 0.9$ we find from the above formula

$$\mu > 1200\sqrt{e},$$

from which it will be seen that the above assertion is justified. It has already been remarked that this inequality merely states that μ is very much greater than the right hand side. It is in fact easy, when $\frac{V_0}{V}$ does not differ much from unity, to find a superior limit for μ. If we place

$$\frac{V^2 - V_0^2}{V^2 + V_0^2} = \nu$$

we have

$$\cos F = \nu e$$

and by formula (5),

$$\mu = \left(\frac{1 - \nu}{1 + \nu}\right)^{\frac{3}{2}}\left(\frac{V}{c}\right)^3 \frac{ct}{R} \cdot \frac{\nu}{e\nu \tan F - \nu \log \tan\left(45^\circ + \frac{1}{2}F\right)}$$

For given values of t, e and ν we can compute the value of the right hand side. We will, however, seek the maximum value of $y = e\nu \tan F - \nu \log \tan(45^\circ + \frac{1}{2}F) = \sin F - \nu \log \tan(45^\circ + \frac{1}{2}F)$ by determining e as a function of ν.

$$\frac{dy}{de} = \left(\cos F - \frac{\nu}{\cos F}\right)\frac{dF}{de} = \frac{\nu(1 - \nu e^2)}{e\sqrt{1 - \nu^2 e^2}}$$

y therefore increases as long as $c < \frac{1}{\sqrt{\nu}}$ and diminishes continuously for $e > \frac{1}{\sqrt{V}}$. y is therefore a maximum when $e^2 = \frac{1}{\nu}$, and the maximum value is

$$y = \sqrt{1 - \nu} - \nu \log\left(\frac{1 + \sqrt{1 - \nu}}{\sqrt{\nu}}\right)$$

We have therefore

$$\mu > \frac{ct}{K}\left(\frac{V}{c}\right)^3\left(\frac{1 - \nu}{1 + \nu}\right)^{\frac{3}{2}} \cdot \frac{\nu}{\sqrt{1 - \nu} - \nu \log\left(\frac{1 + \sqrt{1 - \nu}}{\sqrt{\nu}}\right)} \qquad (8)$$

and with $\frac{V}{c} = 30$, $t = 60$ days,

$$\mu > 27800\left(\frac{1-\nu}{1+\nu}\right)^{\frac{3}{2}} \cdot \frac{\nu}{\sqrt{1-\nu} - \nu \log\left(\frac{1+\sqrt{1-\nu}}{\sqrt{\nu}}\right)}$$

For the above example $\frac{V_0}{V} = 0.9$, the result is now

$$\mu > 2800$$

thus a considerably greater mass than before.

I have now to give a more complete proof of the statement that the two bodies could be in close proximity for a very short time only. For this purpose we make use of the following relations:

For the parabola we have found

$$\mu = \frac{V^3 t}{4k^2 x}; \quad x = \sin \tfrac{1}{2}v[1 - \tfrac{2}{3}\sin^2 \tfrac{1}{2}v]$$

from which it follows, since $V^2 = \frac{2k^2\mu}{\nu}$, that

$$r = \frac{Vt}{2x}$$

We have therefore

$$r > \frac{3}{2\sqrt{2}}Vt = 1.06Vt. \tag{9}$$

For the hyperbola we have

$$r = \frac{2k^2\mu}{V^2 - V_0^2}$$

and by formula (5)

$$2k^2\mu = \frac{(V^2 - V_0^2)^{\frac{3}{2}}}{\sqrt{2}}tX,$$

therefore

$$r = \frac{\sqrt{V^2 - V_0^2}}{\sqrt{2}}tX$$

For excentricities which are not quite equal to unity we had

$$X > \frac{3^{\frac{3}{4}}}{\sqrt{2}}\sqrt{e}$$

hence in either case

$$r > \frac{3^{\frac{3}{4}}}{2}\sqrt{e} \cdot \sqrt{V^2 - V_0^2}\, t > 1.06\sqrt{V^2 - V_0^2}\, t \tag{10}$$

For $V_0 = 0$, (10) of course becomes the same as (9). For the hyperbola we can apply a second relation.

Since
$$2\frac{a}{r} = \frac{V^2 - V_0^2}{V_0^2}$$
formula (5) may be written
$$k^2\mu = \left(\frac{a}{r}\right)^{\frac{3}{2}} V_0^3 tX$$
and since $k^2\mu = aV_0^2$, it follows that
$$r = \sqrt{\frac{a}{r}} \,.\, V_0 tX = V_0 ty$$
in which
$$y = \frac{e - \cos F}{\cos F} \cdot \frac{1}{e \tan F - \log \tan (45^\circ + \tfrac{1}{2} F)}$$
We now readily find that
$$\frac{dy}{dF} = \frac{-1}{e \sin F - \cos F \log \tan (45^\circ + \frac{1}{2}F)} \cdot$$
$$[(1 + e^2) \cos F - 2e + e \sin F \log \tan (45^\circ + \tfrac{1}{2}F)]$$
It is easy to see that the bracketed expression is always positive, since
$$\log \tan (45^\circ + \tfrac{1}{2}F) = 2 \tan \tfrac{1}{2}F + \tfrac{2}{3} \tan^3 \tfrac{1}{2}F + \ldots . > 2 \tan \tfrac{1}{2}F$$
and consequently the expression in brackets $> (e - 1)^2 \cos F$. $\frac{dy}{dF}$ is therefore negative, and y diminishes as F increases. From this it follows that
$$y > 1$$
and we obtain the relation
$$r > V_0 t. \tag{11}$$

Applying this formula to the case of Nova Aurigæ we find that for

$\frac{V_0}{V} = 0.5$;	$\sqrt{V^2 - V_0^2} = 108$ miles;	$V_0 =$ 60
0.6	96	72
0.7	86	84
0.8	72	96
0.9	—	108

Near perihelion the velocity was in all cases greater than 120 miles, and we shall therefore obtain values of r quite materially too small if we place
$$r > t \times 85 \text{ miles.}$$

For one day either before or after perihelion it is therefore certain that
$$r > 7.3 \text{ million miles.}$$

It can therefore hardly be assumed that any mutual action beteen the supposed two bodies which is worthy of consideration could have lasted for more than a couple of hours.

MUNICH, July, 1892.

POSTSCRIPT.

Since the above article was written, the reappearance of Nova Aurigæ, and particularly the observations of Mr. Barnard, have again awakened interest in this star. So far as the reappearance of the star is concerned, it will be seen that this must be regarded as a visible confirmation of such parts of my article as are devoted to criticism. The hypothesis which I have advanced is moreover in no way contradicted, for it is from the nature of the case very probable that the supposed nebulous clouds, or aggregations of dust-like particles, should be more numerous in certain parts of space than in others. It is also allowable to make a great variety of assumptions in regard to the distribution of the denser parts of these clouds.

In regard to the observations of Mr. Barnard I have to add the following remarks: I had formed a mental picture of the processes that caused the outburst of the Nova, which was so completely realized in Mr. Barnard's drawing that I could desire no more perfect representation of it. No appearance of the kind was seen, so far as I know, during the winter. This naturally does not imply that it did not exist, and it seemed to be possible that photography, as often before in similar cases, might have some information to furnish. I therefore, in May of the present year, inquired of Dr. M. Wolf at Heidelberg whether he had any long-exposure photographs of the vicinity of the Nova, taken at that time, and if so, whether a nebulous object could be found on them. Unfortunately Dr. Wolf had none. It is indeed doubtful, from Mr. Barnard's description, whether so small an object would have been visible on a photographic plate.

ON THE CONDITION OF THE SUN'S SURFACE IN JUNE AND JULY, 1892, AS COMPARED WITH THE RECORD OF TERRESTRIAL MAGNETISM.*

GEORGE E. HALE.

The large collection of solar photographs which has already accumulated at the Kenwood Observatory places at our disposal a nearly complete record of the condition of the Sun's surface from

---

* Communicated by the author.

the first of last February up to the present time. The greater part of them have been taken with the spectroheliograph, and are of special value in the study of faculæ. The remarkable disturbance photographed on July 15 has led to a preliminary examination of the plates giving the early history of the spot in which it occurred, in order to trace, if possible, some relation between the condition of the solar surface and the simultaneous record of terrestrial magnetism. I am indebted to Mr. S. J. Brown of the U. S. Naval Observatory for copies of the magnetic record for the period July 11—17. A description of the Stonyhurst curves for the period June 11—July 29 is given by the Rev. Walter Sidgreaves in his article in the November number of ASTRONOMY AND ASTRO-PHYSICS. The following notes refer only to some of the more important features of the photographs, the complete reduction of the plates having not yet been undertaken. For convenience of reference the plate-numbers recorded in the observatory note-book are used in the discussion.

The position on the Sun's surface of the spot group in which the disturbance of July 15 occurred is first indicated on plate 752 (June 10, $1^h\,29^m$)[*] by a small and faint facula near the eastern limb. On plate 764 (June 11, $11^h\,25^m$) the facula has advanced on to the disc, and is still very faint. On the same date a large group of bright faculæ in the northern hemisphere of the Sun has just reached the central meridian. Plates 767 to 773 show no material changes in the small facula. On plate 775 (June 13, $10^h\,40^m$) the facula is well advanced on the disc, and contains a small spot. It is still quite faint and inconspicuous. On the same plate there is a large group of bright faculæ in the southern hemisphere, and several groups of faculæ extending entirely across the disc in the northern hemisphere. One of these contains two spots of considerable size, and has but recently crossed the central meridian. Plate 776 was taken shortly after 775, and shows the facula around Spot A[†] to be fairly bright, though still inconspicuous. The brighter (northern) portion of the facula has a curved form, and terminates in a knob-like expansion at each end. Plate 777 was taken an hour later, and shows slight changes in the form. On plate 780 (June 14, $11^h\,53^m$) the facula has undergone a marked change, and considerably increased in length. A large group of faculæ is near the meridian at this time. On plate 784 (June 15, $10^h\,27^m$) the facula is larger and

---

[*] In all records given in this paper Chicago Mean Time is used unless otherwise stated

[†] For convenience of reference, the spot-group in which the disturbance of July 15 occurred will be called "Spot A".

brighter, and exactly on the central meridian. A large group in the northern hemisphere is also on the meridian. Plates 785, 786, 787, 789, 790 (the last taken June 15, 2^h 27^m), record no important changes. On plate 791 (June 16, 10^h 47^m) the form of the facula is very materially changed; no increase in brightness is noticeable, however. On the same plate there is a bright facula on the central meridian in the northern hemisphere. Plates 792, 793, 794 (the last taken June 16, 11^h 48^m), show no changes. On plate 799 (June 17, 12^h 19^m) the facula has become a brilliant, roughly circular object, preceding a single large spot, and containing two other smaller spots. On the following side of the large spot there is a narrow faculous border. The facula is totally unlike that shown on plate 794, which contains only faint traces of very small spots. A marked disturbance accompanying the formation of the spots therefore occurred between June 16, 11^h 48^m and June 17, 12^h 19^m.

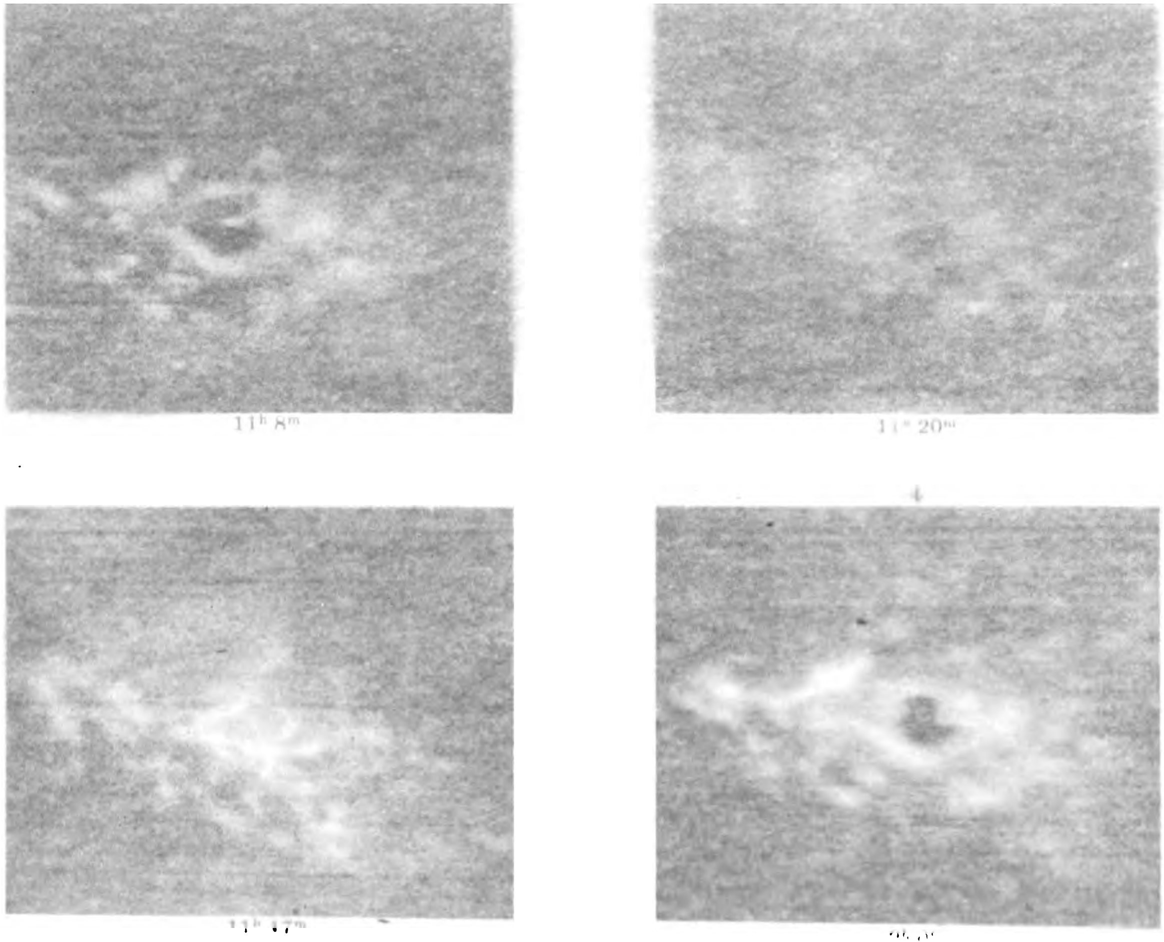
From Father Sidgreaves' paper we learn that "the magnets had been perfectly quiet from June 11 until at about 3 P. M. G. M. T. on the 16th, a slight disturbance commenced in the longitudinal force magnet. This continued, and later appeared in all three elements as a series of small intermittent oscillations, which lasted until the morning of the 18th." As Chicago is 5^h 50^m west of Greenwich, the disturbance of the magnets commenced June 16, 9^h 10^m Chicago M. T. Plate 794 was taken 2^h 38^m later, and up to this time no marked change had taken place in Spot A. On this plate there is a bright facula on the central meridian in the northern hemisphere, but there is nothing at the eastern limb of the Sun. Plate 799, which shows both prominences and faculæ in addition to spots, records no disturbance at the eastern limb, but shows a faint facula on the central meridian. It is evident, therefore, that so far as our records go, the magnetic perturbation was not caused by a simultaneous disturbance at the eastern limb of the Sun. As to whether it was caused by the sudden change in the spot, or, in accordance with Marchand's theory, by the passage of spots and faculæ across the central meridian of the Sun, we have no means of deciding. I am myself inclined to the former supposition, though it is of course quite possible that the magnetic perturbation was related to neither of these events.

We are informed by Father Sidgreaves that a series of small oscillations in the magnets again commenced on June 21, and continued until the morning of the 26th. An examination of the photographs does not seem to show any connection of Spot A with this disturbance. The spot and accompanying faculæ passed quietly around the western limb, if we may judge from photographs taken just before and just after the passage. Plate 811 (June 20, 1^h 35^m) is an excellent composite photograph showing both faculæ and prominences. On this plate Spot A is a short distance from the western limb, where there is shown only a long, low prominence. On plate 815 (June 22, 9^h 39^m) Spot A has disappeared behind the limb, and in a composite plate (817) taken at 4^h 22^m on the same day, no prominence is shown at the point where the spot disappeared.

There were, however, two very active groups of faculæ and spots on the Sun at this time. One of these was a large spot group with faculæ in the southern hemisphere, which changed greatly between June 17, 2^h 43^m (plate 801) and June 20, 9^h 42^m (plate 802). During this time the large (preceding) nucleus divided into two, each equalling the original single nucleus in area, and the smaller (following) nucleus acted similarly, a new nucleus adding itself to it. Another small nucleus also appeared in the northern part of the group. The activity in this group continued, and on June 22, 9^h 39^m (plate 815) there were three large nuclei, with bright faculæ following.

But a more remarkable group was one in the northern hemisphere, which is shown on plate 802 (June 20, 9^h 42^m) near the eastern limb. It then consisted of a large group of faculæ, with two well marked spot nuclei in the southern part of the group. Plate 806 (June 20, 11^h 27^m) shows the facula of about the same form, except for a marked change in the northern part of the group, a change somewhat similar to the phenomenon of July 15, though on a much smaller scale. Between two bright points—one of which seems to correspond with a small spot nucleus, and the other with a bright point, shown on plate 804 (June 20, 10^h 11^m)—there extends a straight, bright object, no trace of which is shown on plate 804, taken 1^h 16^m earlier. The bright object lies across a portion of the facula, and does not seem to affect its form in the least. In plates 807 (11^h 34^m) and 808 (12^h 30^m) it has given place to a broad and ill-defined expansion, which is much fainter; but the bright point, shown also on plate 804, in which the outburst may have had its origin, still remains.

During the same time other minor changes took place in the group. Plates 809, 810, 811 show no marked changes. On plate 815 (June 22, 9^h 39^m) the group has advanced well on to the disc, and is greatly changed in form. It is greatly lengthened in an east and west direction, and two well defined spot nuclei have appeared preceding it, where before there was only a small, faint


11h 8m
11h 20m
4
11h 17m

[illegible] the western limb, if we may judge from [illegible] just before and just after the passage. Pl[illegible] [illegible] 35^m) is an excellent composite, show[illegible] [illegible]culae and prominences. On this plate spot A i[illegible] [illegible] the western limb, where there is shown [illegible] [illegible] prominence. On plate 815 (June 22, 9^h 39^m) spot A [illegible] and the limb, and in a composite plate (817 [illegible] on the same day, no prominence is shown at the [illegible] has disappeared.

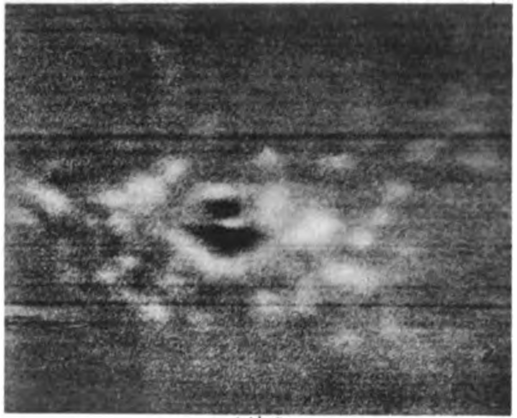
[illegible] however, two very active groups of faculae and [illegible] seen at this time. One of these was a large spot [illegible] faculae in the southern hemisphere, which developed [illegible] between June 17, 2^h 43^m (plate 801) and June 20, 9^h 42^m [illegible] 802). During this time the large (preceding) nucleus [illegible] into two, each equalling the original single nucleus [illegible] and the smaller (following) nucleus acted similarly, a new [illegible] attaching itself to it. Another small nucleus also appeared [illegible] the northern part of the group. The activity in this group [illegible]nued, and on June 22, 9^h 39^m (plate 815) there were [illegible] [illegible]ge nuclei, with bright faculae following.

But a more remarkable group was one in the northern [illegible] [illegible]ere, which is shown on plate 802 (June 20, 9^h 42^m) [illegible] [illegible]stern limb. It then consisted of a large group of faculae, with two well marked spot nuclei in the southern part of the group. Plate 806 (June 20, 11^h 27^m) shows the facula of about the same form, except for a marked change in the northern part of the group, a change somewhat similar to the phenomenon of [illegible], though on a much smaller scale. Between two bright points—one of which seems to correspond with a small spot nucleus and the other with a bright point, shown on plate 804 (June 20, [illegible] 11^m)—there extends a straight, bright object, no trace of which [illegible] shown on plate 804, taken [illegible] earlier. The bright object [illegible] across a portion of the faculae and does not seem to affect its [illegible] in the least. In plates 807 (11^h 34^m) and 808 (12^h 30^m) [illegible] given place to a broad and ill-defined expansion, which is [illegible] fainter; but the bright point, shown also on plate 804, in which the outburst may have had its origin, still remains.

During the same time other minor changes took place in [illegible] group. Plates 809, 810, 811 show no marked changes, [illegible] 815 (June 22, [illegible] 39 [illegible] the group has advanced well [illegible] and is greatly changed in form. It is greatly length[illegible] east and west direction, and two well defined spot nuclei [illegible] appeared preceding it, where before there was only [illegible].

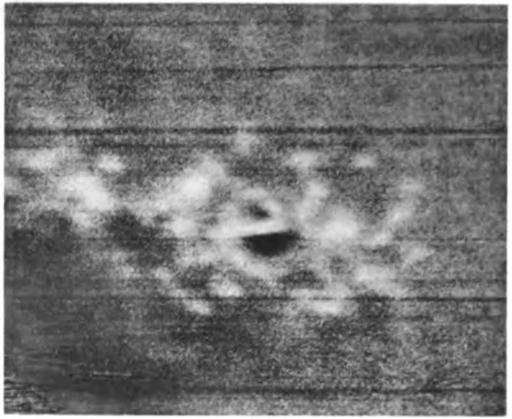
PLATE XLVI.

1



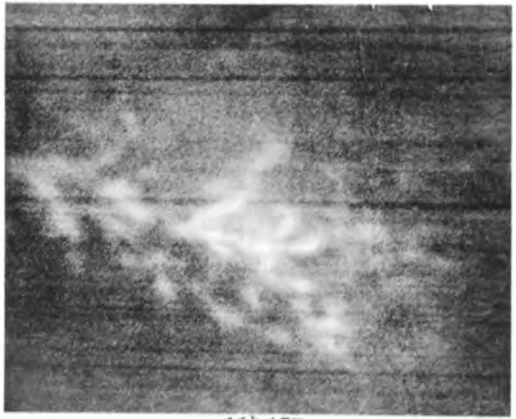
11ʰ 8ᵐ

2



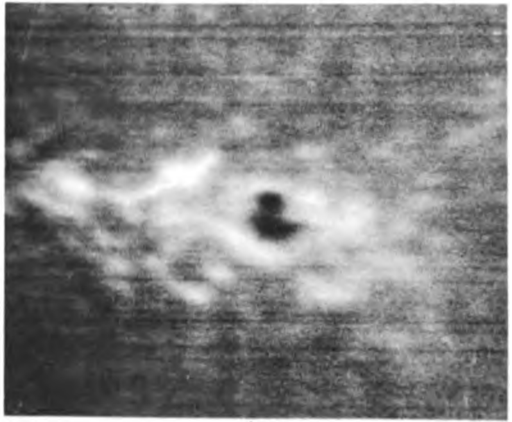
11ʰ 20ᵐ

3



11ʰ 47ᵐ

4



2ʰ 0ᵐ

Solar Eruption Photographed

[illegible]tly around the western limb, if we may judge from photographs taken just before and just after the passage. Plate 814 (June 22, 1h 35m) is an excellent composite photograph showing both faculæ and prominences. On this plate Spot A is a short distance from the western limb, where there is shown a small, low prominence. On plate 815 (June 22, 9h 39m) Spot A has disappeared behind the limb, and in a composite plate (817) taken at 4h 22m on the same day, no prominence is shown at the point where the spot disappeared.

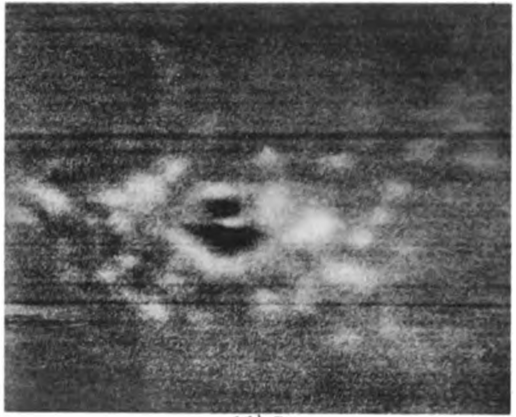
There were, however, two very active groups of faculæ and spots on the Sun at this time. One of these was a large spot group with faculæ in the southern hemisphere, which changed greatly between June 17, 2h 13m (plate 801) and June 20, 9h 52m (plate 802). During this time the large (preceding) nucleus divided into two, each equalling the original single nucleus in area, and the smaller (following) nucleus acted similarly, a new nucleus adding itself to it. Another small nucleus also appeared in the northern part of the group. The activity in this group continued, and on June 22, 9h 30m (plate 815) there were three large nuclei, with bright faculæ following.

But a more remarkable group was one in the northern hemisphere, which is shown on plate 802 (June 20, 9h 52m) near the eastern limb. It then consisted of a large group of faculæ, with two well marked spot nuclei in the southern part of the group. Plate 806 (June 20, 11h 27m) shows the faculæ of about the same form, except for a marked change in the northern part of the group, a change somewhat similar to the phenomenon of July 15, though on a much smaller scale. Between two bright points—one of which seems to correspond with a small spot nucleus, and the other with a bright point shown on plate 804 (June 20, 10h 11m)—there extends a straight, bright object, no trace of which is shown on plate 804, taken 1h 16m earlier. The bright object lies across a portion of the faculæ and does not seem to affect its form in the least. In plates 807 (11h 34m) and 808 (12h 30m) it has given place to a broad and ill-defined expansion, which is much fainter; but the bright point shown also on plate 804, in which the outburst may have had its origin, still remains.

During the same time other minor changes took place in the group. Plates 809, 810, 811 show no marked changes, but on plate 815 (June 22, 9h 39m) the group has advanced well on to the disk, and is greatly changed in form. It is greatly lengthened in an east and west direction, and two well defined spot nuclei have appeared preceding it, where before there was only a [illegible]

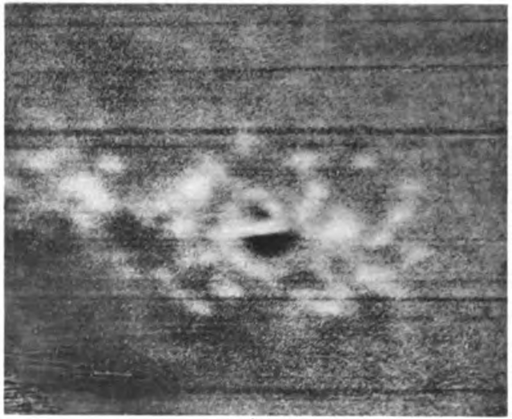
PLATE XLVI.

1



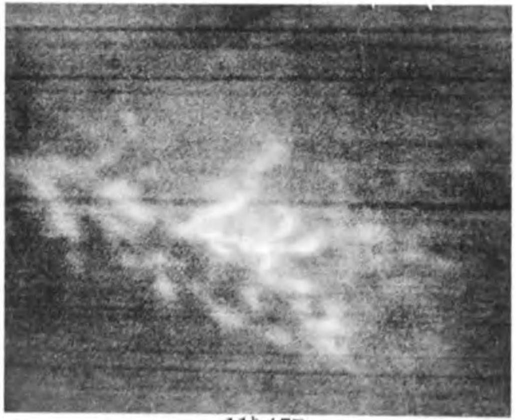
11h 8m

2



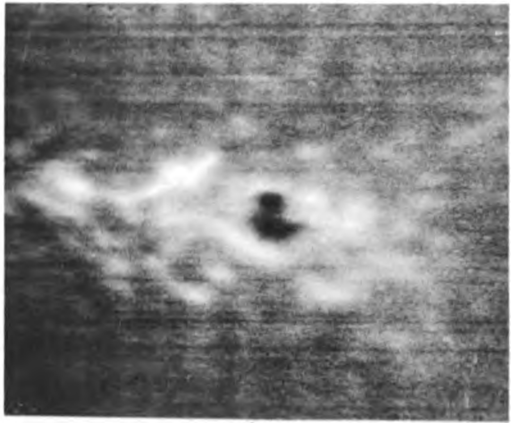
11h 20m

3



11h 47m

4



2h 0m

Solar Eruption Photographed

facula. This facula was long and narrow, convex toward the equator, and the spots formed exactly at its east and west extremities. In none of the preceding plates can any trace of these spots be seen, though the facula is well shown. Plate 819 (June 23, 1^h 53^m) shows the group on the central meridian; the four spots are arranged in a line nearly parallel to the equator, and marked changes have taken place in their relative distances. Nothing is shown at the eastern limb of the Sun. On Plate 821 (June 24, 2^h 27^m) considerable change is shown in the facula since plate 819. The following part of the group has reached the central meridian. Of the four spots the two middle ones, which were approaching when plate 819 was taken, are now nearly in contact. At the eastern limb there are two prominence disturbances in the northern hemisphere. Plate 822 shows that these eruptions had become much fainter twelve minutes later. Plate 824 (June 25, 11^h 37^m) shows no important changes in the facula, but the two middle spots are now in contact. There is a bright prominence at the eastern limb. Plates 825, 827, 828, 829, 830, 831 (the last taken June 25, 3^h 35^m) record nothing of present importance.

At this time the spectroheliograph was dismounted for several days while the new photographic objective was being attached to the telescope. The next photograph of faculæ (plate 838) was consequently not taken until July 5, at 12^h 6^m. At this time there were two large groups near the eastern limb, one in the northern and one in the southern hemisphere. There was also a group of faculæ in the northern hemisphere, which had just crossed the central meridian. Plates 839, 840, 842, 843, 844, 846 (the last taken July 6, 10^h 20^m), differ but little from plate 838. On plate 846 a prominence is shown at the point on the eastern limb where Spot A appeared later. The same prominence is shown on plates 847 and 849.

It is thus seen that the magnetic disturbance beginning on June 21, and continuing until June 26, was simultaneous with the passage of two active spot groups across the solar surface. No mention is made by Father Sidgreaves of a magnetic disturbance on June 20, at the time of the outburst which has been described as somewhat similar to the much more violent outburst of July 15. The oscillations of the magnets commenced one day later, on June 21, and this retardation together with the fact that the July 15 outburst was followed by a violent magnetic storm on July 16, may possibly have some significance.

As has already been mentioned, the reappearance of Spot A at the Sun's eastern limb was heralded by a prominence at the same position angle. On plate 850 (July 6, 11^h 55^m) the facula surrounding the spot is shown projecting above the limb. On plate 857 (July 7, 11^h 19^m) the facula has entered the disc. The spot was probably exactly on the limb at this time, as a depression at the limb is distinctly shown on the photograph. The same thing is shown on plate 858. On July 8, 10^h 15^m, the large spot nucleus had advanced on to the disc (plate 862). No more photographs were secured until July 11, 10^h 8^m, when Spot A was well advanced on the Sun's surface. A comparison of plate 811 with plate 863 shows that Spot A and the group of faculæ preceding it greatly increased in size while on the invisible hemisphere. On July 11 this spot group was, with possibly one exception, the most important on the visible hemisphere. On June 20, just before the passage of the spot around the western limb, the group was inconspicuous, and of minor importance.

Plates 864, 865, 866 (the last taken July 11, 10^h 34^m) agree closely with 863, and record no disturbances or groups of faculæ at the eastern limb. Plate 867 (July 11, 12^h 21^m) shows an eruptive prominence at the eastern limb. Plate 868, taken 13^m later, seems to show some changes in the faculæ west of Spot A. Unfortunately no more photographs were secured until July 12, when plate 873, exposed at 11^h 35^m, showed that marked changes had taken place in the spot and in the faculæ just preceding it during the previous 23 hours. No faculæ were recorded at the eastern limb at this time.

From Father Sidgreaves' paper * we learn "that the magnets now remained generally quiet (after June 28) with the exception of some slight movements, the more noticeable taking place at early morning and at midnight of July 10th. The spot had reappeared on the Sun's visible disc on July 8th. On the 11th, the day Mr. Townsend observed the remarkable reversals of the C line in the spot at about 12.15 P. M., G. M. T., a single sharp upward movement, both on the declination and the horizontal force magnets, alone interrupted their otherwise quiescent state." It will be seen that while our records contain no photographs taken at the time of the disturbance witnessed by Mr. Townsend they show that a marked change took place in the spot and faculæ on the day in question. It does not seem unreasonable to connect this sudden movement of the magnets with the simultaneous disturbance in the spot.

Plate 874 was taken a few minutes later than 873, and shows

---

* ASTRONOMY AND ASTRO-PHYSICS, November, 1892, p. 818.

no changes. In plate 875, (July 12, 11^{h} 51^{m}) a faculous bridge seems to have formed over Spot A, but no other marked changes are shown. A marked disturbance of the declination magnet commenced almost simultaneously with the formation of the bridge.

This was the prelude to a violent magnetic storm, which continued on July 13 and 14. Plate 881 was taken at 11^{h} 36^{m} on July 13, and agrees with Plate 883, taken 25^{m} later, in showing that important changes in the faculæ surrounding Spot A took place during the preceding 24 hours, while the magnetic storm was in progress. Plate 884 was taken only 3^{m} later, but shows a very marked change during this brief interval in the faculæ near a spot in the southern hemisphere not far from the western limb. Just at this time there was a sudden movement of the declination magnet at the U. S. Naval Observatory. There were no faculæ at the eastern limb.

Plates 886 (2^{h} 34^{m}) and 889 (4^{h} 19^{m}) reveal no further important changes, but Plate 891 (July 14, 10^{h} 9^{m}) shows marked differences in all of the larger groups of faculæ. Plates 892, 893, 894, 895, 896, 897, 901 (the last taken at 3^{h} 55^{m}), have mainly a negative value in showing a state of comparative quiet in the various groups of spots and faculæ. Between 3^{h} 55^{m} and 4^{h} 8^{m} there was a great change in the form of a curiously shaped facula in the southern hemisphere. The declination magnet was quiet after 10^{h} A. M. until 3^{h} 40^{m} P. M., when there was a sudden fall, followed by slight oscillations lasting about an hour. The horizontal force magnet also was quite steady after noon, but at about 4^{h} P. M., the exact time of the sudden change noted above, the record shows a marked maximum.

We now come to the eruption of July 15, the various phases of which are shown in the accompanying plate. Some difficulty has been experienced in reproducing the photographs by the photogravure process, and the results by no means do justice to the original negatives. Unfortunately, the grain of the plate is brought out by the enlargement,* and the horizontal dark lines (due to dust on the slit of the spectroheliograph) could not be removed. In spite of their shortcomings, the photographs will serve to show the successive stages of a rare and important phenomenon. As I have already described this eruption,† it is unnecessary to enter into its details here. It evidently had its rise in the bridge shown in the first figure between the two umbræ,

---

* The photographs are on a scale of about 12 inches to the Sun's diameter.

† See ASTRONOMY AND ASTRO-PHYSICS, August, 1892, p. 611.

from a photograph taken at 11ʰ 8ᵐ. The hook-shaped form which had developed 12ᵐ later is shown in the next figure. At 11ʰ 47ᵐ the eruption was at its height, and the spot itself was hidden from view. The last figure is from a photograph taken at 2ʰ, when the eruption had subsided. A careful examination of the original negatives shows that the faculæ surrounding the spot were not changed in form by the disturbance, which, as I have before suggested, was probably a true eruption. The greater brightness of the faculæ in the last figure as compared with the first figure is probably not due to any effect of the eruption, but simply to the fact that the latter is the better photograph of the two, on account of a more careful adjustment of the spectroheliograph.

In *l'Astronomie* for September, four illustrations are given from drawings of the spot on July 15 by M. L. Rudaux. M. Rudaux's observations were made at Dauville, France, at 4ʰ 30ᵐ P. M. (about 10ʰ 30ᵐ A. M. Chicago M. T.). In his paper he says: "About 5ʰ 5ᵐ (11ʰ 5ᵐ), just as I had finished my drawing, the tongue of fire which traversed the large nucleus suddenly became brilliantly white; luminous points of an extraordinary intensity were visible at its surface, especially toward the base, and a less luminous and slightly diffuse border formed on the east side of this tongue. At the same instant, an equally brilliant luminosity appeared in the oval spot exactly in the place of the luminous bridge which had been visible there before." M. Rudaux goes on to describe the changes which ensued before 5ʰ 30ᵐ (11ʰ 30ᵐ), when his observations were unfortunately stopped by clouds. From his drawings it is evident that he was witness to only the earlier stages of the phenomenon. He speaks of a partial cessation of the eruption at 5ʰ 25ᵐ (11ʰ 25ᵐ) but of this I have no record. He also adds that the spot underwent no marked change in form.

The records of the Naval Observatory declination and vertical force magnets at the time of this remarkable outburst agree with those of Stonyhurst in showing not the slightest disturbance. The Naval Observatory trace of the horizontal force magnet being imperfect at this point I give Father Sidgreaves' statement that "there was, however, a slight trembling in the horizontal force magnet which was the prelude to the violent storm which set in and lasted over the 16th until midnight of the 17th."

Plate 915 (July 16, 10ʰ 44ᵐ) shows a great change in the faculæ around Spot A since the preceding day. Plates 916, 917, 18, 9921, 922, 924 (the last taken July 16, 3ʰ 22ᵐ) continue to show changes, and prove that this region of the Sun was in a state of great activity at this time. No disturbances are recorded at the eastern limb of the Sun. The movements of magnets were very violent all day, the maximum in the case of the horizontal force magnet occurring about 2 P. M., and amounting, according to Father Sidgreaves, to 1° 34.73′.

It would be premature to attempt to draw any definite conclusions from the result of this inquiry, but two or three matters of interest may be pointed out. As the perturbations of terrestrial magnetism seem to synchronize closely with the activity of various groups of spots and faculæ indifferently situated in various parts of the visible solar surface, neither the "eastern limb theory" advocated by Veeder, nor the "central meridian theory" of Marchand, seems to receive any support. Nor can I agree with Father Sidgreaves that the supposition that particular classes of spots exercise a special magnetic influence has received any confirmation. I am inclined to believe, however, that M. Tacchini's explanation of terrestrial magnetic phenomena as the result of exceptional disturbances in prominences or faculæ on any part of the Sun's visible surface is slightly strengthened by the results here presented.

KENWOOD OBSERVATORY,
University of Chicago, Nov. 17, 1892.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in ASTRO-PHYSICS, should be addressed to George E. Hale, Kenwood Observatory of the University of Chicago, Chicago, U. S. A. Authors of papers are requested to refer to last page for information in regard to illustrations, reprint copies, etc.

The 40-inch Telescope of the Yerkes Observatory.—The large discs of optical glass made by Mantois for the University of Southern California have been purchased by the University of Chicago. They are nearly 42 inches in diameter, and will allow of a clear aperture of 40 inches. The glass is said by Mr. Alvan Clark to be exceptionally good. Mr. Clark will shortly undertake the work of grinding the objective, which he has contracted to complete within eighteen months. The contract for the mounting will be let within a short time. The site of the Observatory is still undecided, but it will probably be several miles outside the city.

Unusual Appearance in a Sun-Spot.—On Sunday, August 21, at 5:35 P. M., my usual arrangements for solar observation by projection on a sheet of cardboard being completed, my attention was at once arrested by a remarkable appearance in an oval spot of moderate dimensions (in length not more than 40″ of arc), in longitude 276°, latitude 24° N. Between the umbra and penumbra was a band of bright light exceeding the brightness of the faculæ then visible near the W. limb, although the spot was only about 32° from the central meridian.

Besides its brilliancy, which caught the eye at once, it was peculiar from the position of the light as regards the nucleus, being exterior to it rather than interior, such faculous light being not uncommon in the centre of a spot containing several nuclei, or in the form of luminous bridges between nuclei, which are on the point of separation, but not on the outer side.

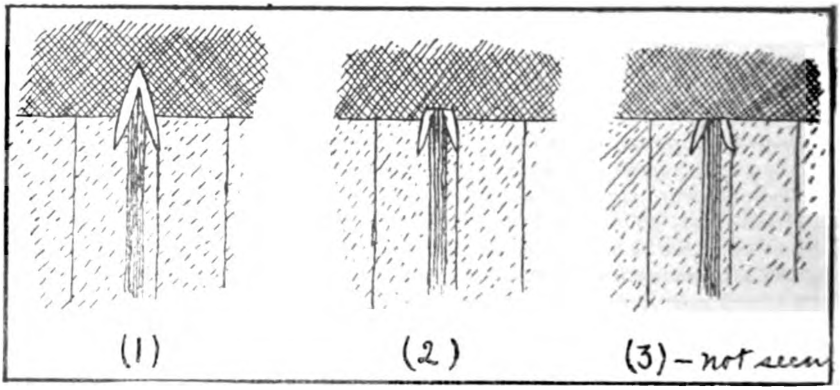
The lustre continued without diminution until 6:5 P. M., after which time passing clouds and poor definition prevented any further observation.

At 7 A. M. on the following day it had disappeared. The only noteworthy alteration in the spot was a separation of a small portion of the penumbra to the N., thus not precisely in the same direction as the band of light, which lay towards the W. I much hope that this appearance may not have been of so transitory a nature as to have escaped the observation of other members of our Solar Section, and that some of the daily photographs taken at Greenwich or elsewhere may be found to confirm it.—*Jour. B. A. A.*, 1892, p. 504.

(MISS) E. BROWN.

Behavior of the Arrowhead in the C line in a Solar Eclipse.—When the slit of a spectroscope is placed radially across the image of the Sun's limb the C and F lines at the boundary of the Sun's spectrum and for a short distance beyond consist of a dark line narrowing down to a point, with a bright line on each side; these two bright lines being joined above the point of the dark line and extending down into the spectrum of the Sun's disc. The whole constitutes the familiar "arrowhead."

In the partial solar eclipse of Oct. 20, just after the observation of first contact, the slit of the spectroscope was placed radially at a point of the Sun's limb which the Moon's advancing edge was about to obscure, with the object of studying the behavior of the arrowhead in the C line. As the Moon advanced the arrowhead was gradually truncated until the two "barbs" were left separated with a dark space between them; but when they were cut down to about the edge of the bright spectrum, the two points of the barbs which extend down into the spectrum vanished together and instantly. The observation was repeated with care a number of times.



In the figure (1) shows the whole arrowhead; (2) was each time easily seen; (3) was not seen at all, though carefully looked for. As nearly as I could judge the time when the barbs disappeared was the instant when the truncation of the

arrowhead reached the edge of the bright spectrum. The observations were made with the Brashear grating spectroscope on the 23-inch equatorial of the Halsted Observatory.
TAYLOR REED.

Princeton, N. J., Oct. 28.

Do Large Telescopes Pay?—Apropos to the announcement that the University of Chicago will have a telescope of forty or more inches aperture, Mr. John Ritchie, Jr., communicates an article to the *Boston Commonwealth* on the subject "Do Large Telescopes Pay?" which is more remarkable for its vigor than for the breadth of the author's views disclosed in it. The question is not, of course, whether large telescopes are to be regarded as successful financial enterprises, but whether the results achieved by them are sufficiently important, in a scientific sense, to justify the expense of their construction. Mr. Ritchie answers this question in the negative, fortifying his position by a somewhat lengthy discussion of the standing of various observatories and the relative merits of well-known observers. For reasons which have a proverbial basis, we prefer not to enter into these personal questions, although we may remark that some persons may be inclined to dissent from Mr. Ritchie's opinion; but the relative importance of various kinds of astronomical work, which is necessarily involved in the discussion, is a subject which may be considered without hesitation. It necessarily rests on the correctness of personal judgment, and is therefore unavoidably affected by personal bias; for where can a man be found whose views are so broad, and, we may say, whose vision is so prophetic, that he can assign to facts their proper relative values, and tabulate them in the order of their importance? We once heard an eminent investigator casually refer to a certain discovery in physics as one of trifling value, while some weeks later an equally competent authority wrote of it in one of the physical journals as a discovery of great importance. Every specialist is naturally inclined to attribute more than ordinary importance to the line of study in which he is himself engaged, and moreover, a value which is in some degree fictitious is attached to whatever is difficult to ascertain.

Mr. Ritchie regards the discovery of a fifth satellite of Jupiter as of little value, probably because it was made by so brutal a method as that of simple visual observation with a large telescope. If the satellite had been found by studying the possible perturbations of the other satellites, he would doubtless have considered the discovery one of the most splendid triumphs of the age. This view has much in its favor, but it places the means before the end. The satellite has been found to exist; we fail to see how the simplicity of the method can so completely destroy the importance of the fact.

The only sphere of usefulness which Mr. Ritchie will allow great telescopes is the observation of objects beyond the range of small telescopes, and to such objects he thinks their use should be restricted. The absurdity of this view does not require pointing out,—certainly not to anyone who has used a large telescope. The same advantages (greater light, magnification, and resolving power) which make the large instrument superior to the small one in the case of very faint and minute objects, still remain a source of superiority for objects that are brighter. We should be inclined to reverse the rule in the apportionment of the field, and confine the use of the small telescope to work in which rapidity is the chief consideration. It is, of course, understood that reference is here made to the equatorial telescope, the superiority of the small instrument, when used with graduated circles for observations of precision, being undisputed. From Mr. Ritchie's point of view it would seem that the field of employment for an equatorial of any kind is a very limited one. If the discovery of a new satellite is not of importance, neither, *a fortiori*, is the observation of satellites already known to exist. An asteroid can hardly outrank a satellite, and it is not easy to see (from the same standpoint) why comets should be assigned to a higher place in the scale. Double stars are also held in low esteem, and as for celestial spectroscopy, and the whole modern development of astronomy in the direction of astrophysics, Mr. Ritchie either does not consider them worthy of mention, or he is unaware of their existence.

A defence of these subjects does not seem to be necessary. A paragraph of Mr. Ritchie's leads us to remark, however, that their scientific importance is not diminished by the fact that they are also of popular interest. But the spectroscope is not only the key which unlocks the constitution of the stars; it has taken its place among time-honored tools of the astronomer as an instrument of precision. For the purposes to which it is applied, the demand is always for more light, and light can be obtained only by constructing large telescopes. It is true that some of the most important investigations (the Potsdam measures of motions in the line of sight, for instance), have been made with comparatively small instruments, but in these cases the work was not done with small telescopes because they were better than large ones, but because larger telescopes were not to be had. That such skillful astronomers as Professor Vogel and Professor Pickering are desirous of securing large telescopes may be regarded as indicating the opinion of the best authorities on this subject.

The part of Mr. Ritchie's article which relates to the insufficient endowment of large telescopes must meet with entire approval. An observatory without the means of carrying on observations is as useless as a manufacturing plant without workmen. We do not anticipate that the Chicago Observatory will be left in such a plight. In regard to the facts of some of the cases given as examples we moreover have reason to think that Mr. Ritchie has been misinformed.

The above remarks have been made not so much in the way of argument as for the purpose of showing that the question has another side, which cannot be ignored, and that it is not to be settled by the off-hand opinion of a single person. As an able defence of the great telescope, we commend the following note by Professor E. S. Holden in the November *Forum:*

> "I should like to call attention to the fact that the history of the great telescopes at Mount Hamilton and at Washington will serve to lay away finally a widely published opinion which we used to hear repeated every few weeks—namely, that great telescopes are of little use. The work of these two great telescopes (not to speak of many others) has conclusively shown their great superiority over less powerful instruments in every field of astronomy, in the observations of planets, nebulæ, stars, comets, satellites, in spectroscopy, and also in those departments of astronomical photography for which they are adapted. Smaller instruments have their appropriate fields, and in some of these they will always be more convenient than larger ones. But the great telescope, when properly used, is and will always be pre-eminent. The proof is easy to give, and I trust that we shall not hear any more idle detraction of the work of our great instrument-makers, the Clarks, or their European rivals."

It will be observed that Professor Holden does not even regard the question as open. K.

A New Combined Visual and Photographic Objective.—In making the new twelve-inch objective for the Dudley Observatory, Mr. Brashear is carrying out a plan which was long ago developed mathematically by Professor Hastings of Yale University. The crown glass lens is mounted in a cell fixed to the end of the telescope tube, and two flint glass lenses are provided, each in a separate cell, which serve to form with the crown lens either a visual or a photographic combination. The flint lens is therefore on the outside. As in both cases the lenses are in contact, but must not be subjected to the least strain, very careful mechanical work is required in fitting the cells. Mr. Brashear has also added some very simple but ingenious appliances by which the exchange of cells can readily be made by one person.

This form is not so simple as the objective with single reversible crown lens, but it gives a more perfect correction for color and spherical aberration. It is well known to the practical optician, and is also demonstrable mathematically, that the reversible crown lens cannot meet both requirements in a perfectly satisfactory manner. In making the necessary compromise the greater sacrifice is generally thrown on the photographic arrangement, as the one in which errors are least noticeable. In the new form the definition of each combination is equal to that of a specially constructed objective.

If the glass-makers could furnish glass with the requisite optical properties, both combinations could be made to have the same focal length. This may possibly be the next improvement to be looked for. The advantages of the new form over the visual objective with photographic corrector are obviously less loss of light by reflection and absorption, and greater lightness.

The Spectrum of Holmes' Comet.—On the evening of Nov. 16, I examined the spectrum of Holmes' comet, using a spectroscope of 1.12 inches effective aperture attached to the 13-inch equatorial. The spectroscope carried a single light flint prism, and the power of the observing telescope was about 6.

The spectrum was continuous, and fairly bright. It extended from D to a point half way between F and G, the maximum brightness being a little below *b*. With the most careful attention I could see no lines. A somewhat brighter streak running through the spectrum was due to the nucleus of the comet.

By means of a comparison prism I threw in the spectrum of a piece of white paper, illuminated by a distant argand lamp. Both spectra were of about the same brightness. That of the comet was somewhat the longer, and as a whole it lay farther toward the violet; otherwise they were very much alike. These are just the appearances that we should expect if the comet shines entirely by reflected sunlight.

Cloudy weather has prevented any attempt to photograph the spectrum.

J. E. KEELER.

Professor Seeliger's Explanation of Nova Aurigæ.—The hypothesis which Professor Seeliger has advanced to account for the phenomena attending the appearance of new stars, explains all except the latest observations of Nova Aurigæ. It is sufficiently flexible to include a great variety of possible appearances, and it avoids difficulties which are quite serious when viewed from the standpoint of other hypotheses. Nevertheless recent unexpected developments in the case of Nova Aurigæ show that it is open to grave and perhaps even fatal objections. In our present number we give a translation of Professor Seeliger's article in the *Astronomische Nachrichten*, which, it will be observed, was written before the reappearance of the star. By far the most complete and important observations which have been made since that time are those of Professor Campbell at the Lick Observatory. and their bearing on Professor Seeliger's views is a matter of great interest. Some of the earlier observations, also, are not quite completely explained by the latter, as we may first point out. According to this hypothesis, the dark lines observed in the spectrum of Nova Aurigæ during the winter had their origin in a gas stratum which partook of the motion of the solid body, and hence their observed displacement is a measure of the motion of the star in the line of sight. The velocity thus determined is about 300 miles per second, and that of the star on entering the cosmical cloud must therefore have been equal to or greater than this. An initial velocity of this magnitude is certainly surprising, but it is not impossible, or even without a parallel, as the isolated star 1830 Groombridge is moving at a minimum rate of 200 miles per second, and actually perhaps several times faster than this. New stars are, moreover, exceptional phenomena, and it is rather to be expected that their attending circumstances should be exceptional.

But we have now to point out some difficulties. As the dark lines were displaced toward the violet, the star was approaching the Earth. The gaseous matter giving the bright lines was receding from the Earth at the rate of over 400 miles per second. It is not clear how matter detached from the solid body could have so great a velocity. On the other hand, if the light came from particles of the nebulous cloud heated by friction, or by radiation from the incandescent surface of the body, one would expect that the most swiftly moving particles would be those most intensely heated; but according to observation, the bright lines were brightest and most sharply defined on the upper side, which was that least displaced, this appearance indicating a low limiting velocity for the brightest particles.

These are perhaps not serious objections, but how are we to account for the observed fact that after the reappearance of the star the bright lines in its spectrum were displaced toward the violet, whereas the bright-line spectrum during the winter was displaced toward the red? It is true that the two spectra do not seem to be very closely related, but some lines, notably those of hydrogen, are common to both, and it is not easy to see how such a change in the direction of their displacement can be accounted for on any hypothesis involving rectilinear motion only. The slackening in the rate of approach which Professor Campbell has recently observed, and which has not been accompanied by any outburst of light, is also incompatible with rectilinear motion. The difficulty might be met by calling to our aid some center of attraction, as a dark body within the nebula (although the nearly constant velocity during the winter would remain unexplained) but in that case the hypothesis would lose its extreme simplicity. Professor Seeliger's criticism of former hypotheses is of great value, and its force remains, whether his own explanation is regarded as tenable or not. We have not yet seen the end of Nova Aurigæ, and a complete solution of the difficult problems which it has presented to us may have to wait for the light of future investigations.

A Small Spectroscope by Mr. Brashear.—Mr. Brashear has recently designed a small but high-class spectroscope which is light enough to be used on telescopes of from four to eight inches aperture, and which can be sold at a price that will bring it within the reach of amateurs. It has telescopes of 8 inches focus and $^3/_4$ inch aperture, and it can be used with either a prism or a grating. All necessary attachments are provided, and some luxuries. Another instrument designed especially for amateurs is a small position micrometer.

On the Mass of the Earth's Atmosphere.—M. Mascart, with his usual lucidity, has revised Laplace's computation of the mass of the atmosphere. Laplace obtained his well known barometric formula by assuming that

$$\rho = \rho_0 e^{-\frac{R}{H}s}$$

where ρ_0 = density of atmosphere at sea level.

R = radius of Earth.

H = height of the homogeneous atmosphere [density = ρ_0] whose pressure will just balance that of the barometer.

h = height above sea level.

$s = \frac{h}{R + h}$.

But this law makes the mass of the atmosphere infinite and must, therefore, be discarded.

Mascart proceeds to take account of the variation of gravity with altitude and also of the fact that the bounding spherical surface increases as one goes from the surface of the Earth outwards. But he distinctly disregards the complication introduced by the rotation of the Earth on its axis. His method is to assume, using the notation above,

$$\rho = \rho_0 f(s)$$

and then find the most probable form of $f(s)$. The considerations which determine the form of this function are three in number, viz.:

(1) The mass of the Earth's atmosphere must be finite.

(2) The value of $\frac{H}{R}$ must be small.

(3) The function must become unity for the surface of the Earth, *i. e.*, for $s = 0$; it must decrease continuously as h increases and become zero when $h = \infty$.

These lead, not with mathematical rigor, but with a high degree of probability, to the following expression for the density at any point

$$\rho = \rho_0 (1 - s)^4 e^{-as}$$

where α is a constant to be determined by barometric observations at elevations as different as possible.

Solving for α,

$$\alpha = \frac{1}{s} \log (1 - s^4) \frac{\rho_0}{\rho}$$

Data obtained on Mt. Blanc, Pike's Peak, and the Sonnblick give

$$\alpha = 660. \text{ approx.}$$

This value is next employed to get the mass of the atmosphere by integration, in the usual manner

$$\text{Mass} = \int_0^\infty 4\pi (R + h)^2 \rho \, dh = 4\pi R^3 \rho_0 \int_0^1 \frac{f(s)}{(1 - s)^4} ds.$$

$$= \text{constant} . \int_0^1 e^{-\alpha s} ds.$$

Performing the quadrature one sees that Mascart's statement of the law of variation of density with altitude is equivalent to saying that the ratio of the mass of air above any height, h, to the total mass is e^{-as}.

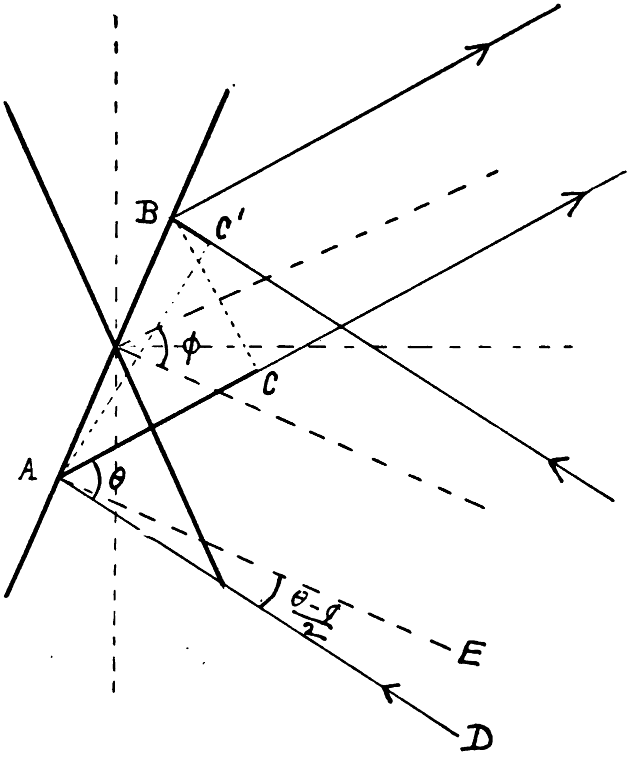
From this integral the author also readily derives the height of a homogeneous atmosphere defined as follows, *viz.*: ***one whose density is constant and equal to ρ_0, and whose mass is equal to the integral above.***

This definition implies simply that in defining the homogeneous atmosphere one takes into account the diminution of gravity at high altitudes. The result is somewhat surprising. The height thus obtained is one-sixth greater than that of the homogeneous atmosphere as ordinarily defined, *viz.*: ***the height of atmosphere of density ρ_0 which will produce the same pressure as that indicated by the*** *barometer at sea level.* These values are confessedly approximate, as, indeed, all values obtained by extrapolation must be. One cannot, however, doubt that the corrections of M. Mascart are in the right direction and very much larger than would have been imagined without rigid computation. The author adds the important remark that although Laplace's expression for density leads to an infinite mass, the refraction formulæ of Laplace and Bessel still hold good since they are derived from the consideration of a column of air of constant cross-section.

The original paper of Mascart will be found in the *Journal de Physique* for March of the present year.

A New Proof of a Fundamental Equation of the Spectrometer.—The following demonstration, by Mr. Robert R. Tatnall, is certainly neat and apparently new. The method he employs for measuring wave-lengths is that in which the telescope and collimator are firmly clamped at a fixed angle with each other.

Under these conditions, the grating was employed successively in the two positions in which it gave the same Fraunhofer line first in a left-hand spectrum and then in the right-hand spectrum of the same order.



From the principle of the reversibility of light rays it follows that the two positions of the grating will be symmetrical about the bisectrix of the angle between collimator and telescope. Let us call this angle θ while we denote by φ the angle between the two positions of the grating.

In the figure, consider either position of the grating, say AB; and let the distance AB represent the grating space, s.

The retardation of paths will then be AC — BC′ and

$$AC - BC' = s(\sin C\hat{B}A - \sin B\hat{A}C')$$

But by symmetry,

$$C'\hat{A}E = D\hat{A}E = \frac{\theta - \varphi}{2}$$

Also

$$\begin{aligned} C\hat{B}A = C\hat{A}E &= C\hat{A}D - D\hat{A}E \\ &= \theta - \frac{\theta - \varphi}{2} \\ &= \frac{\theta + \varphi}{2} \end{aligned}$$

Hence, if λ = required wave-length and κ = order of spectrum

$$\kappa\lambda = s\left(\sin\frac{\theta + \varphi}{2} - \sin\frac{\theta - \varphi}{2}\right)$$

or

$$\lambda = \frac{s}{\kappa} \,.\, \cos\frac{\theta}{2} \,.\, \sin\frac{\varphi}{2}$$

On a Simple Method for Obtaining the Color Curve of a Lens.—Having at my disposal one of Rowland's deep concave gratings, I found it very useful for studying the achromatism of lenses in the following manner. The method is essentially that of Hasselberg [*Melanges Math. et Astron., t. VI, p. 669 (1888)*,] who uses a prism to produce bright line spectra in the focal plane of the view-telescope and then observes these bright lines with the lens in question.

The only objection to this process is that, in order to obtain the required color curve, one has either to know or neglect the color curve of the lens in the view-telescope, an objection which is not serious, of course, for long focus lenses such as are used in astronomical telescopes.

Since the concave grating is perfectly achromatic, it avoids this difficulty and permits one to use the method for measuring short-focus lenses. In this way, I have examined several photographic objectives. The grating is collimated with the direction of the ways of an optical bench and then fixed. The slit is mounted after the manner of Waterhouse [*Mem. Soc. Spettroscopisti Ital., Vol. 18, pp. 14-16. 1889.*] so as to rotate in a circle having for its center the point midway between the grating and its center of curvature.

The various bright lines of metallic spectra were then brought to focus strictly at the center of curvature of the grating and were examined in succession by the photographic objective mounted on the bench.

Another method by which one may avoid the chromatic aberration of a view-telescope is to employ a candle (or, better still, a brighter source) to produce a continuous spectrum, either by prism or grating, and then suspend, approximately in the focal plane, a pair of fine spider webs with small weights attached so as to bring the webs to strict parallelism. The distance at which the image of the spider webs will appear, depends, other things being equal, upon the wave-length of the light with which the webs are illuminated.

To prevent air currents blowing the webs out of a fixed plane, it is well to immerse the stretching weights in a small cup of oil.

Having obtained a sharp object of any desired color by either of the above methods, one proceeds to determine the corresponding focal length. Bessel's formula is probably the best; but if one has a good micrometer eyepiece he may compare the size of the image produced by the lens in one of its symmetrical positions with that produced by the lens in the other symmetrical position, and thus rid himself of the troublesome measurement of distance of image from object.

If, in any particular lens, one has convinced himself that the separation of the principal planes does not vary appreciably with the wave length, the following method is quick and convenient.

Mount the observing eyepiece in a graduated drawtube. Place the lens in any convenient position on the bench. Call the distance of its first principal plane from the object s: and let i denote the distance from the second principal plane to the image. If f be the focal length for light of any wave-length λ, *Newton's Rule* gives

$$(s - f)\,(i - f) = f^2$$

whence

$$df = \left(\frac{s}{s+i}\right) di.$$

Now di can be read off the draw tube as the spider webs are illuminated by one color after another while comparatively rough measurements of s and i will give the factor $s/s + i$ with required accuracy. All that remains is to plot df as a function of λ.

HENRY CREW.

Nova Aurigæ.—The reappearance of Nova Aurigæ seems to have been noticed almost simultaneously on both sides of the Atlantic At Mt. Hamilton the star was observed to have augmented in brightness on August 17, and in England Mr. Henry Corder made the same observation on August 19. Earlier discovery was prevented by the unfavorable position of the star. On the ground of Professor Seeliger's hypothesis no special importance would attach to the photometric observations of Nova Aurigæ, the fluctuations of brightness being indicative of nothing more than casual variations of density in a cosmical cloud.

A Translation of Scheiner's *Die Spectralanalyse der Gestirne.*—Messrs. Ginn & Company of Boston announce for early publication a translation of Dr. Scheiner's well-known work by Prof. E. B. Frost of Dartmouth College. They have established a Department of Special Publication, which, according to a recent circular "will prepare and send out to all likely to be interested detailed prospectuses of works of this class that may be offered us, and invite subscriptions or pledges for a specified number of copies. If the responses are sufficiently encouraging, the book will be published." We sincerely hope that in the case of the present work the responses will be "sufficiently encouraging," for the need of an English edition has been widely recognized. Professor Frost's stay of two years at Potsdam, and his intimate acquaintance with Dr. Scheiner, give him special advantages in undertaking the translation, and we look for a book of great value. We give below the prospectus issued by Messrs. Ginn & Co.

A TRANSLATION OF DR. SCHEINER'S DIE SPECTRAL-ANALYSE DER GESTIRNE.
By Professor EDWIN B. FROST *of Dartmouth College.*

This work, by one of the brightest astronomers of the Royal Observatory at Potsdam, was published in the autumn of 1890, and has already made itself the standard treatise on Astronomical Spectroscopy.

The *aim* of the work has been to provide a thoroughly scientific handbook, which should explain the most practical and modern methods of research in observatory and laboratory, and should present a clear account of the present state of our knowledge of the constitution, physical condition and motions of the heavenly bodies, in so far as these are revealed by spectroscopic researches.

A simple and straightforward style of expression and development has been followed by the author, and will be preserved by the translator, so that it is hoped that the physical interpretation of the principles and theorems discussed will be entirely clear to those who do not care to, or are unable to follow out, the mathematical demonstrations.

The subject matter of the work is divided into three parts:—

I. Spectroscopic Apparatus.
II. Spectral Theories.
III. Results of Spectroscopic Observations of the Heavenly Bodies.

To these is added a fourth part containing a number of extensive and useful tables of wave-lengths of lines of the solar spectrum, catalogues of stars with special types of spectra, and a full bibliography of the subject, which will be brought down to 1893.

The edition in English will be finely illustrated with the 75 woodcuts and lithographed plates of the original, with some additions. The illustrations are, it should be said, almost wholly new, and not reproductions of the traditional figures which have so long appeared in all books touching upon this subject.

A number of additions and some changes will be made in the translation to adapt it more nearly to English and American readers.

The cordial support and co-operation of the author is assured.

The volume will comprise about 350 pages of text and 100 pages of tables and bibliography. The price will be set at $5.00. It is hoped that it may be ready in about a year.

It is expected that this Treatise on Astronomical Spectroscopy will be found of constant and specific service to —

Recent Spectroscopic Determinations.—The letter printed below appeared in *Nature*, Sept. 29, 1892, and refers to an important article by Professor Michelson which will be found on another page:

In the September number of the *Philosophical Magazine* Mr. Michelson has published determinations, by a most interesting method, of very close double and multiple lines. In any attempt to interpret his results, it is necessary to bear in mind the profound modifications which the internal motions of a gas—the rectilinear motions of the molecules between their encounters, as well as the motions going on within each molecule—had undergone within the Geisler's tubes upon which he experimented.

In a gas under ordinary circumstances the rectilinear journeys of the molecules take place indifferently in all directions, and where this is the case it follows from the well-known relation between the surface of a sphere and that of its circumscribing cylinder, that the effect of the velocities which happen to lie between ν and $\nu + \delta\nu$ is to substitute for each line of the spectrum of the gas a band of uniform intensity and without nebulous edges, the width of which can be calculated. This width, for example, is .04 of an Ångström or Rowland unit (the tenth-metre), in the yellow part of the spectrum and for velocities of the molecules which lie in the neighborhood of two kilometres per second, which is about the average velocity of molecules of hydrogen at atmospheric temperatures. Hence with all the velocities that prevail among the molecules, the effect of the rectilinear motions under ordinary circumstances is that each line will be symmetrically widened and rendered nebulous. To this effect Mr. Michelson calls attention.

But in the residual gas of a Geisler's tube through which electricity is passing, the case is altogether different. Here the rectilinear motions of the molecules are not alike in all directions, but preponderate in some; a state of things which must at least double the lines, and may introduce greater complications.

Moreover, different lines may be differently affected, since the behavior of the gas varies according to its position between the electrodes; as is evidenced by the observed differences in the form and coloring of the striæ, &c., in the several parts of a Geisler's tube.

We must also be on our guard in another respect, when we attempt to interpret the results, since the distribution of the heat energy of a gas between the rectilinear motions of its molecules and the motions within the molecules, which in the case of ordinary gas is a fixed ratio, is certainly largely departed from in gas through which electricity is passing. Until the laws of the new distribution are understood, the temperature of the gas, judged of by its behavior to neighboring bodies, will give us little information

It is to such events as are referred to above, or others which like them may arise from the special circumstances under which the vapor of sodium was in Mr. Michelson's experiments, that we must apparently turn for an explanation of the doubling of the constituents of the principal pair of sodium lines which he has detected; since he found that "the width of the lines, their distances apart, and their relative intensities vary rapidly with changes in temperature and pressure."

The method of investigation which Mr. Michelson has so successfully applied appears to be by far the most searching means yet discovered of experimentally investigating the intricate and obscure phenomena which present themselves in Geisler's tubes, and we seem justified in hoping for great results from it.

G. JOHNSTONE STONEY.

9 Palmerston Park, Dublin, September 22.

CURRENT CELESTIAL PHENOMENA.

PLANET NOTES FOR JANUARY, 1893.

H. C. WILSON.

Mercury during the first few days of January will be visible to the naked eye in the morning. One should look toward the east at 7 A. M., a little above the point where the Sun will rise.

Venus will be in the same part of the heavens, but about 15° toward the west. There will be no difficulty in seeing Venus with the naked eye during this month, but telescopic observations will be difficult, because of the low altitude of the planet.

Mars will be visible in the evening until 11 P. M. The best time for observing the planet is just after Sunset. The disk of Mars will be less than 8″ in diameter during the greater part of the month so that we need not expect to see much of detail on its surface. At 10 P. M. Jan. 25 there will be a conjunction of Mars and Jupiter. Mars will pass 1° 36′ to the north of Jupiter on its eastward course. A telescope with low power will at that time show both planets in the field of view at once. It will be an excellent time for comparing the light of the two planets.

Jupiter will be at quadrature 90° east from the Sun, Jan. 5. On Jan. 23 at $6^h\ 43^m$ P. M., central time, there will be a close conjunction of Jupiter and the Moon. As seen from the center of the Earth Jupiter would then be only 6′ north of the Moon's center. In the southern part of the United States, Mexico, Central America and the greater part of South America, there will be an occultation of Jupiter. In latitudes north of 38° parallax will throw the Moon to the south of Jupiter.

Since our last notes were written, Professor Ormond Stone has published, in the *Astronomical Journal* No. 277, micrometric observations of the new satellite of Jupiter, made by himself with the 26-inch equatorial of the Leander McCormick Observatory on the night of Oct. 18. Professor G. W. Hough also has reported that he was able to see the new satellite with the 18-inch equatorial of Dearborn Observatory. Professor Barnard, the discoverer, gives the period of the fifth satellite as $11^h\ 57^m\ 20.5^s$, and its mean distance from the planet's center as 112,510 miles (*Astr. Jour.* No. 277).

We presume it is unnecessary to tell many of our readers where the planets Jupiter and Mars are, but for the sake of any who may not know we will say that they are the two bright stars which we see towards the south and about half way up to the zenith in the early evening. Both exceed in brilliancy any other stars in the evening sky. Jupiter is white, while Mars is red.

Saturn will be at quadrature 90° west of the Sun Jan. 2. This planet will be in good position for observation in the morning during January. It may be easily recognized by its position in the center of the constellation Virgo and its bright yellow color. There will be a conjunction of Saturn with the Moon at $2^h\ 15^m$ A. M., Jan. 6. This will produce an occultation of the planet as seen from South America.

Uranus will be at quadrature, 90° west from the Sun, Jan. 29, and may be observed best at from 4 to 6 A. M. This planet is in the constellation Libra a little west of the bright star α. It may be recognized with a telescope of moderate power, by its dull green disk.

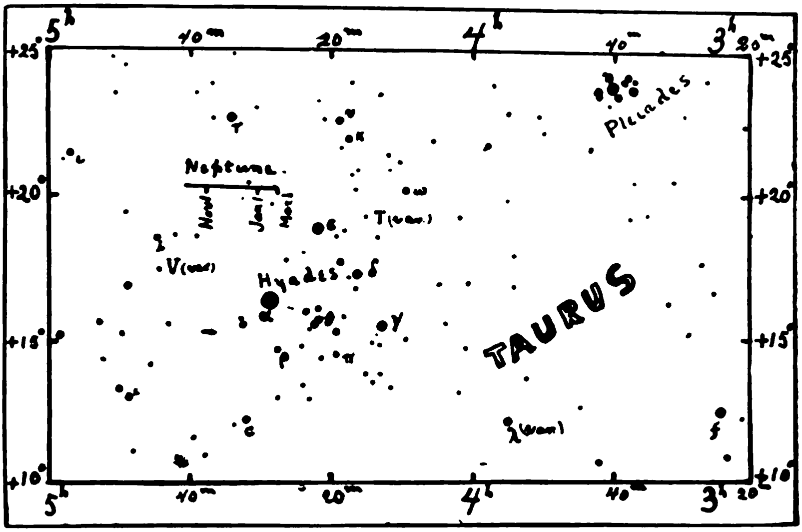


CHART OF NEPTUNE'S POSITION IN THE CONSTELLATION TAURUS.

Neptune will be in excellent position for observation during January. The accompanying chart will indicate where this planet should be looked for. It cannot be recognized by its disc except with large telescopes. The best way for an amateur to find it will be to make a careful chart of all the stars seen in this region and note from night to night which star changes its position. Neptune will be in conjunction with the Moon, 4° 37′ south, Jan. 27 at 9h 36m A. M.

Date. 1893.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Jan. 5	17 31.3	− 22 06	5 59 A. M.	10 29.5 A. M.	3 00 P. M.
15	18 29.0	− 23 29	6 25 "	10 47.5 "	3 11 "
25	19 33.6	− 23 01	6 47 "	11 12.7 "	3 38 "
			VENUS.		
Jan. 5	17 04.8	− 21 45	5 31 A. M.	10 02.8 A. M.	2 34 P. M.
15	17 58.3	− 22 48	5 50 "	10 16.9 "	2 43 "
25	18 52.4	− 22 42	6 05 "	10 31.7 "	2 59 "
			MARS.		
Jan. 5	0 21.7	+ 2 17	11 06 A. M.	5 18.6 P. M.	11 31 P. M.
15	0 45.7	+ 5 04	10 40 "	5 03.2 "	11 27 "
25	1 10.0	+ 7 47	10 14 "	4 48.2 "	11 22 "
			JUPITER.		
Jan. 5	1 01.9	+ 5 13	11 35 A. M.	5 58.6 P. M.	12 23 A. M.
15	1 05.7	+ 5 40	10 57 "	5 23.2 "	11 49 P. M.
25	1 10.5	+ 6 12	10 21 "	4 48.6 "	11 16 "
			SATURN.		
Jan. 5	12 50.2	− 2 45	11 52 P. M.	5 45.0 A. M.	11 38 A. M.
15	12 50.9	− 2 47	11 13 "	5 06.4 "	11 00 "
25	12 50.9	− 2 44	10 34 "	4 27.1 "	10 20 "
			URANUS.		
Jan. 5	14 31.0	− 14 24	2 25 A. M.	7 29.7 A. M.	12 35 P. M.
15	14 32.2	− 14 30	1 47 "	6 51.5 "	11 56 A. M.
25	14 33.1	− 14 34	1 08 "	6 13.0 "	11 18 "

NEPTUNE.

Date. 1893.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Jan. 5......	4 30.1	+ 20 14	1 58 P. M.	9 26.3 P. M.	4 55 A. M.
15......	4 29.3	+ 20 13	1 18 "	8 46.2 "	4 15 "
25......	4 28.7	+ 20 12	12 38 "	8 06.2 "	3 35 "

THE SUN.

Date. 1893.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Jan. 5......	19 08.2	– 22 32	7 37 A. M.	12 05.9 P. M.	4 35 P. M.
15......	19 51.6	– 20 59	7 33 "	12 09.9 "	4 46 "
25......	20 33.8	– 18 46	7 26 "	12 12.7 "	5 00 "

Configuration of Jupiter's Satellites at 8h p. m. Central Time.

Jan.		Jan.		Jan.	
1	4 2 ○ 1 3	11	3 2 ○ 1 4	21	4 1 2 ○ 3
2	4 3 ○ 2 ●	12	3 1 ○ 4 ●	22	4 2 ○ 1 3
3	4 3 1 ○ 2	13	○ 3 1 2 4	23	4 1 ○ 3 2
4	4 3 2 ○ 1	14	1 2 ○ 3 4	24	4 3 ○ 1 2
5	4 1 3 ○ 2	15	2 ○ 1 3 4	25	3 2 4 ○ ●
6	4 ○ 1 3 2	16	1 ○ 3 2 4	26	3 1 2 ○ 4
7	4 2 1 ○ 3	17	♃ ♃ 3 ○ 2	27	○ 3 1 2 4
8	2 4 ○ 1 3	18	3 4 2 ○ 1	28	♃ 1 ○ 3 4
9	♃ ○ 4 2 ●	19	4 3 1 2 ○	29	2 1 ○ 3 4
10	3 1 ○ 2 4	20	4 ○ 3 1 2	30	1 ○ 2 3 4
				31	3 ○ 1 2 4

Phenomena of Jupiter's Satellites.

1893.		h m					h m		
Jan.	1	9 54 P. M.	I	Sh. In.		17	6 54 "	I	Tr. In.
	2	5 06 "	III	Tr. Eg.			8 14 "	I	Sh. In.
		5 53 "	I	Oc. Dis.			9 09 "	I	Tr. Eg.
		8 17 "	III	Sh. In.		18	7 46 "	I	Ec. Re.
		9 25 "	I	Ec. Re.		19	4 56 "	I	Sh. Eg.
	3	5 16 "	I	Tr. Eg.			8 47 "	II	Oc. Dis.
		6 36 "	I	Sh. Eg.		20	6 26 "	III	Ec. Dis.
		9 18 "	II	Tr. In.			7 14 "	III	Ec. Re.
	5	6 04 "	II	Oc. Re.		21	6 33 "	II	Tr. Eg.
		6 18 "	II	Ec. Dis.			6 39 "	II	Sh. In.
		8 39 "	II	Ec. Re.			9 06 "	II	Sh. Eg.
	9	6 40 "	III	Tr. In.		24	8 52 "	I	Tr. In.
		7 49 "	I	Oc. Dis.		25	6 13 "	I	Oc. Dis.
		9 09 "	III	Tr. Eg.		26	4 39 "	I	Sh. In.
	10	4 57 "	I	Tr. In.			5 36 "	I	Tr. Eg.
		6 19 "	I	Sh. In.			6 52 "	I	Sh. Eg.
		7 12 "	I	Tr. Eg.		27	4 58 "	III	Oc. Dis.
		8 31 "	I	Sh. Eg.			7 27 "	III	Oc. Re.
	11	5 50 "	I	Ec. Re.		28	6 42 "	II	Tr. In.
	12	6 07 "	II	Oc. Dis.			9 16 "	II	Tr. Eg.
		8 42 "	II	Oc. Re.			9 17 "	II	Sh. In.
		8 55 "	II	Ec. Dis.		30	5 49 "	II	Ec' Re.
	14	6 28 "	II	Sh. Eg.					

Phases and Aspects of the Moon.

		d	h m	
Full Moon..	Jan.	2	7 41	A. M.
Last Quarter..	"	9	4 28	P. M.
Apogee.......................	"	12	1 00	A. M.
New Moon...	"	17	7 28	P. M.
First Quarter.......................................	"	25	12 27	A. M.
Perigee...	"	27	7 36	P. M.
Full Moon..	"	31	8 11	"

Occultations Visible at Washington.

Date 1893.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h	m	IMMERSION Angle f'm N pt. °	EMERSION Washington M. T. h	m	EMERSION Angle f'm N pt. °	Duration. h	m
Jan. 7	10 Virginis	6.4	11	40	121	12	45	303	1	05
8	38 Virginis	6.2	11	36	64	12	11	356	0	34
11	ι^1 Libræ	5.0	15	24	156	16	21	268	0	57
11	ι^2 Libræ	6.5	15	41	93	16	45	333	1	04
14	3 Sagittarii	4.6	16	08	104	17	09	287	1	00
22	10 Ceti	6.2	8	53	81	9	48	220	0	55
25	50 Arietis	6.8	7	51	77	9	07	230	1	16
25	54 Arietis	6.3	12	10	62	13	06	268	0	56
26	32 Tauri	6.0	6	36	72	7	57	238	1	21
29	W. *vi*, 1656	8.2	4	37	109	5	30	241	0	53
29	47 Geminorum	6.0	8	05	128	9	07	234	1	02
31	B.A.C. 3138	6.3	8	20	28	8	36	2	1	16
31	B.A.C. 3206	6.3	14	58	116	16	06	305	1	08

Minima of Variable Stars of the Algol Type.

U. CEPHEI.

R. A.................$0^h\ 52^m\ 32^s$
Decl.................+81° 17′
Period.............2*d* $11^h 50^m$

1893.	
Jan. 1	1 A. M.
6	1 "
11	1 "
15	midn.
20	"
25	"
30	11 P. M.

ALGOL.

R. A.................$3^h\ 01^m\ 01^s$
Decl.................+40° 32′
Period.............2*d* $20^h 49^m$

Jan. 2	11 P. M.
5	8 "
8	5 "
23	1 A. M.
25	9 P. M.
28	6 "
31	3 "

R. CANIS MAJORIS.

R. A...............$7^h\ 14^m\ 30^s$
Decl................— 16° 11′
Period............1*d* $03^h 16^m$

Jan. 8	10 P. M.
10	1 A. M.
11	4 "
16	8 P. M.
17	midn.
19	3 A. M.
24	7 P. M.
25	11 "
27	2 A. M.
28	5 "

S CANCRI.

R. A.................$8^h\ 37^m\ 39^s$
Decl..................+ 19° 26′
Period.............9*d* $11^h 37^m$

Jan. 3	6 P. M.
13	6 A. M.
22	5 P. M.
Feb. 1	5 A. M.

S ANTLIÆ.

R. A.................$9^h\ 27^m\ 30^s$
Decl..................—28° 09′
Period............. $7^h 47^m$

Jan. 1	2 A. M.
2	1 "
2	midn.
3	midn.
4	11 P. M.
5	10 "
6	10 "
7	9 "
8	5 A. M.
9	4 "
10	3 "
11	3 "
12	2 "
13	1 "
14	1 A. M.
14	midn.
15	11 P. M.
16	11 "
17	10 "
18	9 "
19	9 "
20	5 A.M.
21	4 "
22	3 "
23	3 "
24	2 "
25	1 "
26	1 "
26	midn.
27	11 P. M.
28	11 "
29	10 "
30	9 "
31	9 "

δ LIBRÆ.

R. A...............$14^h\ 55^m\ 06^s$
Decl.............— 8° 05′
Period..........2*d* $7^h\ 51^m$

Jan. 3	11 P. M.
6	7 A. M.
10	11 P. M.
13	7 A. M.
17	10 P. M.
20	6 A. M.
24	10 P. M.
27	6 A. M.
31	10 P. M.

U CORONÆ.

R. A...............$15^h\ 13^m\ 43^s$
Decl...............+ 32° 03′
Period...........3*d* $10^h\ 51^m$

Jan. 17	6 A. M.
24	4 "
30	2 "

Two New Asteroids.—These were both discovered by means of photography. 1892 J was found on plates exposed by Wolf at Heidelberg, Sept. 25 and 30. Its position, Sept. 30, at 12^h Berlin mean time was: R. A. $0^h\ 21.^m7$; Decl, — 2° 50′. Daily motion — $1^m.03$ and — 1′.

1892 K was found on plates by Wolf, Oct. 17 and 20. Its position Oct. 20, $9^h\ 50^m$ Greenwich mean time was: R. A. $2^h\ 18^m\ 38^s$; Decl. + 18° 08′.

COMET NOTES.

Three New Comets have been discovered during November. The first was discovered by Mr. Edwin Holmes, of London, Eng., whose letter to the *English Mechanic* we print below. It is a bright telescopic comet, barely visible to the naked eye but easily seen with an opera-glass. It has attracted unusual attention from the fact that it appeared in the direction from which Biela's comet might be expected to approach the Earth. Dr. Berberich, of Berlin, immediately called attention to this fact, and several astronomers, assuming the comet to be Biela's, calculated the distance at which it ought to be and the time when it would cross the Earth's path. This time was found to be within a few hours of the the time when the Earth would pass the same point. These statements given to newspaper reporters were widely circulated and produced the impression that there was to be a collision between the comet and the Earth about Nov. 27. Later calculations do not confirm the assumption of identity with Biela's comet. On the contrary they indicate that this comet is at a great distance from the Earth and is receding. This result is a surprise to those who have been observing the comet for it has rapidly increased in size since it was discovered. Its diameter Nov. 22 was more than three times as great as on Nov. 11, although the brightness was somewhat less. It is moving very slowly southward in Andromeda and is still near the star μ.

The second comet was discovered by Mr. W. R. Brooks on the morning of Nov. 19th. His account of the discovery is given below.

The third, the announcement of which has just been received, was discovered by Mr. Freeman at Brighton, Eng., Nov. 24.389 Gr. mean time. It is described as a faint comet, in R. A. $0^h\ 29^m\ 00^s$; Decl. $+ 30°\ 09'$, daily motion $0^m\ 00^s$ and $- 3°\ 12'$. This is also in Andromeda near the Biela meteor radiant.

Discovery of Comet *f* 1892 (Holmes).—On Sunday night, Nov. 6th, at 11:45, I found a new comet in Andromeda. It was bright enough to be visible in an opera-glass through the haze prevailing. Nucleus bright, with surrounding nebulosity 5′ in diameter. No tail visible. I made the position $0^h\ 46.8^m + 38°\ 32'$ exactly $1^m\ 10^s$ preceding Σ 72. My surroundings prevented me watching for any motion. I think it must have approached rapidly, for I observed that region on Oct. 25 and observed nothing special. EDWIN HOLMES.

English Mechanic Nov. 11, 1892.

Elements of Comet *f* 1892 (Holmes).—Attempts to represent the observations of this comet by a parabola have failed. From observations by Wendell Nov. 8 and my own of Nov. 15 and 22, Mr. Sivaslian has computed the following parabolic elements:

$$\begin{array}{rl} T & = \text{Feb. } 28.143,\ 1892 \\ & \quad \circ \\ \omega & = 346\ \ 21\ \ 56 \\ \Omega & = 325\ \ 43\ \ 48 \\ i & = \ \ 24\ \ 17\ \ 38 \\ \log q & = 0.29587 \end{array} \left.\begin{array}{l} \\ \\ \\ \\ \\ \\ \end{array}\right\} 1892.0$$

The residuals (O—C) for the middle place $\Delta\lambda \cos\beta = -173''$; $\Delta\beta = +160''$ cannot be very much bettered by any variation of the distance. An attempt to calculate elliptic elements from these observations showed that they were insufficient to give results of any accuracy. We decided, therefore, to wait for further observations.

From *Science Observer* special circular, No. 99 we have the following elliptic elements by Dr. Kreutz and Rev. Geo. M. Searle:

	Kreutz.	Searle.
T =	June 11	Oct. 11.9802
ω =	11° 38′	62° 19′ 02″
Ω =	333 31	325 41 16
i =	24 39	19 16 43
q =	2.1509	2.28036
e =	0.4172	0.31963
Period =	7.08 years	6.14 years.

We have no ephemeris extending beyond Dec. 5, but as the comet is bright and moving very slowly observers will have no trouble in following it through December.

Comet Holmes seen Nov. 3.—My friend Mr. W. A. Post of Newport News, Va., writes me that he saw the Holmes comet on the night of November 3d. "but thought it some well known nebula." He was using a five-inch Byrne's glass at the time. He sends a sketch showing the comet rather oval as he remembers it.

New York, Nov. 16, 1892. R. M. SMYTHE

Discovery of Comet *g* 1892 (Brooks).—On the morning of November 19 at 15 hours, Eastern Standard Time, I discovered a rather bright nebulous object which I soon suspected to be a comet. The position of the object was R. A. $12^h\ 56^m\ 40^s + 12^\circ\ 59'$.

It was therefore in that very nebulous region of Virgo and Coma Berenices. But I had no record of such an object in that position. The nearest was Nebula No. 4880 of the N. G. C. = W. H. III 83, which, allowing for precession, came very nearly in the same declination, but was two minutes west of my object in R. A. Moreover, that nebula was described as "considerably faint," and my object was brightish in the 10-inch refractor.

The sky clouded before I could be quite sure of motion, although my impression of the direction of motion proved to be correct. A telegram was at once transmitted to Harvard College Observatory, where the discovery was confirmed by Mr. Reed, and a position secured by Mr. O. C. Wendell, as follows: Nov. 21st, $16^h\ 44^m\ 38^s$ Camb. M. T. R. A. $12^h\ 59^m\ 15.63^s + 13^\circ\ 50'\ 27''.3$ This gives a slow motion in a northeasterly direction.

The comet is a comparatively easy one, fairly large, and has considerable condensation, with which the coma is not quite concentric. WILLIAM R. BROOKS.

Smith Observatory, Geneva, N. Y., Nov. 25, 1892.

Comet *e* 1892 (Barnard, Oct. 12).—We have had no opportunity to look for this comet during November except on Nov. 15 when we failed to find it near the ephemeris place. Mr. Barnard observed it on Nov. 7 and says: "it has faded very much since the last observations. It is scarcely probable this object can be followed much longer." The elements of this comet are found to be elliptic. Professor Krueger from observations Oct. 16, 20 and 25 obtains a period of about 10.4 years (*Astr. Nach. 3127*). Professor Schulhof has also calculated elliptic elements and calls attention to their similarity to those of Wolf's periodic comet which has just passed out of view. He suggests that the two have the same origin, are in fact parts of the same comet which separated at some time previous to 1885. In that year they were in the vicinity of Jupiter together and suffered violent perturbations by the planet. A relatively small difference in their epochs of passing peri-jove would be sufficient to produce the considerable difference in their inclinations and excentricities. Below are the elements calculated by Mr. Schulhof together with those of Wolf's comet.

	Comet Barnard.	Wolf's Comet.
$T =$	Dec. 9.0721, 1892, Paris mean time.	——
$\pi =$	$18^\circ\ 33'\ 44''$	$19^\circ\ 12'$
$\Omega =$	207 41 45	206 22
$i =$	30 51 13	25 15
$\log q =$	0.149245	0.2022
$e =$	0.579619	0.5571

Comet *d* 1892 (Brooks, August 28).—The following elements from the *Astronomical Journal*, No. 279. were computed by Mr. George A. Hill of the U. S. Naval Observatory, from observations at Kiel, August 31, Göttingen Sept. 18 and Hamburg Oct. 7. The residuals for the middle place are $\Delta\lambda \cos\beta = +11''.5$; $\Delta\beta = -3''.1$:

$$\begin{array}{ll} T & = 1892,\ \text{Dec. } 28.11944 \text{ Gr. M. T.} \\ \left.\begin{array}{ll} \Omega & = 264^\circ\ 32'\ 36''.2 \\ \omega & = 252\ \ 23\ \ 21\ .9 \\ i & = \ \ 24\ \ 45\ \ 10\ .8 \end{array}\right\} & \text{Mean Eqr. } 1892.0. \\ \log q = 9.991529 & q = 0.98068 \end{array}$$

Ephemeris.

	h	m	s	°	″	log. r	Br.
Dec. 6	11	58	43.2	− 21	31.9	9.9447	30.9
7	12	04	04.7	22	27.8		
8		09	28.2	23	22.1		
9		14	53.4	24	16.6		
10		20	20.5	25	09.3	9.9498	31.5
11		25	49.4	26	01.1		
12		31	20.0	26	51.7		
13		36	51.5	27	40.8		
14		42	24.4	28	28.5	9.9575	31.5
15		47	58.3	29	14.8		
16		53	33.2	29	59.7		
17	12	59	08.7	30	43.2		
18	13	04	45.5	31	25.3	9.9676	30.9
19		10	23.0	32	06.0		
20		16	01.0	32	45.3		
21		21	39.2	33	23.1		
22		27	17.7	33	59.4	9.9792	29.9
23		32	56.3	34	34.3		
24		38	32.8	35	07.7		
25		44	10.7	35	39.7		
26	13	49	47.4	− 36	10.2	9.9920	28.4

Ephemeris of Comet *a* 1892 (Swift.)

[Computed by Geo. A. Law, student in Goodsell Observatory, from elements by Miss Gertrude Wentworth, *Astr. Jour.* No. 273].

[Continued from Page 837.]

Gr. M. T.	App. R. A.			App. Decl.		log. r	log. Δ	Br.
	h	m	s	°				
1892. Dec. 16.5	23	58	10.6	+ 28	39.8			
17.5		58	49.8		31.7			
18.5	23	59	29.7		23.9			
19.5	0	00	10.2		16.2	0.5670	0.5255	.011
20.5		00	51.3		08.7			
21.5		01	32.9	28	01.4			
22.5		02	15.1	27	54.3			
23.5		02	57.9		47.5	0.5720	0.5381	.010
24.5		03	41.3		40.9			
25.5		04	25.2		34.4			
26.5		05	19.7		28.1			
27.5		05	54.6		22.0	0.5770	0.5503	.009
28.5		06	40.0		15.2			
29.5		07	25.9		10.5			
30.5		08	12.2	27	05.0			
31.5		08	59.0	26	59.6	0.5818	0.5618	.008
1893. Jan. 1.5		09	46.3		54.3			
2.5		10	34.0		49.2			
3.5		11	22.1		44.3			
4.5		12	10.6		39.5	0.5866	0.5739	.008
5.5		12	59.5		35.0			
6.5		13	48.9		30.6			
7.5		14	38.6		26.4			
8.5		15	28.7		22.4	0.5914	0.5853	.007
9.5		16	19.1		18.5			
10.5		17	09.8		14.8			
11.5		18	00.8		11.2			
12.5		18	52.2		07.7	0.5960	0.5964	.007
13.5		19	43.9		04.4			
14.5		20	36.0	26	01.2			
15.5		21	38.3	25	58.2			
16.5	0	22	20.9	+ 25	55.3	0.6006	0.6072	.006

Hw to Compute the Relative Brightness of a Comet.—A subscriber asks us the meaning of relative brightness of a comet and how it is determined. Usually the unit of brightness of a comet is taken as the brightness which the same comet had at the time of its discovery, and the relative brightness is its brightness on any other date expressed in terms of that unit. The brightness is computed on the assumption that the comet shines by reflected light from the Sun only and hence varies in inverse ratio to the squares of the distances from the Sun and Earth. This is expressed by the proportion

$$B : B_0 :: \frac{1}{r^2\Delta^2} : \frac{1}{r_0^2\Delta_0^2}$$

in which B, r and Δ are respectively the brightness, distance from Sun, and distance from Earth on any date and B_0, r_0 and Δ_0 are the corresponding quantities on any other date. If B_0 is the brightness on the date of discovery and is taken as unity, then we have for the relative brightness on any other date

$$B = \frac{r_0^2\Delta_0^2}{r^2\Delta^2}.$$

If the comet gives out light of its own this law does not hold true.

The Shower of Bielid Meteors.—Although the Holmes' comet did not turn out to be Biela's, the prediction that there would be a shower of meteors, when the Earth passed the track of the latter comet, had a partial fulfilment on the evening of Wednesday, Nov. 23. On that evening a shower of meteors radiating from the constellation of Andromeda was observed quite generally throughout the United States. At Northfield, the display had already begun at dark and continued so long as it was watched, *i. e.*, until nearly midnight. The meteors were quite numerous, falling in all quarters of the sky. As many as 15 to 20 on the average could be counted by one person each minute. They were of all magnitudes from the faintest visible to as bright as Jupiter.

We have reports of similar observations from many points, but have space only for the following, which comes from Princeton, N. J. It is unsigned, but is evidently from Professor C. A. Young. Thursday, Friday and Saturday nights were cloudy at Northfield. Sunday night was clear during the first half but no meteors were seen.

The Meteor Shower of Nov. 23, 1892.—On the night of the 23d we had here a fine meteoric display. At 7 o'clock the meteors were already numerous, and from 7:30 until 12:30, when it clouded up, they were falling at the rate of 100 in from four to five minutes. At ten o'clock two observers, standing in an open space and facing in opposite directions, counted 104 in five minutes, and again at eleven they counted 100 in four minutes and a half. The number seen by observers sufficiently numerous to cover the whole sky exhaustively, would have been from four to five times as many, and reckoning on that basis, the total number that fell within our range of vision at Princeton must have been at least 30,000 during the five hours.

The meteors were evidently "Bielids," the radiant at 8:30 being a roughly circular area about 4° in diameter with its centre at R. A. $1^{h}\ 20^{m}$, Dec. + 41° 30′. At 10 it seemed to be a little more definitely limited, and several nearly stationary meteors fixed its position as R. A. $1^{h}\ 30^{m}$, Dec. + 40° 30′, very near Upsilon Andromedæ. At 11, it was again determined, and then it came out R. A. $1^{h}\ 40^{m}$, Dec. + 40°. Whether this apparent change in the position of the radiant was real or not, I am not quite certain, but a motion of the radiant, very similar in amount and direction, is given by Denza in his observations of the shower of 1885: (see *Nature*, vol. 33, page 151). At that time the mean position of the radiant was about 3° N. W. of its place this year.

Holmes's comet, barely visible to the naked eye, was about 10° west and 4° south of the radiant.

It is worth noting that the Earth's heliocentric longitude at the time of the shower the other night was only 62°, and not 65°, which (65°) was the longitude of the descending node of Biela's orbit at the last appearance of the comet in 1852, and was the longitude of the Earth at the time of the showers of 1872 and 1885. The fact suggests the inquiry whether such a recession of the node ca[illegible] accounted for by perturbations (probably by Jupiter) since 1885.

It is obvious also that if the meteoric swarm encountered by the Earth in 1872 and 1885 was really moving in the orbit of Biela's comet, which when last observed had a period of 6.6 years, then the swarm encountered on Wednesday night, just 7 years later, must be an entirely different one: unless indeed a retardation of nearly five months can be accounted for by perturbations within the last six years, which is hardly likely.

Most of the meteors were very small, not exceeding the 5th magnitude; but a few, perhaps ten per cent of the whole, were above the 2d. In the course of the night four were observed which rivalled or surpassed Jupiter.

The brighter ones generally left bluish trains which remained visible for four or five seconds. The smaller ones often came in "flights," three or four together, and fully half of the paths were more or less curved and wavy from the resistance of the air.

Last night (Nov. 24th) was mostly overcast, but there were occasional breaks in the clouds, and a careful watch showed three or four meteors which might possibly be Bielids: but it was clear that there was nothing like a "shower" in progress.

Princeton, N. J., Nov. 25th, 1892.

Meteors of November 23, 1892.—The meteors of Wednesday night, Nov. 23, 1892, have attracted general attention. They were seen here in all parts of the sky at almost every moment. They did not come at a strictly constant rate, though nearly so. On the average a single observer could see from 50 to 60 fairly bright ones every five minutes, which corresponds to a daily rate of from 400,000,000 to 500,000,000 on the hemisphere of the Earth towards the radiant. The radiant, as observed here, was very approximately at

$$\alpha = 1^{h}\,39^{m} \qquad \delta = +42^{\circ}.$$

Palo Alto, Cal., Nov. 28, 1892. W. J. HUSSEY.

NEWS AND NOTES.

Serious delays have made us unusually late this month. With better office facilities and other more favorable arrangements, our publication will appear promptly and regularly hereafter.

A large number of subscriptions expire with this number. It is especially requested that renewals be *promptly* made that our mailing list may be corrected for the January issue.

Mounting of the 40-inch Telescope for Chicago University.—Messrs. Warner & Swasey, of Cleveland, Ohio, have been awarded the contract for mounting the 40-inch telescope for the Yerkes' Observatory of the University of Chicago.

If subscribers interested in still further improvements of ASTRONOMY AND ASTRO-PHYSICS for the coming year, will do us the favor of bringing this publication to the notice of the friends of science generally, we are sure that its merit will commend it favorably, and that our subscription list will be greatly increased. With such increase greater outlay will be made for the illustrated matter, in amount or quality, or both, as the demands of current astronomy shall decide.

Aids for Temporary Star Search.—The following extract from a note by Mr. D. E. Packer in *English Mechanic*, Nov. 11, 1892, may be of use to some of our readers:

"During the recent summer months, in our leisure evenings, Mr. Morris, of Cambridge, and myself were engaged in searching the heavens (especially the Milky Way region) for the detection of new stars. In order to expedite our search, we adopted a scheme which, I think, will find favor with those who are similarly occupied on starry nights, and for which we strongly advocate a trial. We used the excellent maps in Schürig's "Tabulæ Cœlestis," which give all, or nearly all, stars down to the sixth magnitude. The charts were photographed on quarter plates, and the negatives, backed by tissue paper or an ordinary screen glass, were projected in front of a small bull's-eye lantern. A convenient method was thus obtained of comparing any portion of the chart with its corresponding portion in the heavens. It only required the use of an ordinary magnifier to enlarge any portion of the photographed chart to render comparison easier, and the apparatus was complete. The ease and comfort with which considerable areas of sky were swept over, and the enormous saving of time which this method affords over the ordinary method, a trial will suffice to show. Regions near the zenith were viewed by projection in an ordinary mirror, the photographed chart being correspondingly inverted."

Cause of Brightness of the Limb of Mars.—Is it not probable that the apparent increase in brightness of the disc of Mars toward the limb is an optical illusion due to the contrast with the surrounding sky, and to the fact that the spherical form of Mars causes the markings to disappear near the limb? If so, might it not be proved by differential photometric observations of different portions of the disc made when Mars is near opposition? ORMOND STONE.

Oct. 29, 1892.

Peculiar Stellar Spectra.—An examination by Mr. A. E. Douglas of the photographs taken at the Arequipa station of this Observatory has revealed the following peculiar stellar spectra.

1.	A. G. C. 16710.	Type IV. Identification uncertain.
2.	A. G. C. 19254.	Type IV.
3.	—15° 4923.	Type IV. Identification uncertain.
4.	S Carinæ.	Hydrogen lines bright.
5.	X Ophiuchi.	Hydrogen lines bright.
6.	N. G. C. 3918.	Gaseous character confirmed by photograph.
7.	N. G. C. 6618.	" " " " "

Nos. 3, 4 and 7 had previously been discovered independently by Mrs. Fleming from other plates already received in Cambridge.

Harvard College Observatory, Cambridge, Mass. EDWARD C. PICKERING.

Nov. 10, 1892.

Occultation of Mars, July 11, 1892.—The occultation was observed at the Dearborn Observatory with the 18½-inch refractor, power 200, and the times were recorded with the printing chronograph. At immersion, owing to the low altitude of the moon, the definition was poor; at emersion the seeing was very steady.

1st Contact	10^h	14^m	$28^s.2$	Local M. T.
2 "	10	15	25 .9	" "
3 "	11	09	51 .8	" "
4 "	11	10	59 .0	" "

Northwestern University. G. W. HOUGH.

The Fifth Satellite of Jupiter.—Professor Barnard's new satellite of Jupiter was seen with the 18½-inch refractor of the Dearborn Observatory, on Oct. 15th, from $11^h\ 37^m$ to $12^h\ 30^m$ standard time. A number of diagrams were made, showing its position with reference to the 1st satellite which was quite near when first seen. A rough setting of the micrometer lines gave 35″ as its distance from the following limb of Jupiter.

I had looked for the satellite on a number of nights previously, using an ephemeris based on the period $11^h\ 49^m$ and of course without success.

On Oct. 14, Mr. S. W. Burnham kindly communicated to me an observation made by Professor Barnard on Oct. 7. On comparing this observation with that made at the date of discovery, I inferred that the elongation occurred about 5 minutes earlier each day.

I saw the satellite again on Nov. 11, $9^h\ 21^m$ a rough measure referred to the IVth satellite gave 36″ as its distance from the limb of Jupiter.

The satellite could only be seen with power 925, using an occulting bar of tinfoil to hide the planet. It is too difficult an object to make measures of precision with the 18½-inch object-glass.

It is much more difficult than either Ariel or Umbriel, the two inner satellites of Uranus, both of which I have observed under ordinary atmospheric conditions. The Vth Satellite of Jupiter, on the contrary, requires the best possible atmospheric conditions to see it at all with the 18½-inch object-glass.

Northwestern University. G. W. HOUGH.

GENERAL INDEX TO VOLUME XI.

NOTE.—The January number contains pages from 1-96, Februay, 97-176; March, 177-256; April, 257-352; May, 353-448; June, 449-544; August, 545-640; October, 641-752, November, 753-848, December, 849-944. No further reference will be made to the monthly issues of this Journal. The numbers following the tiles are the pages of the volume. This volume is numbered XI in continuation of the series of the ten volumes previously published under the name of THE SIDEREAL MESSENGER.

Annual Subscription Price, $4. 101 *Published Ten Times a Year.*

ASTRONOMY and ASTRO-PHYSICS.

JANUARY, 1892.

CONTENTS.

GENERAL ASTRONOMY:

ASTRO-PHYSICS:

EDITORS:

WM. W. PAYNE,
DIRECTOR OF THE GOODSELL OBSERVATORY, NORTHFIELD, MINN.

GEORGE E. HALE,
DIRECTOR OF THE KENWOOD ASTRO-PHYSICAL OBSERVATORY, CHICAGO, ILL.

Entered at the Post Office at Northfield, Minn., for transmission through the mail at second class rates.

THE

E. Howard Watch and Clock Co.

383 WASHINGTON STREET, BOSTON,
41 MAIDEN LANE, NEW YORK,
34 WASHINGTON STREET, CHICAGO.

MANUFACTURERS OF

Astronomical Regulators

REGULATORS OF PRECISION,

AND ✱ FINE ✱ WATCHES.

To any of our regulators we attach devices for the transmission of electrical currents for operating chronographs, sounders (indicating the time of the standard regulator), or for synchronizing secondary clocks when desired.

These electrical transmitting devices can be attached to our No. 89 regulator, which is especially constructed to meet the wants of the railroad service; and the almost absolute certainty and regularity of the performance of these regulators make them particularly desirable as secondary standards for the railroad service.

To our Astronomical Regulators we apply either Dennison's Gravity or the Graham Dead-Beat escapement. These regulators are made in several grades, thereby meeting the wants of Institutions having ample means for the purchase of the most elaborate form of time-keeping instruments, as well as newly established Institutions with limited means to invest in a regulator.

Our watches are second to none in the world as time-keepers and the manner of their construction is such that they are less liable to injury from improper handling, than any other watch now in the market.

We respctfully solicit correspondence from Corporations, Institutions and individuals contemplating the purchase of a Regulator, regardless of the grade.

Astronomical Instruments,

TELESCOPES,

TRANSITS,

MICROMETERS,

CHRONOGRAPHS,

Sidereal Clocks,

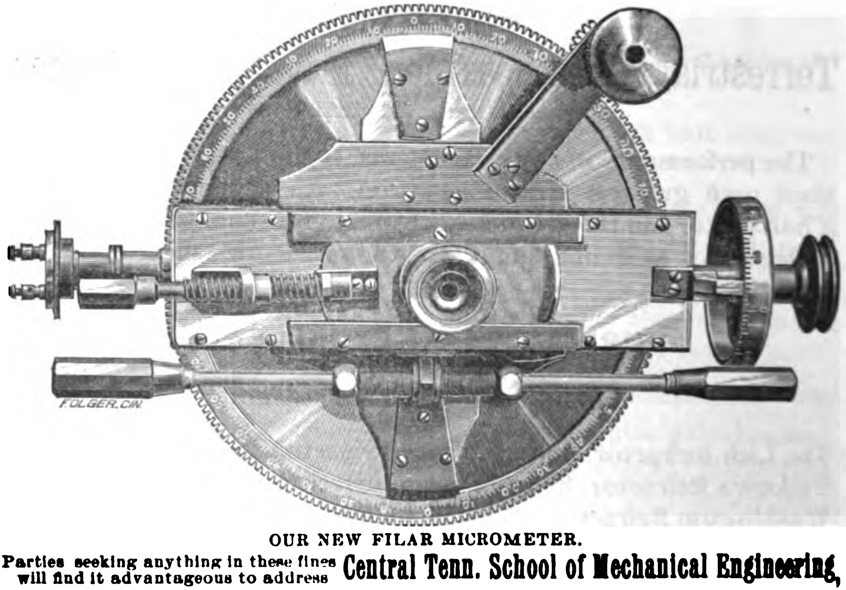
Driving Clocks,

Domes,

Observatories,

Spectroscopes, Microscope Stands, Micrometers for Microscopes.

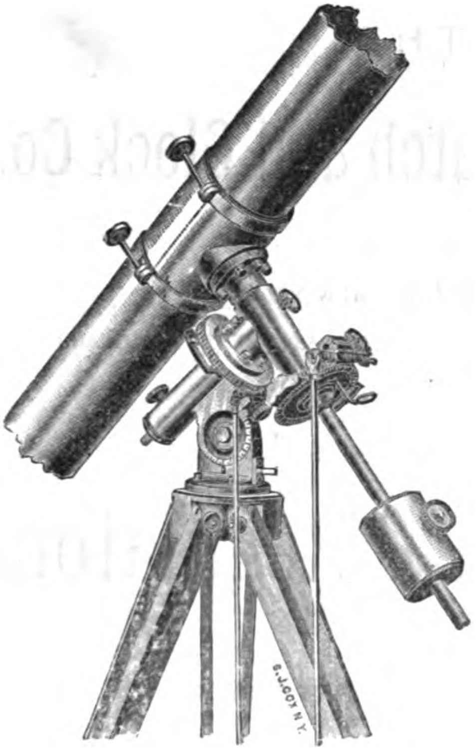
OUR NEW 10-INCH EQUATORIAL.



OUR NEW FILAR MICROMETER.

Parties seeking anything in these lines will find it advantageous to address **Central Tenn. School of Mechanical Engineering,**

NASHVILLE, TENNESEE.


S. J. COX N. Y.

THE

E. Howard Watch and Clock Co.

383 WASHINGTON STREET, BOSTON,
41 MAIDEN LANE, NEW YORK,
170 STATE STREET, CHICAGO.

MANUFACTURERS OF

Astronomical Regulators

REGULATORS OF PRECISION,

AND * FINE * WATCHES.

To any of our regulators we attach devices for the transmission of electrical currents for operating chronographs, sounders (indicating the time of the standard regulator), or for synchronizing secondary clocks when desired.

These electrical transmitting devices can be attached to our No. 89 regulator, which is especially constructed to meet the wants of the railroad service; and the almost absolute certainty and regularity of the performance of these regulators make them particularly desirable as secondary standards for the railroad service.

To our Astronomical Regulators we apply either Dennison's Gravity or the Graham Dead-Beat escapements. These regulators are made in several grades, thereby meeting the wants of Institutions having ample means for the purchase of the most elaborate form of time-keeping instruments, as well as newly established Institutions with limited means to invest in a regulator.

Our watches are second to none in the world as time-keepers and the manner of their construction is such that they are less liable to injury from improper handling, than any other watch now in the market.

We respectfully solicit correspondence from Corporations, Institutions and individuals contemplating the purchase of a Regulator, regardless of the grade.

GINN & CO.,

PUBLISHERS,

BOSTON. NEW YORK. CHICAGO.

Young's Lessons in Astronomy.

Including uranography. By CHARLES A. YOUNG, Ph. D., LL. D., Professor of Astronomy in the College of New Jersey (Princeton), and author of *A General Astronomy*, *Elements of Astronomy*, etc. 12mo. Cloth. Illustrated. IX + 357 pages, exclusive of four double-page star maps. By mail, $1.30; for introduction, $1.20; allowance for an old book in exchange, 30 cents.

Young's Elements of Astronomy.

A Text-book for use in High Schools and Academies. With a Uranography. By CHARLES A. YOUNG, Ph. D., LL. D., Professor of Astronomy in the College of New Jersey (Princeton), and author of *A General Astronomy*, *The Sun*, etc. 12mo. Half leather. X + 472 pages, and four star maps. Mailing Price, $1.55; for Instruction, $1.40; allowance for old book in exchange, 30.

Uranography.

From Young's Elements of Astronomy. 12mo. Flexible covers. 42 pages, besides four star maps. By mail 35 cents; for introduction, 30 cents.

Young's General Astronomy.

A Text-book for Colleges and Technical Schools. By CHARLES A. YOUNG, Ph. D., LL. D., Professor of Astronomy in the College of New Jersey, and author of *The Sun*, etc. 8vo. VIII + 551 pages. Half-morocco. Illustrated with over 250 cuts and diagrams, and supplemented with the necessary tables. Price by mail, $2.50; for introduction, $2.25; allowance for an old book in exchange, 40 cents.

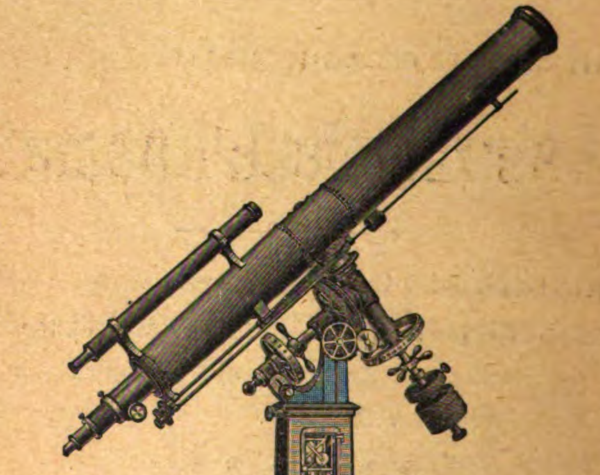
GINN & CO., PUBLISHERS.

A Great Railway.

The Chicago, Milwaukee & St. Paul Railway Company now operates over sixty-one hundred miles of thoroughly equipped road in Illinois, Wisconsin, Northern Michigan, Minnesota, Iowa, Missouri, South and North Dakota. Each recurring year its lines are extended in all directions to meet the necessities of the rapidly populating sections of country west, northwest, and southwest, of Chicago, and to furnish a market for the products of the greatest agricultural and stock raising districts in the world. In Illinois it operates 317 miles of track; in Wisconsin, 1,636 miles; in Northern Michigan, 96 miles; in Iowa, 1,551 miles; in Minnesota, 1,115 miles; in South Dakota, 1'092 miles; in North Dakota, 118 miles; in Missouri, 140 miles, and the end is not yet. It has terminals in such large cities as Chicago, Milwaukee, La Crosse, St. Paul, Minneapolis, Fargo, Sioux City, Council Bluffs, Omaha, and Kansas City and St. Joseph, Mo., and along its lines are hundreds of large and small thriving cities, towns and villages. Manufacturing interests are cultivated, and all branches of trade find encouragement. The Railway Company has a just appreciation of the value of its patrons, and its magnificent earnings are the result of the good business tact which characterizes the management of its affairs.

The popularity of the line is attested by the fact that notwithstanding the strongest kind of competition of old and new lines, the Chicago, Milwaukee & St. Paul Railway continues to carry the greater proportion of all the business between Chicago, Milwaukee, St. Paul and Minneapolis. It is the best patronized route between Chicago, Council Bluffs and Omaha to and from all points in Wisconsin, Minnesota, Dakota and Iowa, and its Kansas City and St. Joseph line has taken equal rank with the other lines leading to and from the Southwest.

On all its through lines of travel the Chicago, Milwaukee & St. Paul Railway runs the most perfectly equipped trains of Sleeping, Parlor and Dining Cars and Coaches. The through trains on all its lines are systematically heated by steam. No effort is spared to furnish the best accomodations for the least money, and, in addition, patrons of the road are sure of courteous treatment from its employes.



Annual Subscription Price, $4. 106 *Published Ten Times a Year.*

ASTRONOMY and ASTRO-PHYSICS.

JUNE, 1892.

CONTENTS.

GENERAL ASTRONOMY:

ASTRO-PHYSICS:

EDITORS:

WM. W. PAYNE,
Director of the Goodsell Observatory, Northfield, Minn.

GEORGE E. HALE.
Director of the Kenwood Astro-Physical Observatory, Chicago, Ill.

Wm. Wesley & Son, 28 Essex St., Strand, London, are authorized to receive foreign subscriptions.

Entered at the Post Office at Northfield, Minn., for transmission through the mail at second class rates.

THE

E. Howard Watch and Clock Co.

383 WASHINGTON STREET, BOSTON,
41 MAIDEN LANE, NEW YORK,
170 STATE STREET, CHICAGO.

MANUFACTURERS OF

Astronomical Regulators

REGULATORS OF PRECISION,

AND * FINE * WATCHES.

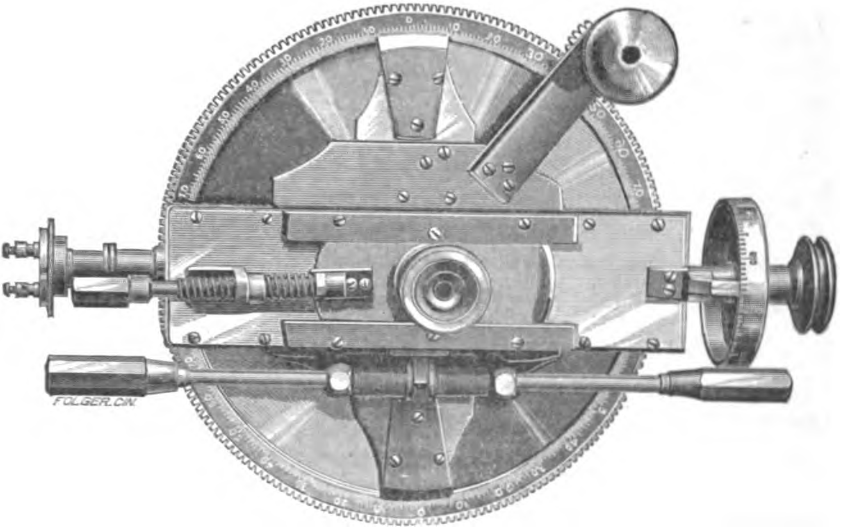
To any of our regulators we attach devices for the transmission of electrical currents for operating chronographs, sounders (indicating the time of the standard regulator), or for synchronizing secondary clocks when desired.

These electrical transmitting devices can be attached to our No. 89 regulator, which is especially constructed to meet the wants of the railroad service; and the almost absolute certainty and regularity of the performance of these regulators make them particularly desirable as secondary standards for the railroad service.

To our Astronomical Regulators we apply either Dennison's Gravity or the Graham Dead-Beat escapement. These regulators are made in several grades, thereby meeting the wants of Institutions having ample means for the purchase of the most elaborate form of time-keeping instruments, as well as newly established Institutions with limited means to invest in a regulator.

Our watches are second to none in the world as time-keepers and the manner of their construction is such that they are less liable to injury from improper handling, than any other watch now in th[illegible]rket.

We [illegible] olicit correspondence from Corporations, Institu[illegible] iduals contemplating the purchase of a Regula[illegible] of the grade.


FOLGER.CIN.

NORTHWESTERN UNIVERSITY,

EVANSTON AND CHICAGO, ILLINOIS.

HENRY WADE ROGERS, LL. D., President. *Two Hundred Professors and Instructors and over 2,300 pupils.*

The University includes the following Departments:

1. College of Liberal Arts, Evanston, Ills.
2. School of Medicine, Chicago, Ills.
3. School of Law, Chicago, Ills.
4. School of Pharmacy, Chicago, Ills.
5. School of Dentistry, Chicago, Ills.
6. Woman's Medical School, Chicago, Ills.
7. Theological Schools, Evanston, Ills.
8. Preparatory School, Evanston, Ills.
9. Conservatory of Music, Evanston, Ills.
10. School of Oratory, Evanston, Ills.

The University is located in Evanston, the most beautiful suburb of Chicago, and one of the most attractive summer resorts on the Great Lakes. It is unusually free from immoral influences. The sale of intoxicating drinks within four miles of the University is prohibited by the charter. The schools of Law, Medicine, Pharmacy, Dentistry and the Woman's Medical School are located in Chicago.

For catalogues of the University address the President.

For catalogues of the Preparatory School address Rev. H. F. Fisk, Principal, Evanston, Ill.

BELOIT COLLEGE.

The 46th year opens Sept. 6, 1892, with New and Extensive [illegible] in Equipment.

SMITH OBSERVATORY OF BELOIT COLLEGE.

CHAS. A. BACON, M. A., Director and Professor of Astronomy. GEORGE E. HALE, S. B., Professor of Astro-Physics.

[illegible]

Address President Edward D. Eaton, Beloit, Wis.

[illegible]

Scientific American

[illegible]

FOR SALE.

Four-inch full aperture Achromatic Astronomical Telescope.

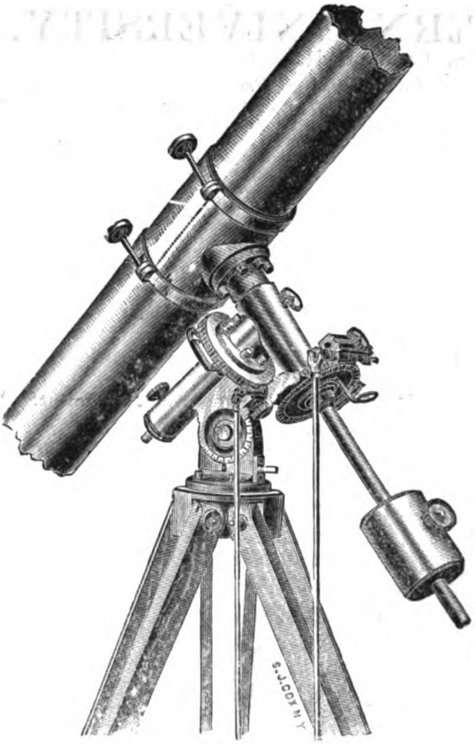
[illegible]

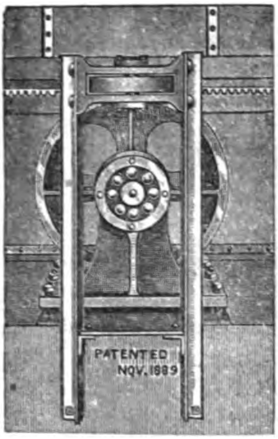
FOR SALE.

[illegible]

FOR SALE.

[illegible]


S.J.COX N.Y.


PATENTED
NOV. 1889


COMPTOMETER.
TRADE MARK

Astronomical Instruments,
TELESCOPES,
TRANSITS,
MICROMETERS,
CHRONOGRAPHS,
Sidereal Clocks,
Driving Clocks,
Domes,
Observatories,
Spectroscopes, Microscope Stands,
Micrometers for Microscopes.

OUR NEW 10-INCH EQUATORIAL.

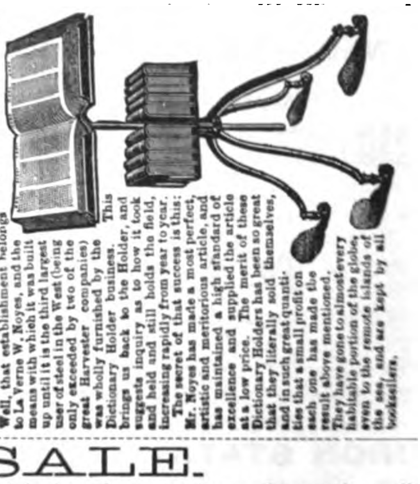
Parties needing anything in these lines will find it advantageous to address **Central Tenn. School of Mechanical Engineering,**
NASHVILLE TENNESSEE.

THE DICTIONARY HOLDER

Did you ever learn what fabulous results grew out of the manufacture by Mr. Noyes of an ornamental stand to hold the dictionary? The story reads like a fable, but to tell it one must ask another question: Have you ever noticed the advertisement of the Aermotor Company, which starts out as follows;

45 sold in '88
2,288 sold in '89
6,268 sold in '90
20,049 sold in '91
60,000 will be sold in '92

A Steel Windmill and Steel Tower every 3 minutes. ☞ These figures tell the story of the ever-growing, ever-going, everlasting Steel Aermotor. Where one goes others follow, and we "Take the Country."



Well, that establishment belongs to La Verne W. Noyes, and the means with which it was built up until it is the third largest user of steel in the West (being only exceeded by two of the great Harvester companies) was wholly furnished by the Dictionary Holder business. This brings us back to the Holder, and suggests inquiry as to how it took and held and still holds the field, increasing rapidly from year to year.

The secret of that success is this: Mr. Noyes has made a most perfect, artistic and meritorious article, and has maintained a high standard of excellence and supplied the article at a low price. The merit of these Dictionary Holders has been so great that they literally sold themselves, and in such great quantities that a small profit on each one has made the result above mentioned. They have gone to almost every habitable portion of the globe, even to the remote islands of the sea, and are kept by all booksellers.

FOR SALE.

Two first-class telescopes 4⅝ and 3⅛ inches clear aperture. In good condition with necessary accessories.

Address, JOHN A. DAUM,
158 North Market St., Canton, O.