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TOTAL SOLAR ECLIPSE, AUG. 19, 1887.

PROF. WM. HARKNESS, WASHINGTON, D. C.

THE following account of the total solar eclipse of Aug. 19, 1887, has been compiled from the best authorities yet available, and shows in a general way what extensive preparations were made for observing the eclipse, how far they were successful, and how largely they were defeated by the bad weather which prevailed throughout Germany and Russia. The stations are mentioned in the order in which they were passed by the moon's shadow, namely, from west to east:

German Stations. The Berlin observatory established stations near the central line of the eclipse at Inselberg in Thuringia, Luckenwalde, Steglitz six miles south of Berlin, Furstenwalde, Frankfurt on the Oder, and Allenstein in East Prussia; and also at Grünberg in Silesia, near the southern boundary, and at Britz near Eberswalde, on the northern boundary of the total zone. Dr. Förster, director of the observatory, occupied the station at Inselberg. Throughout all the region covered by these stations fog, rain, and clouds prevailed. At the extreme eastern stations the clouds in the east were strongly colored at day-break. As the sun neared the horizon the coloration first increased, then slowly diminished, until suddenly there came a complete and general obscuration, and after some minutes the coloration again appeared, only to be banished by full daylight. At Steglitz, a little before totality the observers were favored with a sight of the solar crescent for about five minutes, through a rift in the clouds. The totality itself was not seen, but during its continuance the darkness was so intense that a chronometer could only be read with difficulty, and α Persei, a star of the second magnitude, was visible in the zenith. An attempt was made by two members of the military ballooning department to pass through the clouds in a balloon, but it failed. At Nordhausen and Eisleben, partially successful observations were made.

At Kleistshöhe, about an hour from Frankfurt on the Oder, were stationed Dr. Lachmann from the observatory of Breslau, Mr. Pechüle from Copenhagen, Prof. Tietjen from Berlin, and Dr. Neugebauer from Breslau. As the eclipse was hidden by the clouds, their observations were limited to noting that at the time of totality the northern horizon, to an altitude of about half a degree assumed a deep red tint, and the darkness became so intense that lanterns were required in order to see to read.

At Kolmar, in Posen, Dr. Korber from the Breslau observatory, and Prof. Reimann from Hirschberg, were stationed. Although the sky was covered by clouds, an attempt was made to record the times of third and fourth contact by noting the sudden changes in the light at the beginning and end of totality; and from these changes Dr. Korber concluded that the middle of the eclipse occurred within a second or two of 5*h* 19*m* 22*s* A. M., Breslau mean time. During totality there remained a red streak in the northern horizon, but the gloom was so deep that it was impossible to read the face of a watch without artificial light.

Breslau was not within the zone of totality, and it rained there during the eclipse, but notwithstanding these drawbacks Prof. Leonhard Weber made a careful series of photometric measurements of the daylight at the Breslau observatory.

At Goldap, in East Prussia, Prof. Th. Albrecht was stationed. Clouds rendered the eclipse invisible, but he determined the amount of light during totality in the following simple way: During totality he noted the greatest distance at which he could read a certain manuscript written with a lead pencil, and in the evening he watched for the time when the same manuscript was again just legible at the same distance, and found it to be forty minutes after sunset. Fortunately the condition of the sky with respect to cloudiness was the same in the evening as during the eclipse.

Russian Stations. At Wilna Mr. Paul Garnier was stationed. The weather was so bad that only two glimpses of the eclipse were obtained, one about thirteen minutes before, and the other about five minutes after, totality. During totality some high cumulo-stratus clouds veiled the sun, but by noting the times when darkness came on and passed away the duration of totality was found to be very approximately *2m* 13*s*. Some meteorological observations were also made.

At Ustpenskoie, eight miles east of Rschew, the Princeton College party was stationed. Prof. C. A. Young intended to make spectroscopic observations and observe "the flash" of bright lines at the instant of totality, while Prof. McNeill, Prof. Libby, and three ladies were to make photographs of the corona; but bad weather prevented them from seeing the eclipse. Capt. Witroffsky was also at this place.

At Spirowskaja totality appears to have been observed for twenty seconds.

At Twer a glimpse of the sun was obtained only twice during the eclipse; namely, at the contact, and when his disk was about seven-eighths obscured. The early dawn was beautifully clear, but soon a dense ground-mist involved the town, and when, a little before totality, enough wind arose to clear that away, a heavy bank of rain clouds put an end to all hopes of observation. It had been arranged that Professors Sverinzaff and Dschewetzki should ascend in a balloon—the former to take photographs, draw the contour of the corona, and measure photometrically the intensity of its light; the latter to draw the contour of the corona—but the experiment proved almost a failure. They left the earth twenty-five minutes before totality, but the balloon was met in its ascent by torrents of rain which collected in a large hollow at its top, and it never got through the thick rain which effectually obscured any view of the eclipse. The Messrs. Lewitzky, court photographers, alone obtained a photograph of the sun during the eclipse. It was taken about fifteen minutes before totality, in 0.005 of a second, with a diaphragm having an aperture as small as a pin's head; while during totality an exposure of two minutes with a diaphragm of 1.38 inches aperture was required in photographing the town of Twer.

At Sawidowskaja there were stationed Padre Conte Ferrari, and Messrs. Lais and Buti; all from Count Ferrari's private observatory at Rome. They were to make photographs of the corona and experiments on solar radiation during the eclipse, but as the moment of that event approached, the sky became suddenly cloudy and the sun was not visible till noon. The actual instant of totality could only be noted by the intense darkness which suddenly spread over the whole district. Here and there a yellowish or leaden-gray tint could be distinguished in the clouds, presenting a most wierd appearance; and the strangeness of the scene was heightened by the profound disquiet and fear which seemed to have taken possession of the birds and cattle in the fields.

At a village on the Moscow railroad, fifteen miles from Sawidowskaja, Prince Gagarin succeeded in photographing the corona.

At Schipulino were stationed Prof. Hasselberg and Dr. Renz from the Pulkowa observatory, to make photographs and eye observations of the spectra of the sun and corona; Prof. Müller, Dr. Kempf, and Dr. Scheiner, from the Potsdam observatory, to photograph the corona by means of a special apparatus having a revolving slide to take eight pictures, and to make meteorological observations; and Dr. Donner, from the Helsingfors observatory, to search for intra-mercurial planets. Clouds prevented the eclipse from being seen.

At Wyssokoffsky were stationed Mr. Turner, from the Greenwich observatory, to make spectroscopic eye observations and photographs of the corona; and Count de la Baume, from Paris, to photograph the corona with a twelve-inch reflector. In mounting his instruments Mr. Turner had the advantage of the ample resources of a large spinning and weaving mill, which were generously placed at his disposal by Mr. Skidmore, the acting superintendent; but the cloudy sky made all his preparations vain.

At Klin, after a wet and cloudy night, patches of blue sky in the early morning raised delusive hopes, but during the eclipse the heavens were shrouded in dull gray, and a Scotch mist prevailed. To provide against that very contingency it had been arranged that Prof. Mendeleieff was to observe the form of the corona, its spectrum and the course of the moon's shadow from a balloon furnished by the Russian Imperial Institute of Technology, but the experiment was only partially successful. Partly because it was insufficiently filled with gas, and partly because it was waterlogged by exposure to a heavy dew which had fallen in the early morning, when after much delay the balloon was cast loose it refused to ascend. According to one account Lieut. Kowanko, the aeronout who was to accompany Prof. Mendeleieff, thereupon got out of the car to make some necessary alterations, but on being relieved of his weight the balloon suddenly rose, and amid the hand-clapping of the crowd, the professor was carried away about two minutes before totality, begging his friends to collect his bones. Another account states that the professor—a man over sixty years old, who had never before been in a balloon—deliberately left the aeronaut behind him because the balloon could not carry both. Be that as it may, the balloon shot rapidly through the fog into the clear upper air, where, at an altitude of 11,500 feet, the professor had an excellent view of the corona, and saw the moon's shadow passing through the clouds, but his thoughts were necessarily so fully occupied with the unfamiliar task of managing the balloon that he had little time to give to scientific observations. He saw nothing of the earth for an hour, and, after traveling one hundred and twenty miles, he landed safely near the Serge monastery, not far from Moscow. In recognition of the pluck exhibited in this ascent, the Academy of Aerostation of France has presented a medal to Prof. Mendeleieff.

Messrs. Grassi, Colombo, and Stoppani, from Milan were stationed near Klin, to make photometric observations of the corona.

At Nicholsk, twenty-five wersts from Podsolnitchnaya, Dr. Borgmann was stationed; and at Nikolikojo Messrs. Jegoroff, Wutschithoffsky, and party were established; but nothing was seen of the eclipse at either of these places.

At Elpatievo Narischkine, latitude 56° 58′, longitude 38° 07′ east from Greenwich, Mr. Il. Urech was stationed. Singularly enough, the sky was clear only during the eclipse, being cloudy both before and after. At 5*h* 45*m* A. M., local mean time, the sun emerged from the clouds. First contact, was observed at 5*h* 53*m*; second contact at 6*h* 52*m* 31*s*; third contact at 6*h* 54*m* 45*s*; and fourth contact at 7*h* 53*m*. During totality a magnificent corona and four red prominences were seen, and Regulus and Mercury shone brightly.

At Petrowsk, Prof. Glasenapp, of the St. Petersburg observatory, intended to make a specialty of searching for the supposed planet Vulcan, and for that purpose, as totality approached, he directed his comet-seeker upon α Leonis, close to the sun; but the presence of a thin, nebulous cloud prevented the prosecution of the search. He then turned his attention to the corona and obtained seven sketches and two photographs of it. In a letter to the *Novoe Vremya* he categorically asserts that his observations have led him to the positive conclusion that the corona is a real, and not an optical, appearance; and not, as some think, an illuminated shower of meteoric dust. Prof. Kowalsky, of St. Petersburg, obtained two photographs of the corona with an equatorially mounted portrait lens, of 6 inches aperture and 31.5 inches focus, by Secretan. Dr. Tatschaloff, of the St. Petersburg observatory, took some photographs of the corona; Dr. Stanoiewitsch, of the Meudon observatory, made photometrical determinations of its light by means of photography; and Prof. Kononovitsch, of Odessa, observed and photographed its spectrum, including the famous green line.

At Iwanowa Prof. Upton, of Brown University, Providence, R. I., Mr. Roatsch, and Dr. Köppen, of the Hamburg Seewarte, made meteorological observations for the purpose of determining the influence of the eclipse on the barometer. Some one hundred and seventy stations promised to cooperate with Prof. Upton in this work.

At Kineschma Prof. Bredichin, of the Moscow observatory, was stationed, and with him, by his special invitation, were Miss Brown of the Liverpool astronomical society, Rev. S. J. Perry of the Stonyhurst observatory, and Dr. Copeland of the Dun Echt observatory. The two latter gentlemen intended to photograph the corona and its spectrum, and to facilitate that work Prof. Bredichin had a Russian bathhouse temporarily converted into a most spacious and commodious dark room—or rather a series of photographic rooms—with a copious supply of water. By the aid of generous help in every direction the party completed all their preparations in good season; but only disappointment awaited them. After some days of fine weather, the evening of the 18th had an ominous appearance, and on the morning of the 19th, although the sun was seen for a few minutes, the sky was covered with drifting scud, through which but a momentary glimpse of totality was obtained. Neither photographs nor spectroscopic observations could be obtained.

At Jurjewez, on the right bank of the Volga, were stationed Prof. Belopolsky of the Moscow observatory and Mr. Sternberg; Prof. Kortazzi of the Nicolaieff observatory; Dr. Niesten of the Brussels observatory; and the well known photographers, Dr. H. W. Vogel of Berlin, and Mr. Karelin of Nischnii Nowgorod. Both Belopolsky and Niesten were provided with cameras fitted to take four pictures simultaneously upon a single plate, and Karelin had a Ross portrait lens of six inches diameter. During most of the eclipse the sky was cloudy, but at the time of totality it cleared a little around the sun, and the chromosphere, prominences, and something of the corona, were visible. Totality began at 7*h* 10*m* 44.5*s*, local mean time, and ended at 7*h* 13*m* 11.6*s*, the sun's altitude being then almost twenty degrees. Dr. Niesten made a drawing of the corona which showed a strongly marked ray about a degree in length in the direction of the solar equator, and his assistant secured eight photographs, of which six were good. All showed the chromosphere and prominences, while two gave traces of the corona, and also of Regulus, which was near the sun. The exposures varied from eight to thirty seconds. With his six-inch portrait lens, and a drop shutter giving an exposure of 0.017 to 0.020 of a second, Mr. Karelin made an excellent picture of the corona, which is reproduced in Anthony's Photographic Bulletin for Oct. 22, 1887, page 614.

At Katunski the weather was fine, and the corona was seen in all its grandeur. The red prominences were visible to the naked eye.

At Warnawin Mr. Ceraski, of the Moscow observatory, was stationed, but saw nothing.

At Wjatka were stationed Mr. Doubjago of the Kazan observatory, and Mr. Kleiber; together with Prof. Tacchini of the observatory of the Roman College, and Prof. Ricco of the Palermo observatory, the two latter gentlemen intending to make spectroscopic observations. Clouds and rain prevented them from seeing the eclipse.

At Nolinsk it rained during the eclipse. The greatest darkness occurred about 7:45 A. M., and was like that of a moonless night.

From Perm nothing has been heard. Dr. Niesten of the Brussels observatory had intended to observe there, but owing to a delay in the transportation of his instruments he went to Jurjewez.

At Jekaterinburg the eclipse began in a cloudless sky at 7:25 A. M., and lasted till 9:30 A. M. The temperature fell from 66° F. to 55° at 8:37 A. M., and rose to 75° after the eclipse was over.

At Irbit the weather was fine. The totality began at 8:44 A. M., and lasted one and one-half minutes.

At Tomsk the weather was very fine and the sky clear. Totality occurred about 10:32 A. M., and the corona was most satisfactorily observed. Stars were visible, and the darkness was so great that in most houses it was necessary to light candles or lamps.

At Krasnojarsk Mr. Chamoutoff and party were stationed. The weather was fine and a number of important sketches and photographs of the corona were obtained.

At Irkutsk the sky was cloudless, and a good photograph of the corona was taken by Mr. Gabriel de Bohdanovithz.

In addition to the observations at stations close upon the central line, it was intended to make observations at a series of points near the northern and southern boundaries of the shadow, in order to determine the precise ratio of the apparent diameters of the sun and moon. The stations selected for that purpose, and the observers assigned to them, were as follows:

ON THE SOUTHERN BOUNDARY.		ON THE NORTHERN BOUNDARY.	
Stations.	Observers.	Stations.	Observers.
Soprikino......	Ludwig Struve.	Dunaburg....	A. Dollen.
Gschatzk.......	Lieut. Drischenko.	Velikie Luki..	Capt. Korloffski.
Moscow........	Wittram, Lorentzen.	Perovino......	Prof. O. Struve, Majeffski.
Vladimir........	Fuss, Sacharoff, Schubin.	Jaroslav.......	Lieut. Prince Galitzin.
Balachna.......	An assistant of Kortazzi.	Kostromo....	An assistant of Kortazzi.
Urshum.........	An assistant of Doubjago.	Orloff...........	An assistant of Doubjago.

Only one of these stations were favored with good weather.

At Shirakawa, Japan, on the site of an old castle burned in 1868, Prof. D. P. Todd, of Amherst College, was stationed with several assistants and a very complete outfit of instruments. During the forenoon preceding the eclipse the sky was almost perfectly clear, but about 1 P. M. a small white cloud appeared near the summits of the distant mountains, and before two o'clock it had spread upward to the zenith. Then dense black clouds arose in the east and south, and the beginning of the eclipse was entirely hidden. Shortly afterwards a few photographs of the solar crescent were taken through a rift, which soon closed up, and totality occurred amid peals of rolling thunder. Nothing whatever was seen of the corona or prominences, and during the remainder of the eclipse only a momentary glimpse of the solar crescent was obtained.

EXPERIMENTS WITH ELECTRICAL CONTACT APPARATUS FOR ASTRONOMICAL CLOCKS.

JAMES E. KEELER.

For the MESSENGER.

NEARLY all astronomical clocks are now provided by their makers with electrical apparatus for repeating the beats of the pendulum at a distance, and recording observations by the chronographic method. Various devices have been used for effecting this without disturbing the rate of the clock. With a gravity escapement the contact apparatus can be so adjusted that the extra work required for its operation is thrown on the train at the instant when the latter is detached from the pendulum, which is then entirely unaffected by the friction of the apparatus. With a dead beat escapement, which is still preferred by many of the best makers, it is impossible to use any kind of electrical attachment the effect of which will not reach the pendulum, and it is essential that the friction produced shall be constant.

Sometimes a clock has no electrical contact, or the apparatus provided by the maker is of faulty construction, and it is necessary to devise another more suitable form. In two admirable clocks by A. Hohwü of Amsterdam, which are mounted in the clock room of the Lick observatory, the electric circuit is broken by a small lever projecting from the verge of the dead beat escapement, which at the extremity of the swing of the pendulum, lifts one edge of a light disk resting on three points. Two of these points are conductors, and form part of the electric circuit; the other is an insulating pin of ivory. The circuit is thus broken at intervals of two seconds, and the length of the break can be adjusted by raising or lowering an arm carrying the three points and disc. There is a relay inside the clock case for repeating the beats without sending powerful currents through the contact points. This apparatus, although of very beautiful workmanship, is constructed on erroneous principles, and, therefore, fails to perform properly. As the contact is broken at the extremity of the swing of the pendulum, small variations in the arc of the latter have a great effect upon the duration of the break, as have also slight changes in the relative positions of the lifting lever and movable disc, caused by expansion and contraction of the parts. In one of the clocks the maker has sought to remedy this defect by attaching the support of the disc to the clock frame as near to the verge as possible, but with only partial success. It is evident that to make the length of the break as short as is usually desired, a tenth of a second or less, the lifting of the disk must be extremely small, and the slightest cause is then sufficient to produce failure of the signals. The armature lever of the clock relay, instead of being light, is made large and heavy, so that it moves sluggishly, and does not respond quickly to the break. The relay is inside the clock case, which must be opened every time it is necessary to adjust the length of the signal. The same trouble has been experienced with these clocks in other observatories.* All this apparatus was removed after a few weeks' trial, and experiments were made with a view to finding some more reliable device which could be readily substituted for it.

The first experiment tried was with the very common arrangement of a knife edge, attached to the pendulum, swinging through a globule of mercury, and thus closing an electric current every second. This seems to work well in in most places, but it did not prove to be satisfactory here, probably on account of the extreme dryness of the air, which converts the slightest film of dust or oxide on the surface of

*Publications of the Washburn Observatory, Vol. I., p. 13, and Vol IV., p. 33.

the mercury into a non-conducting coating, causing the contact to fail. The platinum knife-edge must have considerable width, in order to give a sufficient duration to the current, and if good contact is not made at the instant the advancing edge touches the surface of the mercury, the second signals will be displaced on the chronograph sheet, and an erroneous record obtained. The globule of mercury had to be cleaned every time the clock was used, an operation not easily performed without disturbing the pendulum.

I next tried the experiment of replacing the platinum knife-edge by a similar one of copper, amalgamated on its lower edge with mercury, and lacquered elsewhere to prevent the mercury from spreading. Good contact was then secured, but the increase of friction due to the cohesion of the mercury surfaces was so great that it stopped the clock in a few hours. This was prevented by increasing the weight, which is very little more than sufficient to run the clock, but it was then found that the knife-edge carried away minute globules of mercury from the large drop, lowering the level of the latter and consequently altering the friction, so that the rate of the clock was not so good as before. The mercury contact was therefore rejected. In these experiments the knife-edge was placed near the middle of the pendulum rod.

The contact apparatus which I then tried, and which is still in use, is so simple and easily made, and has proved to be so satisfactory, that I have thought it worth while to give a description of it here, although there is nothing whatever of novelty in its principle. It resembles very much the old Saxton tilt-hammer, but has the important advantage over this of producing less friction with greater quickness and celerity of action.

A short piece of glass rod, less than a tenth of an inch in diameter, is cemented with sealing-wax into a tube soldered to a clip or half cylinder of very thin sheet brass, of such size that it tightly embraces the pendulum rod when sprung into place. This rod serves to break the circuit at every oscillation of the pendulum. The other part of the apparatus is carried by a plate of heavy brass, 4.25 inches long and 0.75 inches wide, screwed horizontally to the back of the clock case in a manner which will be described below. The edges of the plate are beveled. At the end farthest from the pendulum is soldered a binding post, with one of its holes vertical. About half an inch from this is bored a round hole, into which fits a shoulder turned on a piece of brass tube one inch long and 0.3 inches in diameter. A long screw passing through the tube, and a washer at its outer end, holds the base plate against the back of the clock case, and forms a pivot about which the whole apparatus can be turned to adjust the length of break. To the outer end of the tube is soldered one end of a light steel spring 3.25 inches long, formed of part of the main spring of a watch. When the tube is in place the spring is parallel to the base plate. A fine needle is soldered to the free end of the spring on its lower side, and the joint is covered with a V shaped bit of sheet platinum. With care it is easy to solder these pieces without drawing the temper of the spring. The needle is bent at an angle of about 120°. To do this it must be slightly softened and the angle repolished with a little rouge.

At the other end of the base plate is an insulating pillar of wood about three-quarters of an inch long, held by a screw through the back of the plate. In the outer end of this pillar is inserted a short piece of stout platinum wire, to which, where it enters the wood, is soldered one end of a copper connecting wire, the other end leading to a binding post screwed into the back of the clock case about eight inches vertically above the binding post on the base plate. From these two posts lead the wires which connect with the clock its relay outside.

The V shaped piece of platinum on the spring rests upon the platinum wire on the end of the insulating pillar, and the pressure is adjusted by turning the tube to which the other end of the spring is attached. A very light pressure is sufficient to insure good contact. The glass pin on the pendulum rod is directed toward the back of the clock case, and at every oscillation of the pendulum lifts the spring by striking against the convex side of the needle, breaking an electric circuit through the clock relay every second. To make the length of break adjustable, a vertical slot is cut in the base plate near the wooden pillar, and the inner end of the plate is held by a short screw and washer through this slot. The amount of lifting of the spring can thus be made as small as desired. The spring arches slightly upward, which depresses the angle in the needle to a more convenient level, and also gives more ready access to the adjusting screw just mentioned.

To prevent the oxidation of the platinum surfaces, a hard lead pencil is introduced between the binding posts which form the terminals of the contact apparatus, and held vertically between two pointed pieces of stout wire clamped by the binding posts. The lead is hollowed out a little at the ends of the pencil to admit the points of the wires. The extra current from the relay magnet passes through the core of the pencil, which has, however, so great a resistance, that the current constantly passing through the pencil and relay is too feeble to affect the armature of the latter. The pencil used with the above apparatus is a HHH Faber, and the clock relay has a resistance of five ohms. With a relay of greater resistance, a harder pencil would be required. This simple device forms a very efficient spark-preventer, and the platinum surfaces up to the present show no signs of oxidation. Is is much superior to a chronometer condenser which I used some time for the same purpose.

To make the arrangements complete, slow motion screws for adjusting would be required, but as no further attention is necessary when once the posts are in place, it seemed to me better to spend more time in the first adjustment than to complicate the apparatus. The friction of the glass rod on the spring is very small, even less than that of a knife edge swinging through mercury, as was shown by the smaller effect upon the arc of the pendulum. After a month's trial of this break-circuit attachment, I made a quite similar one for the other Hohwü clock, and they have both been in use now for more than six months, never failing to act promptly in that time. The rates of both clocks have been as good as with the original contact apparatus, and equal, perhaps, to the rate of any clock in the world.

A disadvantage of this contrivance, but one which is shared also by the mercury contact and the apparatus which was furnished by the maker, is that the zero second, or beginning of the minute, is not indicated in any way. For this reason a spring lifted by a toothed wheel on the second-hand arbor is more convenient. On account of irregularities in the wheel cutting, however, the intervals between the breaks made by such an apparatus are not uniform, but differ often by several hundredths of a second, so that to get the best result from a comparison of two clocks whose daily rates vary only by quantities of this order, it is necessary to average a number of intervals in measuring the chronograph sheet. With the apparatus described above the intervals are of precisely the same length. To identify the zero seconds' column on the chronograph, a small switch is introduced in the circuit of the clock relay, in a convenient position near the clock case, and the zero second of any minute is cut out by hand.

THE PLACE OF ASTRONOMY AMONG THE SCIENCES.*

PROF. SIMON NEWCOMB.

It is often said that we live in an age of specialties. Two or three centuries ago a learned man was master of all the knowledge of his time. That learned man, however, has disappeared, and in his place has come the master of a special branch. There wrs a period of several centuries in which we had astronomers, physiologists, physicists, and philologists, but we might almost say that these classes are disappearing and giving way to the students of branches so remote from each other that one can scarcely know what another is doing. He who would now be a master even in the minutest branch, must devote an enormous number of energies to its cultivation. In mathematics each particular branch is studied almost exclusively by some one or two of its votaries. In medicine the general physician is rapidly giving way to the specialist; and even in philology one is generally the student of some particular language which he makes a specialty. When we see a self-dividing process like this going on generation after generation we are naturally led to inquire where it will lead to and how it will stop. We all recognize the usefulness of knowledge in society; but of what use to society will that kind of knowledge be which is confined to one or a few investigators, and which it is impossible, perhaps, for them to indicate to any large body of ther fellow men? We must look to

* Address delivered at the dedication of the new observatory of the University of Syracuse, N. Y., Nov. 18, 1887.

the scientific publications of the day to answer this question, and see the character which they present to us. It is a recognized fact that the man of science works for the good of society and posterity, and so he must publish what he learns. That is why we find such an increase in our libraries of periodical literature. The mere titles of the scientific periodicals which have appeared during the last three hundred years fill a good sized printer's volume; not the titles of books, but of serials devoted to the publication of original investigations and really new additions to human knowledge. We may admit that far the greater number of these serials are of but local or temporary interest; but if we take only those which are intended to add to the world's permanent advances of knowledge we shall still find the number to be appalling. And we have not only these scores of scientific periodicals which abound in every country, but we have scores, or perhaps hundreds of learned societies, who publish volumes which are supposed to contain nothing but important additions to human knowledge. We have in the department of mathematics alone one serial in America and two or three in each of the great countries in Europe. Altogether there are perhaps more than a dozen volumes issued annually in the department of astronomy. The leading astronomical journal of the world was established about 1824; during the earlier years of its existence about one volume appeared annually; now its 118th volume is in progress, and the series is going on at the rate of three volumes a year, with an unmistakable tendency towards an increase as the years go on. The Royal Astronomical Society of London publishes two volumes annually. And how many other societies there are through England and Europe which add to the number, it would be hard to say.

How will it be in the future? You will pardon an astronomer if he looks a long ways ahead, because he is accustomed to dealing with long intervals of time. We cannot set any limits to the duration of our earth or the time the human race may live upon it, but still let us look ahead at what is astronomically the very short interval of 1,000 years. What will the astronomer do when he has to consult Vol. 2,000 or 3,000 of the Greenwich Observations? By strict industry the students can now generally find out what is going in on any one subject, but what will he do when the volumes are counted by thousands when perhaps an index alone will nearly fill a library? Even now it is almost impossible to determine whether a general result reached is a new one, unless the investigator has gone out into some entirely new field where he knows no one has preceded him. So, perhaps, in time, the discoverer of something new in an old book will be equally meritorious with the discoverer of a new law of nature.

You may naturally inquire how it is possible to write so much on so small a subject, or how so much can be written on a subject of scientific knowledge. I recollect a visitor once said to me he did not see how the astronomers could find anything to do, he thought the study of the movements of the heavenly bodies had already been exhausted. Now let us in imagination visit an observatory. We see before us a large collection of instruments—telescopes, spectroscopes, micrometers, sextants, etc. Out of these let us select the most modest-looking—perhaps it is a spectroscope; let us take it to pieces and find the smallest and most insignificant part. Perhaps the simplest portion will be the glass prism through which the light is sent. Apparently we shall then hold in our hands nothing but a very small piece of glass, triangular and polished on two of its faces. Surely here is something about which very little is to be said. However not only is there a great deal to be known on the subject, but as a matter of fact it may well happen that you cannot find in the whole body of literature something which the astronomer may desire to know about this little prism. One subject of investigation is its refracting power in regard to various colors and lights. It requires great skill in the handling of the apparatus with which the measures are made. Only a few years ago I had to make an investigation concerning the great Lick telescope of California, in regard to the various kinds of flint and crown glass. I was unable to find an entirely satisfactory explanation of their refracting powers in any publication. Equally complex and difficult is the investigation of the influence which this little piece of glass exerts upon the various kinds of light and heat which pass through it. Ordinarily we have been concerned with the action exercised by the prism upon the light; but now within the last few years an eminent American astronomer has gone into the question of the heat rays absorbed by this glass, and the results he has obtained about transmissibility of heat through glass are creating almost a new branch of investigation, having important bearing upon the meteorology of our globe. The specific gravity and chemical constitution of the glass also are to be carefully determined with a view to determining the action of light upon different kinds of glass. Equally important is the kind of glass. Equally difficult is the question how to shape and polish the glass so that its faces shall be perfect mathematical planes. Perhaps the investigator will find that each edge of the glass is a little curved towards its edge, so that its action towards the rays of light is not what it ought to be. Finally, when the astronomer has brought the glass to completion and in working order, how he shall keep it from dust and the action of time and deterioration from the action of the elements is an important question. Now, if the simplest piece of glass in the smallest instrument of the observatory can be the subject of such a mass of investigation, by what shall we measure the amountof study required by all the instruments in every department of astronomy and physics?

If this constant subdivision of specialties were all we could look forward to, we might inquire if, after all, we were not going a little too fast on the road to learning. The ultimate result will be that our time will be entirely absorbed in the study of some one thing, much as in the division of labor it was said the whole of one man's life was spent in making the tenth part of a pin. But science has an exploring work of a higher order than that of investigating spectroscopes and quadrants. It is one of the great advantages of science which gives especial interest to much of our investigation, that the great multitude of facts which we discover from time to time have their origin in a few simple laws. The fundamental idea on which the scientific man investigates nature is that there is a uniform plan back of everything which is capable of being grasped by the human mind; and however complex the phenomenon may appear to be in its form, there is some simple cause, which, if we only knew, we should be able to trace out without going through the laborious process of examining every detail. But the sciences are growing more and more alike in their form; the ultimate result will be that the plan of nature will be presented to us in a series of mathematical formulæ, by which we shall be able to understand the result without laboriously consulting every detail. In the first stage of every science the study of details is, from the very nature of the case, the most conspicuous part of the process. But we are never satisfied with these details until they carry us back to their general laws. The fundamental principles of astronomy are simpler now than when that celebrated Spanish monarch said that if he had been consulted on the construction of the heavens he would have made them on a simpler plan.

In the days of Ptolemy the whole geometry of the heavens was on a simpler plan than when that monarch lived; now, however, the whole complexity of motion in the solar system is traced back to the law that every body attracts every other body with a force as the inverse square of the distance and directly as the product of the masses. Given those two laws, and the mathematical ability to ascertain their results, and the details all disappear, giving place to the general law which can be grasped by any mind properly trained for the purpose.

We see the same tendency in many other branches of science. The leading phenomena of electricity are now traced back to a few first principles. So with chemical subjects. The first result is, the mathematical study of every science will be found to be the uttermost. Even in subjects of such complexity and apparently so far removed from general laws as biology and zoölogy, the same tendency is observable. The method of studying organic life has undergone a great change in the last twenty years. In the last generation the biological text book .consisted of a labored plan of each animal described in barbarous Latin. We now not only study animals in their individual history, but in the origin of their qualities, showing how the various peculiarities which we notice originated. So, every science should be studied in the same way, the ultimate end being to understand it, not in its multiplicity of details, but as you understand the branches of a tree; the root or the stem being the prominent part, while the branches are merely the details and belong to the stem. And though it is impossible for any one to master all the principles on which the results of general law are worked out, yet that faith in the unity of nature which is implanted in the breast of every studious man will lead us to believe that the integrating progress will outgrow the disintegration.

The lesson we draw from these tendencies of science will now be clear to you. There is something more than the mere investigation of multitudinous details, such as those which I have described. It is in astronomy that the integrating process is most fully seen. It has been called the most perfect of the sciences. As I have already said, all the geometry and astronomy, all the phenomena of the motions of the heavenly bodies are already reduced to one general law.

I now desire to say something upon its dignity and its historical character. Every well constituted mind enjoys the flavor of antiquity. Nothing more impresses the visitor to the Coliseum than the reflection that around the very arena where he stands, the walls of which he is looking at, echoed 1,000 years, or 1,500 years ago the plaudits of the Roman people as they viewed the contesting gladiators in the arena. As he looks at the opening on one side, which the guide will tell him was reserved for the entrance of the Cæsars, he cannot but be impressed with the might of the period. The reigning nobility of all the people of Europe take a just pride in tracing back their ancestry unbroken through centuries. Now, the astronomer may take the same pride in tracing back his intellectual descent from Hipparchus and Ptolemy through an unbroken series of workers from the dawn of history to our own time.

I know it is very common to speak with contempt of the ideas of the ancient astronomers. When a man to-day wishes to picture an idea as being entirely behind the age he compares it with the Ptolemaic age; and writers sometimes tell us the ancients did not know the earth was round. Now, I am here this morning to vindicate the character of our ancient ancestors. The fact is, the Ptolemaic age sent forth, not only the most wonderful production of the human intellect, but principles which are now, to-day, at the foundation of astronomy. How unjust is the popular notion of Ptolemy will be seen by merely noting how well he could predict the motions of the heavens. Let us suppose the writer who lived in the year 150 of our era had been told that to-day in a distant city of another hemisphere which he had never seen, an audience would be assembled to discuss his favorite science, and that for the benefit of that audience he was requested to prepare an account of how the heavens would look to-day in our eyes. Through the seventeen or eighteen centuries which have intervened he would correctly calculate every revolution of the earth and tell us to-day when the moon would change, and what its aspect would be, with an error of only about two hours. If he had been asked what eclipses would occur during this year, he would have told that on the 18th of August there would be an eclipse of the sun in certain parts of the world. He could not have told, perhaps, that it would pass through Siberia and Japan, because he did not know there were any Siberia and Japan, but he would have made a map and shown where the eclipse would pass within about 20 degrees of longitude. So with the position and aspects of each planet. He could have told you where we could to-night see Jupiter and Saturn, with an error of only a few degrees, and would have predicted the time of their rising within about half an hour.

[TO BE CONTINUED.]

A NOTE ON THE DISTRIBUTION OF THE STARS.

W. H. S. MONCK, DUBLIN.

For the MESSENGER.

THE distribution of the stars is a very wide subject and it is only with a small branch of it that I propose to deal. I found it, however, not easy to define this branch in the title of my paper. My object is to compare some well-known catalogues of star-magnitudes with the results derived from the hypothesis of uniform distribution so as to see to what extent and in what manner the actual results differ from those deduced from this hypothesis.

If the stars are uniformly distributed round the sun and are all of equal mass and brilliancy, it is easy to compute the proportion which would exist between the numbers of stars of different magnitudes. Draw a series of spheres around the sun with different radii. Then the number of stars which would be cut by, or would lie close to, the surface of each of these spheres, would be proportional to the spherical surfaces themselves. They would therefore be proportional to the squares of the respective radii. But the light of each star as seen by us would vary inversely as the square of its distance—that is, inversely as the squares of the respective radii. The number of stars would therefore be increased in exactly the same proportion that the light of each star was diminished: and the total light received from each sphere-surface would be the same. This reasoning, indeed, involves two assumptions: viz., that no pair of stars lies precisely in the same direction so that one would intercept the light of another, and that there is no medium in space which absorbs light. And before proceeding further, I desire to say that either the hypothesis of uniformity itself or else one of these assumptions must differ very widely from the truth, not merely in detail, but in the general average result. For we could otherwise go on drawing sphere beyond sphere to infinity receiving an equal quantity of light from each, and the sum total of the starlight received would be enormously greater than that received from 1,000,000 of the nearest and brightest stars. There are good grounds, I think, for concluding either that the stars known to us form part of one great cluster, beyond which there is a comparative void, or else that there is a medium in space which intercepts light.

It is now conceded that our ordinary estimates of star-magnitudes are best represented by a geometrical ratio. But we can hardly rely on the results as agreeing precisely with such a ratio defined by a constant number except where the stars have been photometrically measured, this number being adopted as the basis of arrangement. This has been done in the *Harvard Photometry* and in the *Uranometria Nova Oxoniensis*, the constant ratio adopted in both cases being 2.512 for each magnitude. If we subdivide the stars in these catalogues to such an extent that the stars in each sub-division may, on the hypothesis of uniformity, be regarded as equidistant, then if that hypothesis be correct the numbers of the stars comprised in these successive sub-divisions should form a geometrical series with a constant ratio. I adopted one-tenth of a magnitude for my unit of sub-division, and it is easily shown that if the constant ratio for one magnitude be 2.512 the corresponding ratio for one-tenth of a magnitude is 1.0965. Thus if the number of stars rated at 4.5 to 4.6 was 100 and the distribution was uniform, the number rated at 4.6 to 4.7 would be 109 (or rather 110); the number rated at 4.7 to 4.8, 120; the number rated at 4.8 to 4.9, 132; and so on, until finally the number rated at 5.5 to 5.6 would be 251. Moreover from the number of stars comprised in any particular sub-division we could compute the entire number of brighter stars, since a decreasing geometrical series can be summed although carried on to infinity. The sum of the series $ax + ax^2 + ax^3 +$ etc., *ad infinitum* is $\frac{ax}{1-x}$, or since x is here $= \frac{1}{1.0965} = 10.363a$; and in the case which I have taken as an illustration the total number of stars brighter than the 4.5th magnitude should be 1,036.

Neither the Harvard nor the Oxford catalogues are complete. The former contains no stars whose southern declination is greater than 30°, while the Oxford list stops at a southern declination of 10°. The Harvard catalogue is thus preferable as including a larger portion of the heavens and a greater number of stars, and there is, I think, some reason for believing that its estimates of magnitude are also more reliable. Both catalogues are incomplete in another way. They do not contain all the stars down to the point at which they stop in their descent in the scale of magnitudes: and I am somewhat at a loss to know down to what sub-division I can regard them as complete in this respect. The maximum number of stars in any of my sub-divisions in the Harvard catalogue occurs between 5.7 and 5.8. From 5.8 to 5.9 there is a small decline which becomes more rapid as we proceed lower. The maximum number in the Oxford list occurs between 6.0 and 6.1, below which point the decline is still more rapid. Probably the sub-division 6.0 to 6.1 in the Oxford list corresponds most nearly with that from 5.9 to 6.0 in the Harvard, but the Oxford maximum would thus coincide with a considerable decline at Harvard. The conclusion to be drawn from these results is, I think, that the Harvard list cannot be relied on as containing all the stars below the 5.8th magnitude, while the Oxford list is similarly defective below the 6.1 magnitude. Of course it is useless to institute a comparison between the actual and theoretical numbers of stars comprised in any sub-division unless the actual number includes all the stars which ought to be included, *i. e.* all comprised in the sub-division which lie in the portion of the sky observed. Not feeling confident of this below the points mentioned I did not use the catalogues beyond these limits.

The following table may contain a few errors of transcription but nothing to affect the general result. It contains the stars in each sub-division from 1.5 onward according to Harvard and Oxford respectively:

Magnitudes.	No. of Stars (Harvard.)	No. of Stars (Oxford.)	Magnitudes.	No. of Stars (Harvard.)	No. of Stars (Oxford.)
1.5 to 1.6	1	1	3.9 to 4.0	43	23
1.6 to 1.7	1	0	4.0 to 4.1	35	20
1.7 to 1.8	2	3	4.1 to 4.2	46	31
1.8 to 1.9	4	4	4.2 to 4.3	52	33
1.9 to 2.0	3	3	4.3 to 4.4	59	37
2.0 to 2.1	7	5	4.4 to 4.5	72	44
2.1 to 2.2	7	6	4.5 to 4.6	71	39
2.2 to 2.3	5	6	4.6 to 4.7	86	57
2.3 to 2.4	8	2	4.7 to 4.8	95	58
2.4 to 2.5	3	9	4.8 to 4.9	95	58
2.5 to 2.6	5	3	9.9 to 5.0	130	90
2.6 to 2.7	6	5	5.0 to 5.1	142	136
2.7 to 2.8	10	5	5.1 to 5.2	153	105
2.8 to 2.9	11	4	5.2 to 5.3	167	111
2.9 to 3.0	9	4	5.3 to 5.4	183	121
3.0 to 3.1	18	13	5.4 to 5.5	200	142
3.0 to 3.2	18	10	5.5 to 5.6	227	157
3.2 to 3.3	10	11	5.6 to 5.7	248	179
3.3 to 3.4	17	11	5.7 to 5.8	284	172
3.4 to 3.5	18	14	5.8 to 5.9	(279)	148
3.5 to 3.6	21	21	5.9 to 6.0	(235)	162
3.6 to 3.7	22	24	6.0 to 6.1	(207)	239
3.7 to 3.8	33	13	6.1 to 6.2	(179)	(117)
3.8 to 3.9	29	21			

A glance will show that the Oxford table presents many more anomalies than the Harvard, though some unexpected features are common to both. Among these are the exact equality of the numbers between 4.7 and 4.8, and 4.8 and 4.9, and the very considerable increase which follows between 4.9 and 5.0. So, too, we have the comparative paucity of stars between 2.3 and 2.6 as compared with the three preceding sub-divisions and the decline instead of increase at 4.0 to 4.1.

We might expect that where the number of stars was small considerable deviations from the law suggested by the hypothesis of uniformity would appear; but that, when the numbers were larger, in the absence of some special cause, the deviations in opposite directions would tend to balance each other and the results would be in fair accordance with the law. In portions of the Harvard list this expectation is realized. The closest approach is in the portion from 4.9 to 5.8 (the lowest point at which I regard the Harvard catalogue complete). In the following table I have endeavored to distribute the same number of stars in geometrical progression with a common ratio of 1.0965 in the column headed "Computed" but in avoiding fractions the totals are not quite identical:

Magnitudes.	Observed (Harvard) No. of Stars.	Computed No. of Stars.
4.9 to 5.0	130	128
5.0 to 5.1	142	140
5.1 to 5.2	153	154
5.2 to 5.3	167	169
5.3 to 5.4	183	185
5.4 to 5.5	200	203
5.5 to 5.6	227	222
5.6 to 5.7	248	244
5.7 to 5.8	284	267
(5.8 to 5.9)	(275)	(293)

The Oxford catalogue affords a tolerably close approach to the law during a portion of the same stage. I have not deemed it necessary to write out any other tables. There is however, some degree of approximation to the law almost throughout the whole extent of the Harvard catalogue, subject to one remarkable qualification: viz., that *the number of stars* (with occasional fluctuations) *increases more rapidly than the law of uniformity will account for*, and therefore to keep level with the actual number of stars he must from time to time raise the ratio. For example, from 3.9 to 4.9 we get a tolerable approximation to the number of stars actually observed (at Harvard), by dividing the figures in the above table by 3 instead 2.512, the theoretical divisor; from 2.09 to 3.9 again we obtained a fair approximation by dividing by 10 instead of the theoretical value of $(2.512)^2$ or 6.310; and for those between 1.9 and 3.9 we may divide by 30 instead the theoretical $(2.611)^3$ or 15.851, the stars lying between 3.9 and 4.9 being thus nearly twice as numerous relatively to those between 1.9 and 2.9 as if the law of uniformity held good throughout. The Oxford catalogue here exhibits similar results, the best divisions for it being 3.4, 10, and 28 respectively. And that the same rule applies to stars below the 1.9 magnitude may be shown by summing the series in the manner already explained. Re-distributing the stars between 1.9 and 2.9 in accordance with the law of uniformity the number which best represents the interval 1.9 to 2.0 is 4. It will suffice for my purpose, however, to take the actual number (in the Harvard catalogue), which is 3. According to law of uniformity the number of brighter stars ought to be 31, but it is in fact only 24. And here too a similar result might be deduced from the Oxford list. I give the numbers from the two catalogues from somewhat wider intervals than before, in order to explain this:

Limits.	No. in Harvard List.	No. in Oxford List.
Brighter than 1.9	24	22
1.9 to 2.9	65	48
2.9 to 3.9	195	142
3.9 to 4.9	654	400
4.9 to 5.9	2,009	1,351

On the hypothesis of uniformity the ratio between the first and second of these numbers should be about 1.50, and that between each succeding pair, 2.512. It will be seen that these ratios are in all cases exceeded. It seems to follow that we are at present traveling through a region somewhat barren of stars, which is surrounded by regions of greater richness, this richness constantly increasing up to the mean distance of a star of the 6th magnitude, if not beyond it. This richer star-region may have produced effects on the climate of the earth in the remote past, and may do so again in the remote future.

[TO BE CONTINUED.]

THE SYSTEM OF SIRIUS.

REV. NEWTON M. MANN.

For the MESSENGER.

THE Dog-star has fairly resumed its ancient pre-eminence in human interest. It has for the great telescopes, on account of its companion even more than the charm which, from its transcendent brightness, it has ever had for the naked eye. And for the student of double-star motions, it easily holds the first place as well for the enormous mass of the system as the comparative brevity of its period.

In the SIDEREAL MESSENGER for August, 1883, I presented some work which I had done on this star, and which I wish now to correct and supplement. The extension of the known arc of revolution, then needed definitely to establish the orbit, has now been made, and I present with more confidence the results which I have reached. The positions fixed upon are:

1863.919	80°	1878.526	50°
1868.484	70°	1883.001	40°
1873.452	60°	1886.112	30°

An ellipse drawn from these epochs and angles alone gives as elements of the orbit:

Semi-axis major,	21″.8
Position of periastron,	257°40′
Inclination,	75°.5
Position of node,	188°
Eccentricity,	0.945
Period,	51.22 years.
Time of Periastron-passage,	1890.55

This result compared with the observations of angle is very satisfactory, as may be seen from the table at the end of this note; but the observed distances introduce another problem. To harmonize these with the observed angles, it needs to take into account the motion of the principal star, which, in the case of so eccentric an orbit, becomes a very important consideration.

Consulting the measures of distance only for about the time the companion was at its widest apparent remove, I found the distance corresponding to the angular position of 60° to be 11″.50. The distances then at intervals of 10° become:

At 80°	10″.48	At 50°	11″.26
At 70°	11″.17	At 40°	10″.04
At 60°	11″.50	At 30°	7″.79

Charting the observed distances, I found them departing from this curve by an increasing difference as the distance decreases, falling short at 30° as much as 0″.75. This divergence must be the key to the motion of the principal star, and so to the relative mass of the two.

Comparing the figures in the above table of distances from 60° on, we find the computed distance decreasing at the three following stages by 0″.24, 1″.22, and 2″.25. These figures represent the approach of the companion toward the centre of the system, but there is a discrepancy at the last step from the observations of 0″.75, or one-third of the 2″.25, and therefore the motion of the principal star is one third that of the other.

The table of distances then may be reconstructed thus:

Position. Angle.	D. comp. as above.	Approach of Comes to Centre.	Approach of Sirius.	Distance from Star to Star.
60°	11″.50			11″.50
50°	11″.26	0″.24	0″.08	11″.18
40°	10″.04	1″.22	0″.41	9″.63
30°	7″.70	2″.25	0″.75	7″.04

The same principle applied to the two preceding points gives their distances 10″.25 and 11″.06 respectively. The discrepancy between the curve indicated by angles and epochs, and that indicated by measures of distance is such as to imply that the principal star is moving in an ellipse one-third the diameter of that in which the companion is moving. In 1874.211 the pair were at their greatest apparent distance, 11″.52; their apparent distances then from the centre of the system was 8″.64 and 2″.38. Calculation of the orbit from angles and epochs alone gives only the distance (proportionally) from the centre of the system. The marked departure of such calculation from the measures of distance, is resolved by taking into account the motion of the principal star. As the companion moves toward its periastron, not only is its distance from the centre of the system shortening, but the distance also of the principal star from that point is shortening at a rate uniformly one-third as great.

This implies, of course, that the mass of the companion amounts to one-fourth the mass of the system.

How far this motion of Sirius goes to answer for the perturbations long observed in that star, I leave for those better versed on that subject. But I call attention to the fact that assigning to the companion one-fourth that of the system harmonizes well with the observations. Indeed, I venture to say they can no otherwise be harmonized. Subjoined is a comparison with sixty-four observations that I have at hand. A few others have been rejected for obviously excessive inaccuracy. As the principal point in this discussion turns on the measures of distance, I call particular attention to the comparison in that regard:

Observer.	Time.	θ_o.	$\theta_o - \theta_c$.	R.	R. o.—R. c.
A. Clark	1862.08	85.0	+0.5°	10.00″	+0.12″
Bond	.19	84.6	+0.3	10.07	+0.17
Challis	.23	85.0	+0.8	10.42	+0.52
Lassell	.28	83.9	−0.1	....	....
Rutherford	3.10	81.2	−0.8	....	....
Mitchell	.20	79.2	−2.5	10.40	+0.52
O. Struve	.21	82.5	+0.8	10.14	+0.02
Dawes	.23	......	....	10.00	−0.12
Winnecke	.24	79.7	−1.9	....	....
Bond	.27	82.8	+1.2	....	....
Lassell	4.15	80.3	+0.8	9.53	−0.77
Lassell	.21	80.1	+0.8	9.67	−0.65
O. Struve	.22	79.5	+0.2	10.92	+0.60
O. Struve	5.20	77.2	+0.1	10.60	+0.11
Forster	.22	77.9	+0.9	10.78	+0.28
Struve	.24	73.7	−3.3	10.79	+0.29
Tietzen	.25	76.8	−0.2	....	....
Englemann	.26	76.9	0.0	....	....
Bond	.26	76.0	−0.9	....	....
Struve	.70	73.7	−2.2	....	....
Knott	6.08	77.1	+2.0	10.43	−0.22
Tietzen	.20	76.8	+1.9	10.97	+0.30
Bruhns	.20	......	....	10.74	+0.07
O. Struve	.20	75.2	+0.3	10.93	+0.26
Washington observatory.	.23	74.3	−0.5	10.21	−0.47
Washington observatory.	.25	74.3	−0.4	10.65	−0.03
O. Struve	7.22	72.1	−0.6	10.98	+0.14
Forster	.24	72.3	−0.3	....	....
Brahns	8.24	69.5	−1.0	11.35	+0.33
Englemann	.26	71.6	+1.1	10.95	−0.07
Brunnon	1869.10	......	....	11.26	+0.10
Vogel	.15	......	....	11.23	+0.06
Duner	71.22	64.1	−0.3	10.92	−0.47
Pechule	.25	......	....	12.10	+0.71
Duner	2.18	59.8	−2.6	11.00	−0.45
Washington observatory.	.24	62.7	+0.4	11.55	+0.10
Duner.	3.22	60.8	+0.4	10.57	−0.92
Washington observatory.	4.14	58.0	−0.6	11.39	−0.11
Duner	5.19	57.1	+0.5	10.73	−0.63
Washington observatory.	.23	56.2	−0.3	11.47	0.00
Washington observatory.	7.17	52.8	+0.1	11.35	+0.01
Burnham	.93	53.2	+2.0	10.71	+0.45
Burnham	8.03	51.1	+0.1	....	....
Cincinnati observatory	9.75	46.5	−0.9	10.29	−0.67
Holden	81.12	43.3	−1.2	10.83	+0.10
Washington observatory.	.26	45.3	+1.1	10.00	−0.50
Washington observatory.	2.18	42.2	+0.1	9.95	−0.13
Washington observatory.	23	42.5	+0.3	9.67	−0.43
Burnham	3.10	40.1	+0.4	9.05	−0.52
Young	.10	39.0	−0.7	9.41	−0.16
Hough	.12	39.7	0.0	9.02	−0.55
Washington observatory.	.17	41.4	+1.8	9.75	+0.20
Washington observatory.	.21	39.1	−0.3	9.26	−0.28
Hough	4.05	36.0	−1.1	9.67	+0.70
Hough	.17	36.7	−0.1	8.81	−0.09
Burnham	.19	36.4	−0.2	8.39	−0.45
Washington observatory.	.23	37.7	+1.1	8.81	+0.03
Paris observatory	.27	36.3	−0.2	8.70	−0.12
Paris observatory	5.11	34.1	+0.2	8.09	−0.04
Hough	.20	32.7	−0.9	7.96	−0.09

OBSERVER.	TIME.	θo.	θo.—θc.	R.	R. o.—R. c.
Washington observatory.	.27	34.7	+1.4	8.06	+0.10
Washington observatory.	6.14	30.6	+0.7	7.21	+0.20
Washington observatory.	.22	28.7	−0.8	7.39	+0.49
Young..............................	7.14	25.4	+0.7	7.08	+1.58

As to angles, this comparison leaves little to be desired. Let us take the mean of the distances, observed minus calculated, by periods:

1st Period,	1862 to 1866....................................	12	observations,	+0″.070
2d "	1866 to 1871....................................	12	"	0″.000
3d "	1871 to 1882....................................	12	"	—0″.114
4th "	1882 to 1888....................................	18	"	+0″.024
Total mean	....	54	"	−0″.005

I see no occasion for the hypothesis of a third body disturbing the measures of this system. In fact, the measures for the most part are much more accordant with the calculated orbit than might reasonably be expected in the case of an object so difficult of observation.

Rochester, N. Y., Dec., 1887.

NOTES ON THE PROGRESS OF ASTRONOMY IN 1887.

DANIEL KIRKWOOD.

For the MESSENGER.

The Discovery of Asteroids. Seven minor planets were discovered in 1887, bringing the whole number at the close of the year up to 271. Their distances, dates of discovery, etc., are given below:

ASTEROID.	Date of Discovery.	Name of Discoverer.	Place of Discovery.	Mean Distance.
265 Anna.................	Feb. 25....	Palisa............	Vienna...........	2.4096
266 Aline..................	May 17....	Palisa............	Vienna...........	2.8078
267 Tirza.................	May 27....	Charlois.........	Nice................	2.7742
268..........................	June 9......	Borelly...........	Marseilles.......	3.0852
269..........................	Sept. 21...	Palisa............	Vienna...........	2.6168
270 Anahita.............	Oct. 8.......	Peters............	Clinton...........	2.1883
271..........................	Oct. 16.....	Knorre...........	Berlin.............	3.0059

Anahita, No. 270, is very near the inner margin of the ring. Its period is 1184 days, and the plane of its orbit is nearly coincident with that of the ecliptic.

Comets. The first comet of 1887 was discovered by Dr.

Thome of Cordoba, January 18. It became, in the Southern hemisphere, a conspicuous object, with a tail at least 40° in length. The second of the year was first seen by Mr. W. R. Brooks, of Phelps, N. Y., January 22. Its elements have no special resemblance to those of any known comet. The third, fourth, and fifth comets of the year, were detected by Prof. Barnard, of Nashville, Tenn., on January 23, February 16, and May 3, respectively. The sixth comet of 1887, discovered by Mr. W. R. Brooks, on the morning of August 25, proved to be the Olbers' comet of 1815. This was its first predicted return.

New Nebulæ. The first volume of the History and Work of the Warner Observatory, Rochester, N. Y., was published in 1887. Dr. Swift's discoveries of Nebulæ, 540 in number, form an important part of this interesting report. The distinguished director is still engaged in his persevering search, which will be better appreciated, perhaps, in the future than at present.

FOR STUDENTS AND YOUNG OBSERVERS.

Interesting Objects and Phenomena for January.

THE PLANETS.

Mercury will be at superior conjunction, *i. e.*, on the opposite side of the sun from the earth, on the 18th, and is therefore not in favorable position for observation during the month. All of the other planets are in good position to be seen if one is willing to take the late hours of the night. Neptune may be observed in the early evening, Saturn through the whole night, Mars and Uranus after midnight, and Venus and Jupiter in the morning.

Neptune is the first to cross the meridian, and is about 6° directly south of the well-known group of the Pleiades, in a space where there are no stars brighter than the seventh magnitude. It will be difficult to recognize him with a telescope of less than six inches aperture, although he may be seen with a good opera glass.

Saturn comes next and is in excellent position for observation. The rings are inclined at an angle of about 20° to the line of sight. He may be found directly in the east at 8 P.

M., about a quarter of the way from horizon to zenith, forming a triangle with the two pairs of bright stars in Gemini (Castor and Pollux) and Canis Minor (Procyon and β Canis Minoris). A little east of Saturn is the Præsepe cluster of stars just visible to the eye, and easily resolved with an opera glass. Saturn will be at opposition on the 23rd; and in conjunction with the moon on the 28th at 8:20 A. M., so that at the time of the lunar eclipse that evening he will be a few degrees west of the moon.

Mars is in Virgo a few degrees northwest of the bright star Spica. His ruddy color enables one easily to recognize him. He will be in conjunction with the moon Jan. 6 at 3 A. M., south 2°46′.

Uranus is near Mars, and about 1° exactly south of the 3rd magnitude star θ Virginis, the nearest star northwest of Spica. He may be seen with an opera glass, and is easily recognized with a telescope of moderate power by his greenish hue and perceptible disk. He will be in conjunction with Mars, south 1°40′, Jan. 9.

Jupiter and *Venus* are near together in Libra, just a little northwest of the familiar constellation Scorpio. Jan. 2 Jupiter will be 1°51′ exactly south of Venus. Both of these planets are very conspicuous in the southeast at 5 A. M. Venus will move toward the east more rapidly than Jupiter and at the end of the month will be found in the upper part of the bow of Sagittarius, very close to the naked eye double star μ Sagittarii, in the edge of one of the brightest portions of the Milky Way. The phase of Venus is gibbous and increasing, the light now extending about 0.7 of the way across the disk.

	R. A.	Decl.	Rises.	Transits.
	H. M.		H. M.	H. M.
		NEPTUNE.		
January 1	3 43.0	+17°57′	1 46 P. M.	8 58.2 P. M.
January 15	3 42 1	+17 55	0 50 "	8 92.2 "
January 30	3 41.6	+17 54	11 51 A. M.	7 02.8 "
		SATURN.		
January 1	8 28.9	+19 32	6 24 P. M.	1 43.4 A. M.
January 15	8 24.5	+19 49	5 23 "	12 43.8 "
January 30	8 19.5	+20 07	4 17 "	11 39.8 P. M.
		MARS.		
January 2	12 52.4	−3 19	12 21 A. M.	6 06.1 A. M.
January 15	13 14.6	−5 27	11 57 P. M.	5 33.2 "
January 30	13 34.7	−7 17	11 25 "	4 54.2 "

URANUS.

	R. A.	Decl.	Rises.	Transits.
January 2	13 04.0	−6 06	12 43 A. M.	6 17.6 A. M.
January 15	13 04.6	−6 09	11 49 P. M.	5 23.2 "
January 30	13 04.5	−6 08	10 50 "	4 24.1 "

JUPITER.

	R. A.	Decl.	Rises.	Transits.
January 2	15 43.0	−18 50	4 16 A. M.	8 56.3 A. M.
January 16	15 53.4	−19 22	3 34 "	8 11.5 "
January 31	16 02.9	−19 49	2 47 "	7 22.0 "

VENUS.

	R. A.	Decl.	Rises.	Transits.
January 2	15 42.9	−16 59	4 08 A. M.	8 56.2 A. M.
January 16	16 50.6	−20 14	4 35 "	9 08.6 "
January 31	18 07.0	−21 54	5 00 "	9 25.9 "

While waiting for Saturn to rise into good position one may look at some of the other objects of interest to be seen in the early evening. Turning to the west the eye catches at once the four bright stars of the Square of Pegasus. The upper one of these four stars is α Andromeda (Alpheratz), and a little further up toward the zenith is β Andromeda. Turning almost at a right angle toward the northwest we see two fainter stars in line with β and beside the second one is a hazy patch of light. This is the great Nebula of Andromeda, a large oval mass of nebulosity, having in its centre a bright condensation like the nucleus of a comet. Almost directly east of the Andromeda Nebula, the second conspicuous star is β Persei or Algol, the noted variable star, which at intervals of about three hours less than three days, fades from 2nd to 4th magnitude for a few hours, resuming then its former brightness. The principal part of the constellation of Perseus is north of Algol in the Milky Way. Between Perseus and the familiar group of Cassiopeia's Chair, toward the northwest, is another large hazy patch of light. This is a splendid double cluster in the sword hand of Perseus. A little way east of the zenith is Capella, one of the brightest of the stars; toward the south, a little east of the meridian, Aldebaran, a very red star in the V-shaped group of the Hyades; and in the southeast, the finest of all the constellations, Orion, with the red star Betelgeux in one corner and the blue Rigel in the opposite corner of a quadrilateral, three stars between them forming the belt, and three the dagger suspended from the belt. The middle star in the dagger appears to the eye blurred or hazy. It is, in fact, not a star but the Great Nebula, one of the most wonderful objects in the heavens. In its centre is a dark opening which contains four stars in the form of a trapezium, which may be seen with small telescopes. Southeast of Orion, near the horizon is Sirius, the Dog Star, brightest of all the stars.

DRAWING THE PLANETS.

For young observers who have the aid of good small telescopes, the study of the physical structure of the planets can not be advanced, probably, in any other way so well as by making numerous carefully executed sketches of the outlines of the planets, especially those of Mars, Jupiter, and Saturn. Take the case of Mars first, and suppose his disc subtends an angle of 17″, and that he is sufficiently near the earth to exhibit a phase that is perceptibly gibbous, like the moon two days before it is full. With a pair of compasses, from the centre C′ (Fig. 1) to a radius C′A, one-half inch, describe the circle ACBD. For any particular date, turn to the Nautical Almanac, and find, as in this case (Jan. 31), that 0.9 of that diameter of the planet passing through the sun is illuminated. Let CD be this diameter, and AB one at right angles. Then CE will be the part in light. First with center C′ as before, and radius C′D, describe the circle ACBD, measure off one-tenth of CD to E. Join AE, BE, and bisect AE in G and BE in H; from G draw GF at right angles to AE, and from H HF, at right angles to BE. Finally from F where these two lines intersect, and with radius FE describe the arc AEB; then will AEBC represent the outline of Mars sought, as he will appear on the last day of this month, with a diameter 9″.4. The phase will be well marked only when the planet is nearer the earth. This figure and method are taken from that excellent little book by Capt. Wm. Noble of England entitled "Hours with a Three-inch Telescope." The drawings for Saturn and Jupiter will be given next time.

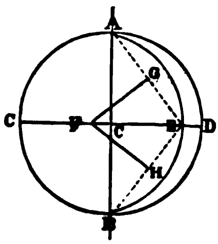

FIG. 1.

The Opera Glass is an inexpensive instrument, but it is a helpful one in the study of astronomy, and it is a wonder that teachers of astronomy in any grade of school, do not make more use of it. It is our purpose in the next number of the

MESSENGER to give a few examples of its uses in viewing celestial objects, in the hope of awakening general interest in this mode of study. A plan of regular instruction will be furnished to those who desire it on terms and conditions that involve continuous and useful observation. Correspondence is solicited.

Sun-Glows.— From February, 1886, to February, 1887, peculiar color after sunset was seen 67 times, and classed as follows:

3 times marked rich.
9 " " considerable.
55 " " some.

From February, 1887, to August, 1887, color was seen 22 times:

3 times marked considerable.
19 " " some.

Various writers have frequently alluded to the bad state of the atmosphere for astronomical observations during the entire period of these sun-glows. That trouble has apparently passed. J. R. H.

Baltimore, Dec. 13, 1887.

A Bright Meteor was seen by J. E. Keeler, of Lick Observatory, on the night of Oct. 18th. Its path was towards the south, nearly in line with α and β Orionis. It passed about a degree above ν^1 Eridani and disappeared five degrees beyond. Its light was a brilliant pale green. Its bright train was visible in a small glass for more than twenty minutes.

Mr. Geo. H. Peters, of Hartford, saw a meteor, Oct. 19th, 10*h* 49*m*, brighter than Jupiter and of a pale green color. It first appeared near ε Orionis, moved in a slightly curved line towards the horizon, between η and β Orionis, disappearing about 4° beyond. Careful observations of the bright meteors give useful data for obtaining altitude and the elements of their orbits.

Meteors. On the night of Dec. 11th, my attention was attracted by the number of meteors which originated in Orion. Between the hours of 9 and 9:30 P. M., I saw twenty-four.

The direction was from N. E. to S. W. I continued my observations at the same time on the following evening and counted twenty-one. On the evening of the 16th the radiant point was about one degree north-east of Betelgeuse. The color of most was bluish white; some were red, and some had well-defined trails. Most of the meteors moved southward.

San Francisco, Dec. 16, 1887. MONTE KOSHLAND.

Total Eclipse of the Moon. At the time of full moon on January 28, the moon will pass through the shadow of the earth and will be totally eclipsed for an hour and thirty-eight minutes. This eclipse in some of its phases will be visible throughout most of the inhabited part of the world. In the western part of the United States the first phases will not be seen, but the moon will rise totally eclipsed, and the last phases may be observed.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of conjunction in right ascension, 28d 11h 22m 03.6s

Sun's right ascension	20h 43m 52.65s	Hourly motion	10.31s
Moon's " "	8 43 52.65	" "	142.56
Sun's declination	18° 08′ 11.9″ S.	" "	0′ 39.7″ N.
Moon's "	18 01 43.2 N.	" "	5 52.5 S.
Sun's equa. hor. parallax	9.0	S.'s true semidiam	16 14.4
Moon's " "	58 11.1	M.'s "	15 50.6

TIMES OF THE PHASES.

	Washington Mean Time. H. M.	*Central Time. H. M.
Moon enters penumbra, January 28,	3 19.5	2 27.7
Moon enters shadow	4 22.2	3 30.4
Total eclipse begins	5 22.7	4 30.9
Middle of the eclipse	6 11.9	5 20.1
Total eclipse ends	7 01.0	6 09.2
Moon leaves shadow	8 01.3	7 09.5
Moon leaves penumbra	9 03.7	8 11.9

Magnitude of the eclipse = 1.647, (moon's diameter = 1).

OCCULTATIONS VISIBLE AT WASHINGTON.

Date.	Stars Name.	Magnitude.	IMMERSION. Wash. Mean Time. H. M.	IMMERSION. Angle fr'm N. P't. °	EMERSION. Wash. Mean T. H. M.	EMERSION. Angle f'm N. P't. °	Duration. H. M.
Jan. 1	7 Leonis	6½	81 59	161	19 38	340	0 39
3	B. A. C. 3837	6½	11 47	66	12 36	333	0 49
7	ξ^1 Libræ	6	15 16	177	15 45	231	0 28
15	ι Aquarii	4½	7 36	137	8 27	264	0 51
21	μ Ceti	4½	7 25	53	8 51	257	1 26
25	χ^3 Orionis	6	5 24	46	6 24	289	0 59
25	68 Orionis	6	10 35	97	12 00	261	1 25
31	b Virginis	5½	16 22	93	17 29	324	1 07

* Six hours from Greenwich.

PHASES OF THE MOON.

		Washington Mean Time. H. M.
Last Quarter	January 5,	18 34.2
New Moon	January 12,	15 30.4
First Quarter	January 20,	11 40.9
Full Moon	January 28,	6 10.7

MINIMA OF ALGOL (β Persei; R. A. 3h 01m, Decl. + 40°31′).

	Central Time. D. H. M.		Central Time. D. H. M.		Central Time. D. H. M.
January	3 00 55	January	14 12 10	January	25 23 26
	5 21 43		17 8 59		28 20 15
	8 18 32		20 5 48		31 17 04
	11 15 21		23 2 37		

GREAT RED SPOT ON JUPITER—TIMES WHEN ITS ZERO MERIDIAN PASSES THE CENTRE OF JUPITER'S DISC.

	Central Time. D. H. M.		Central Time. D. H. M.		Central Time. D. H. M.
January	1 18 04.1	January	12 12 13.7	January	22 20 27.1
	2 13 55.6		13 18 00.9		23 16 18.6
	3 19 42.9		14 13 52.4		24 12 10.1
	4 15 34.4		15 19 39.6		25 17 57.2
	5 21 21.6		16 15 31.1		26 13 48.7
	6 17 13.2		17 21 18.3		27 19 35.8
	7 13 04.7		18 17 09.8		28 15 27.3
	8 18 51.9		19 13 01.3		29 21 14.4
	9 14 43.5		20 18 48.5		30 17 05.9
	10 20 30.7		21 14 40.0		31 12 57.3
	11 16 22.2				

EDITORIAL NOTES.

Our new volume begins with this number, in a new dress, from new type, and a new printing office. We, therefore, hope that our New Year greeting to all our readers is a peculiarly happy one.

Subscribers will please notify the publisher promptly if the continuance of the MESSENGER for the ensuing year, or beyond paid subscription, is desired; otherwise it will not be sent. If annual subscriptions be paid during the month of renewal, two dollars only, as usual, will be charged; if paid later the annual fee will be $2.50.

We take pleasure in announcing that our next issue will contain an illustrated article showing the present condition and the prospects of the great Lick observatory, at Mt. Hamilton, California. Though exceedingly busy, as every one must suppose President Holden at present to be, he has kindly consented to prepare the article himself.

Orbits of Meteors. The following orbits I have computed from well defined radiants deduced by Mr. W. F. Denning from observations in September, and published in the *Observatory* for November, 1887, p. 384. Several of these radiants have been confirmed by observations in previous years:

Current Number.	Longitude of Perihelion.	Longitude of Node.	Inclination.	Perihelion Distance.
1	106.9°	173.3°	5.7°	0.300
2	87.7	175.2	67.4	0.478
3	24.6	174.3	85.6	0.932
4	94.7	175.2	127.3	0.418
5	52.2	173.3	178.5	0.758
6	43.4	177.2	51.0	0.846
7	49.5	173.3	69.5	0.778

O. C. WENDELL.

Harvard College Observatory, Dec. 15, 1887.

Lunar Photography. Mr. H. C. Maine, associate editor of the Rochester N. Y. *Democrat and Chronicle*, and an enthusiastic astronomer, has recently produced some excellent work in lunar photography. The negatives were made in the principal focus of a silver-on-glass reflecting telescope constructed by Mr. Maine. The speculum is thirteen inches in aperture and seventy-eight inches focal length. A Barlow lens, or amplifier is placed a few inches inside the focus of the mirror, by which a direct image of the moon about 1¾ inches in diameter is obtained. The telescope is mounted as a Newtonian, and on an alt-azimuth stand. Clock-work for driving the telescope is therefore inapplicable, and the exposures are instantaneous by means of a simple drop shutter.

The writer recently had the pleasure of examining some of the original negatives and also contact and enlarged prints from the same, and their sharpness and detail were surprising. The enlargements (fifteen inches in diameter) were on "argentic paper"—a modification of bromide paper—and represented the moon near the half and full phases. They were exhibited at a recent meeting of the Rochester Academy of Sciences, at which time Mr. Maine read a paper on the history and practice of lunar photography. He has for several years made photographs of the sun, and his work ranks with the very best that has been produced in this line. W. R. B.

Red House Observatory, Dec. 1887.

The Equatorial Telescope. The objection to the use of the prism, that the position of the objects in the field depends upon the angle at which the prism is placed, I have found to be entirely obviated by placing the prism at right angles with the polar axis, facing towards the pillar, and never changing its position. Suppose the telescope to the east of the pillar; in observing objects in the meridian the eye looks horizontally towards the west. As the objects pass toward the west, the eye looks more and more downward, until the depression equals the complement of the latitude; but it never exceeds this. When the telescope is reversed, the prism is in position for equally convenient observation towards the east.

The finder should be upon the same side of the large telescope with the prism eyepiece; when it will always be at hand, in whatever direction the telescope is pointed. Both in variable star comparisons, and in photometric work, I have required unusually large finders, which have been placed below the line of the declination axis, making it impossible to balance the telescope with the sliding weight. I have recently attached a short rod with a small sliding weight, at right angles with the telescope, and in the meridian. With this I can balance the finder; and the telescope is then in adjustment for all positions. At first I attached this additional counterpoise to the saddle on the side towards the eye; but it sometimes interfered with the stand, and I have found it less in the way on the other side of the saddle. It would be still less in danger of interference with the stand if attached to the tube nearer the end; but it is my impression that it would be better still to have the finder in the line of the declination axis, the additional convenience from placing it on one side not being sufficient to offset the disadvantages of a counterpoise. HENRY M. PARKHURST.

Brooklyn, N. Y., Dec. 15, 1887.

New Nebulæ at the Warner Observatory. On May 23rd of the present year, the sixth catalogue, of one hundred each, of nebulæ discovered at this observatory was mailed to the editor of the *Astronomische Nachrichten*, and published in No. 2798 of that journal. It was then expected that, ere this, another list, containing a like number, would be ready for publication, but, during the last eight months, the weather, which has been more unfavorable for work so delicate than for thirty years past, has prevented its completion. However, since the printing of No. 6, sixty-six, not previously known, have been found, most of which are recorded in Dr. Dreyer's new General Catalogue of Nebulæ, containing all known nebulæ up to date, July 1, 1887, when it went to press. The printing of Dr. Dreyer's list, which contains in the body of the work 7840 numbers, is in a forward state, having, on Sept. 1, reached *7h 1m*. The book will be found one of the most valuable astronomical publications of the century.

It was formerly supposed that because the heavens had been so thoroughly searched by the Herschels, D'Arrest and others, the quest for new ones would be an almost fruitless one, indeed, time well nigh lost, but the numbers since discovered by Tempel, Stephan, Stone and at this observatory, show that the nebulæ, like the stars, are inexhaustible. As a matter of course, those that remain must be exceedingly faint, requiring not only a large telescope, a keen eye long trained to the search, and exceptionally fine seeing, but also an eyepiece constructed expressly for this work.

The writer has found all of Sir William Herschel's faintest nebulæ—his class III.—easy objects. A short time ago while sweeping near Alpha Lyra, it was desired to observe one of his faintest nebulæ (No. 4417 of Sir John's G. C. of nebulæ) near that star. It was found much brighter than expected, and, strangely enough, two others were seen which he had overlooked, one on either side, and not over three or four minutes of arc apart. One of them is so exceedingly faint, it is not surprising that it should have escaped his observation. Its place for 1890 is R. A. *18h 26m* 15s, Dec. $+ 39°55' 5''$. It is described, in the director's note-book, as "Exceedingly, exceedingly, exceedingly faint, pretty small, little elongated, three stars in line point to it, in finder field with Vega." It is, however, more to be wondered at that Herschel failed to detect the other, as it is as bright as his own, though very much smaller. Just previously, Edward, the director's seventeen year old son and his occasional and only assistant, had discovered another almost as near Vega. Stephan, also, has one near. A few months since a new one was picked up in finder field with the Dog Star, of which no published record exists. But stranger than these, the young tyro mentioned above, found one, and his father, a second, in finder field with Epsilon Lyræ, that wonderful double-double which has been a target for all the great telescopes of the world, and which astronomers have scanned without suspicion that two undiscovered nebulæ were near. That, seen by the younger observer was the fainter of the two, he overlooking the brighter one subsequently captured by his father.

A few years ago, while sweeping, the thought of the possibility of faint, undiscovered nebulæ being in close proximity to some of the bright stars occurred, and, Delta Leonis chancing to be near, the telescope was turned on it, and a pretty faint, new nebula was found 6′ or 8′ from it. Encouraged by this success, the search was continued, though nearly a year elapsed before another was thus found, the last being in the field with Algol. Several close doubles have been found here, the duplicity of one which was suspected with a power of 132, having been fully confirmed with 200, and well separated with 350. A triple nebula with components near enough to be ranked as a triplet proper, cannot be claimed among the discoveries of this observatory.

Doubtless many nebulæ yet remain to be detected. Probably several thousand will be discovered from our present position in space by the great telescopes of to-day.

Warner Observatory, LEWIS SWIFT.
Rochester, N. Y., Dec. 15, 1887.

Observatory of Nice. Volume II. of the "Annales de l'Observatoire de Nice" has recently been published under the auspices of the Bureau of Longitudes of France by the director of the observatory, M. Perrotin. The first volume, containing the description of the observatory and the instruments, is in preparation. The third volume will contain drawings of the solar spectrum by M. Thollon, which are in the hands of the engraver.

Volume II., which we have in hand, is a large quarto of about 440 pages with a number of engravings and seven large and finely executed plates. The first part contains the details and discussion of the determination of the difference of longitude between Paris and Nice, and Milan and Nice, in September and October 1881, by MM. Bassot, Perrotin and

Celoria. An interesting point here is the determination of personal equation between the observers Bassot and Perrotin by exchanging stations and also by means of a personal equation machine, the two methods giving respectively B.—P. = +0.125*s* and +0.100*s*. The following parts contain provisional determinations of the latitude in 1882 and 1884 by M. Perrotin; a long series of double star measurements, principally of the Dorpat and Poulkova catalogues, made by M. Perrotin, from 1883 to 1887, with the 0.38 metre or 15-inch equatorial; micrometric observations of comets and planets by MM. Perrotin and Charlois; physical observations of the comet Pons-Brooks, great comet of 1882, Uranus, Saturn, and Mars; solar spectroscopy, by M. Thollon; and a number of miscellaneous papers by Thollon, Puiseux, Perrotin and Charlois. Some of these papers are very interesting and valuable and altogether the volume is one to be highly prized by those fortunate enough to secure it. H. C. W.

Syracuse University Observatory. The dedication of the the new observatory of the University of Syracuse, N. Y., took place Nov. 18, 1887, with appropriate ceremonies. The formal address prepared for the occasion was given by Prof. Newcomb and part of it appears elsewhere in this number. The building stands on a hill to the west of the Hall of Languages, and is built of rough dressed Onondaga lime stone. The transit instrument was made by Troughton & Simms, of London. It has a telescope of three inches aperture and forty-two inches focus. The chronograph is by Fauth & Co., Washington, chronometer by Dent, of London, and sidereal clock is being made at Dresden, Germany. The equatorial telescope has eight inches clear aperture and was made by the Clarks, of Cambridgeport, Mass. Upon the wall in the reception room is a neat tablet bearing the following inscription:

This observatory was erected and equipped in memory of Charles Demarest Holden, a graduate of Syracuse University in the class of 1877. Born at Charlotteville, N. Y., June 10, 1853. Died at Syracuse, N. Y., February 21, 1883.

The new observatory will be under the direction of Prof. John R. French whose earnest work in this department of science well deserves these fine added facilities.

Messrs. Fauth & Co., of Washington, D. C., have completed the micrometer for the great equatorial of Lick Observatory. Its weight is forty-five pounds. From the photograph of it which the company very kindly sent us recently, it must be a very complete and finely finished piece of mechanism. President Holden will doubtless speak of it later more particularly.

We are not surprised to know that this enterprising firm have largely increased the capacity of their shops and are still crowded with orders for expensive astronomical instruments of various kinds. They have just completed a meridian circle for Greencastle, Indiana, another for Johns Hopkins University, and several special instruments for Thomas A. Edison. They are now making a meridian circle with telescope of five inches aperture and circles thirty inches in diameter for the Cincinnati observatory. Such patronage from the older observatories who know these makers best from the excellent work they have done is evidence of solid and deserved merit. From new and increased facilities astronomers and scientists will be glad to learn that Messrs. Fauth & Co. propose to make circle mountings a specialty and they are now prepared to do work of this kind of the best quality.

The Ring Nebula in Lyra. According to a communication from R. Spitaler of the Vienna observatory, to the "Zeitschrift für Populäre Astronomie Sirius" the existence of a variable star near the centre of the ring nebula in Lyra seems to be fairly established. He says:

"In consequence of the announcement from Herr E. von Gothard, of the probable existence of a ring shaped nucleus near the centre of this nebula, I examined this object, with the aid of the large refractor of this observatory, during the latter part of September and beginning of October, 1886.

"Any change in the appearance of the same I should have at once detected because of my careful examination while making an accurate drawing of this nebula during September, 1885. I utterly failed to detect any change in comparison with my drawing.

"With low powers the inner portion of the ring appears covered with a delicate luminous veil, while higher powers bring out different intensities of light, giving this inner portion a flaky appearance. Nearly west from the centre such a flake is commonly visible. In the eastern portion of the inner ring plane, and near the edge I have frequently seen three faint stars. While infinitesimal points of light flashed momentarily into view in other parts of the nebula, no star could be detected near the centre. This was corroborated by Prof. Vogel in Potsdam and photographically by the Henry brothers in Paris (A. N., 2754). On the 25th of July Prof. Young, of Princeton, visited us, and on this occasion we looked up several objects with the large refractor. The atmosphere was not all that might be desired, still the seeing was fair.

"When we pointed the telescope upon the ring nebula, I was astonished to find, at first sight, a little star near the middle of the inner ring plane, a little north west of the centre, and exactly as shown in the Gothard photograph (a diapositive of which was kindly sent us), only that it appeared proportionally fainter than the photograph.

"On July 26, although the sky was not absolutely clear, I again saw this star, but not as readily as the previous night. Undoubtedly we have a variable here which deserves some attention.

"Concerning the visibility of this star, of which Hahn first made mention in the Berliner Jahrbuch of 1803, there are several other recorded observations (see remarks in A. N., 2754). To the dates collected by Holden (Monthly Notices, Vol. 36 p. 36) should be added that Prof. Young and Mr. R. D. Schimpff, while examining this nebula Aug. 26, 1884, with the 23-inch refractor of the Princeton observatory, also noted a minute star near the centre (Sirius, Vol. XIII., p. 142.) Prof. Young informed me that he, in company with Barnard, again saw this star last year."

Dr. Klein adds that in view of Mr. Spitaler's communication he examined this nebula with his 6-inch refractor, Aug. 23, the atmosphere being exceptionally clear and steady. He was unable to take the star. He admits, however, that with the aid of his instrument it is impossible to pick out, from the fluctuating ground of the nebula, a star of the tenth magnitude and concludes that, at the time of his observation no star of the 9.5 magnitude, or brighter, was near the centre of this nebula.

R. D. S.

Corrections of Catalogues of Nebulæ. Dr. Swift notes (*Astr. Nach.*, 2798) that Nos. 2 and 7 of the sixth catalogue of nebulæ discovered at the Warner observatory are identical with Nos. 277 and 303 of the second list of nebulæ observed at the Leander McCormick observatory (*Astr. Jour.*, 152). Corrections to the Warner observatory third and fifth and sixth catalogues appear, respectively, in the *Astronomische Nachrichten*, No. 2746, and the SIDEREAL MESSENGER, Nos. 52 and 59. These corrections with those given here make, I think, a complete list of corrections to the first six Warner observatory catalogues so far as nebulæ between 0° and 30° south declination are concerned; corrections to the other nebulæ are not given because this observatory has not a list of all the published northern nebulæ.

The numbers given below in the first column are those of the Warner observatory catalogues numbered continuously; the third column contains the number of the nebula as previously published:

25	e F, p s, l E	G. C. 3657	F, S, R
162	p F, neb *.	G. C. 4395	F, p L, c E, *. inv.
261	p B, v S, R	Washburn Obs. I, No. 6	p F, * 11.5 nf 30″
263	v F, p S, R	G. C. 2846	v F, p L, i F
271	e F, p S, R	G. C. 3510	c F, c S, i R

The southern nebulæ in the third catalogue of the Warner observatory have, by an oversight, been until now omitted from the Leander McCormick observatory's general list of southern nebulæ, consequently it was not noticed that Nos. 352 and 359 were identical with Nos. 223 and 229 of the third catalogue; Nos. 352 and 359 should therefore be erased from the second list of nebulæ observed at the Leander McCormick observatory (*Astr. Jour.*, 152). Dr. Swift has a fainter nebula, 3′ sf No. 223, which was not observed here.

Leander McCormick Observatory, FRANK MULLER.
University of Virginia, Nov. 25, 1887.

Dudley Observatory, at Albany, N. Y., is a historic place that we have longed to see. That hope was realized in August last. Though Professor Boss was absent in Europe at the time, his genial assistant, H. V. Egbert, was at the helm and ready for any emergency. Those instruments having the pattern of early days and bearing the marks of long use, are indeed objects of curious interest. All honor to them for the good work they have done, but it is not now a question of debate whether some of them ought to be retired for life or not. In one corner was seen a relic of the reign of Professor Hough, that first pattern of the printing chronograph. No one can tell its age, yet it is believed to be the parent of the Hough Printing Chronograph of to-day that may soon displace all others. Beside this antique piece was the first model of the Mitchel chronograph, with revolving disc, another specimen of American antiquities in astronomical lines that has already had a noble history. But that large calculating machine on the other side of the room is too much for ordinary descriptive powers. The mute visitor wonders if Professor Boss ever shapes his modern calculations by that engine. It doubtless has a history also.

Our friend Mr. Egbert showed us the excellent library of the observatory and its appointments for work, and gave full information of his nightly occupation with meridian circle observations, places of comets, and general routine work. His clock tests, mode of reductions, and orbit calculations were instructive and contained several points that were new.

Catalogue of the Observatory of Paris. A note by Admiral Mouchez (extract from "Comptes rendus de sèances de l' Academie des Sciences, CV., Oct. 17, 1887") gives interesting information concerning the forthcoming catalogue of the Observatory of Paris, which is a revision of the catalogue of 47,390 stars observed under the direction of Lalande, from 1791 to 1800. Le Verrier decided to undertake this revision, in 1854. In order to obtain all the precision considered necessary to-day, he fixed upon three observations of declination and three of right ascension as the determination of each star; this was without doubt a very just appreciation of the actual needs of astronomy, but it imposed upon the Observatory of Paris an enormous work of 300,000 meridian observations, which, to be made under the best conditions, must be executed very rapidly.

Unfortunately, the Paris sky, generally unfavorable to a long series of observations, the insufficient means at Le Verrier's disposal, and the important works of celestial mechanics, to which he then consecrated the greater part of his time, did not permit him, to his great regret, to push the revision of the catalogue of Lalande with all the necessary activity, and when Admiral Mouchez was called to the direction of the observatory in 1878, there were hardly more than a third of the necessary observations made. Since 1879 this work has been pushed more vigorously, so that the annual number of meridian observations has been raised from an average of from 6,000 to 8,000 up to 25,000 or 28,000.

The printing of the first two volumes of the new catalogue was begun in 1884. In order not to delay the publication, it has been decided not to wait until the completion of the observations; the first part, which is being published now, comprises only the stars observed up to 1881; the rest will appear in a complementary volume as soon as the first part is finished. The first two volumes contain all the stars comprised between 0*h* and 6*h* right ascension to the number of 7,245, for which 80,000 observations were made in right ascension and declination.

One of the volumes contains the catalogue proper; the other all the observations used in forming it.

The preparation of the following volumes is being actively carried on and will be continued without interruption until the completion of the work.

The Lick Observatory Prosperous. Not long ago a painful report was in circulation, (starting so far as we know in the far East) that the great Lick observatory was likely, after all, to fail for lack of funds, for running expenses, nearly all of its $700,000 having been expended in the erection of buildings and the purchase of instruments. This is certainly far from the truth, in the light of recent action by the legislature of the state and the regents of the University, from which sources $19,000 have already been appropriated for the running expenses of the observatory for the year 1888. That comfortable little sum of money will certainly give a generous start for the first year.

It is indeed a good sign of progress that so many colleges are furnishing small observatories for the purpose of instruction in astronomy; and colleges and seminaries for ladies are not behind others in this respect. Miss Mitchell of Vassar, Miss Bardwell of Mt. Holyoke, Miss Byrd of Smith, and Miss

Hayes of Wellesly, who is now studying practical astronomy at the Leander McCormick observatory, are worthy examples of the true preparation for right instruction in this noble science.

Recent letters from California say that Mr. Charles B. Hill of Chabot Observatory has been chosen to a position in Lick Observatory, that Alvan G. Clark of Cambridgeport, Mass., arrived at San Francisco Dec. 13, bringing with him the 36-inch photographic corrector which he has made for the great telescope of the observatory, and that Mr. Swasey, of Cleveland, of the firm which made the mounting for the great equatorial, is also there. Mt. Hamilton will be a lively place from this time onward.

Report of U. S. Naval Observatory. The report of the superintendent of the United States Naval Observatory, Capt. R. L. Phythian, for the year ending June 30, 1887 is at hand. The only important change noticed in the personnel of the observatory is in the office of superintendent, which took place in November 1886, at which time Capt. Phythian succeeded Commander Allan D. Brown. The substance of the report of general public interest has already received notice at various times.

Prof. Frank H. Bigelow, of Racine College, has recently given a course of popular lectures on astronomy, before the Racine Academy of Arts, Sciences and Letters, on the following themes:—

The Coördinates of Astronomy, Instruments for Star Positions, Astro-physical Instruments, The Earth's Atmosphere, The Sun's Atmosphere, and Some Important Corrections.

M. D. Ewell, of Chicago, has been giving some attention to apparatus for the study of physical standards. As an important step in this direction, the Northwestern University has furnished Mr. Ewell with a large Rogers' comparator which is already mounted and said to be a most perfect instrument of its kind.

All scientists who do not already know the fact, will be glad to learn that Prof. S. P. Langley, formerly director of Allegheny Observatory, has been elected Secretary of the

Smithsonian Institution at Washington, to succeed the late Prof. Spencer F. Baird. The choice was an excellent one.

Zusatz-Sterne in Auwers' System. For two months past Prof. Brown has been using the meridian circle of Washburn Observatory, Madison, Wis., on the determination of fundamental star-places of the Zusatz-sterne in Auwers' system, undertaken at the request of Prof. Auwers himself. Prof. Brown holds the position of Professor of Mathematics in the Navy, was formerly at the Naval Observatory, went thence to the Naval Academy at Annapolis, Md., to work with the Meridian Circle at that place, thence he was detailed to Washburn Observatory.

BOOK NOTICE.

Easy Lessons in the Differential Calculus, Indicating from the Outset the Utility of the Processes called Differentiation and Integration. Richard A. Proctor, Longmans, Green & Co., London, and New York 15 East 16th Street, 1887, pp. 114.

This book contains the essentials of the Differential Calculus well arranged for elemental study. It gives a series of twenty-one easy lessons, showing first the purpose of this interesting branch of mathematics and then its relation to the Integral Calculus. The main object of the writer is to show the student the real uses of these branches of study, while he is attempting to master elemental principles and methods peculiarly their own, and hold his attention to these things, neglecting as useless, if not hurtful, much of the details which are found in ordinary text-books. The author then states and proves the rules for work and applies them to all the topics ordinarily presented in the elementary calculus illustrating each with appropriate exercises, the solutions of which are fully given. The book is evidently not intended as a text-book, for school or college use, in the sense of furnishing sufficient exercise in the application of the elements of the calculus; but it will be found very useful in review of principles, helpful in the meaning of operations, and instructive in the theories of limits and infinitesimals which so often trouble writers and teachers to explain. We think the author rightly combines the two opposing methods of limits and infinitesimals thereby practically escaping the bald fiction of the one and bridging the dark chasm of the other.

THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE,

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

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THE LICK OBSERVATORY.

BY EDWARD S. HOLDEN.

For the MESSENGER.

MY friend, the Editor of the SIDEREAL MESSENGER, has asked me to write an article on the Lick Observatory at this time, notwithstanding the fact that quite a number of excellent accounts have lately appeared in various places, which seem to me to cover most of the points of interest.

Much of what is here given will appear in Volume I. of the *Publications of the Lick Observatory* shortly to be distributed, but it may perhaps be of interest in its present form.

As very few observations have been made with the instruments, I can only speak of the history of the Observatory up to this time, and of its condition at present, when it is officially pronounced to be ready to begin its work.

SKETCH OF THE HISTORY OF THE LICK OBSERVATORY.

In 1874 Mr. Lick gave $700,000 to a Board of Trustees (Mr. D. O. Mills, President), to provide a telescope "more powerful than any yet made"; and "a suitable Observatory connected therewith" was specified in his second deed made in 1875.

Just before this time, Professor Young had been making observations at Sherman, in the Rocky Mountains, and Professor Davidson had made several reports on the fitness of the high Sierras as a site for an Observatory. Mr. Lick was advised to choose a mountain site for his new Observatory and was seriously considering the selection of a place near Lake Tahoe. This site was subsequently abandoned on account of the severe winters, etc.

In the fall of 1874 Mr. Mills came to Washington to consult Professor Newcomb and myself (then assistant to Professor Newcomb), and others in Washington.

The whole matter was thoroughly discussed between us and a project for the buildings and instruments of the new Observatory was made. This was reduced to writing by me in October, 1874, and rough sketches were made of the principal buildings, etc., by Professor Newcomb and myself. As it was then a question whether "the most powerful telescope" should be a reflector or a refractor, Dr. Henry Draper's counsel was asked for and freely given. Sir Howard Grubb also gave much time to projects for the Observatory.

Finally Professor Newcomb was asked to go to Europe to see where glass discs of a large size could be had, and this journey was made in the early part of 1875. It was strongly urged upon Mr. Mills that Mr. Burnham should test the excellence of the various sites under consideration before a final selection was made. This suggestion was not carried out till 1879, however.

The position of Director of the new Observatory was provisionally offered to me at this time. When Mr. Mills returned to California, he found that Mr. Lick was not satisfied with the policy of his Trustees and after a time the Board resigned and a second Board was appointed. Mr. Lick was equally dissatisfied with the policy of the second Board and finally a third set of Trustees was selected in 1876, which has acted until the present time. On Mr. Lick's death, in 1876, many distressing legal complications arose, and it was not until 1879 that they were finally disposed of, and work on the Observatory was begun.

In 1876 I met Capt. Floyd, the President of the Lick Trustees, in London, and together we visited various observatories and astronomers. Capt. Floyd also spent some months on the continent on the same business.

In the meantime Mr. Lick had agreed to build his Observatory at Mt. Hamilton in Santa Clara county, on condition that the county should build a road to the summit. This road, 26 miles long, costing $78,000, was built in 1876.

The selection of Mt. Hamilton, rather than Mt. Diablo, Loma Prieta, St. Helena, or a mountain further south was made by Mr. Lick on the report of Mr. Fraser who has been the efficient superintendent of construction of the Lick Observatory from 1876 to November, 1887.

It 1879 Mr. Burnham was invited by the Lick Trustees to bring his six-inch telescope to Mt. Hamilton and to observe double stars there, so that he could test the quality of the vision and compare it with that at Chicago, Hanover (N. H.) and Washington. Mr. Burnham spent August, September and part of October on the mountain, in camp. In a capital report to the Lick Trustees (1880) he gave the results of his work. It was found that the nights of summer and autumn, say April to October or November, were excellent both as to clearness of vision and as to steadiness. The daylight hours are less satisfactory. Mr. Keeler has lately shown that the vision in winter time is not specially better than that at lower elevations.*

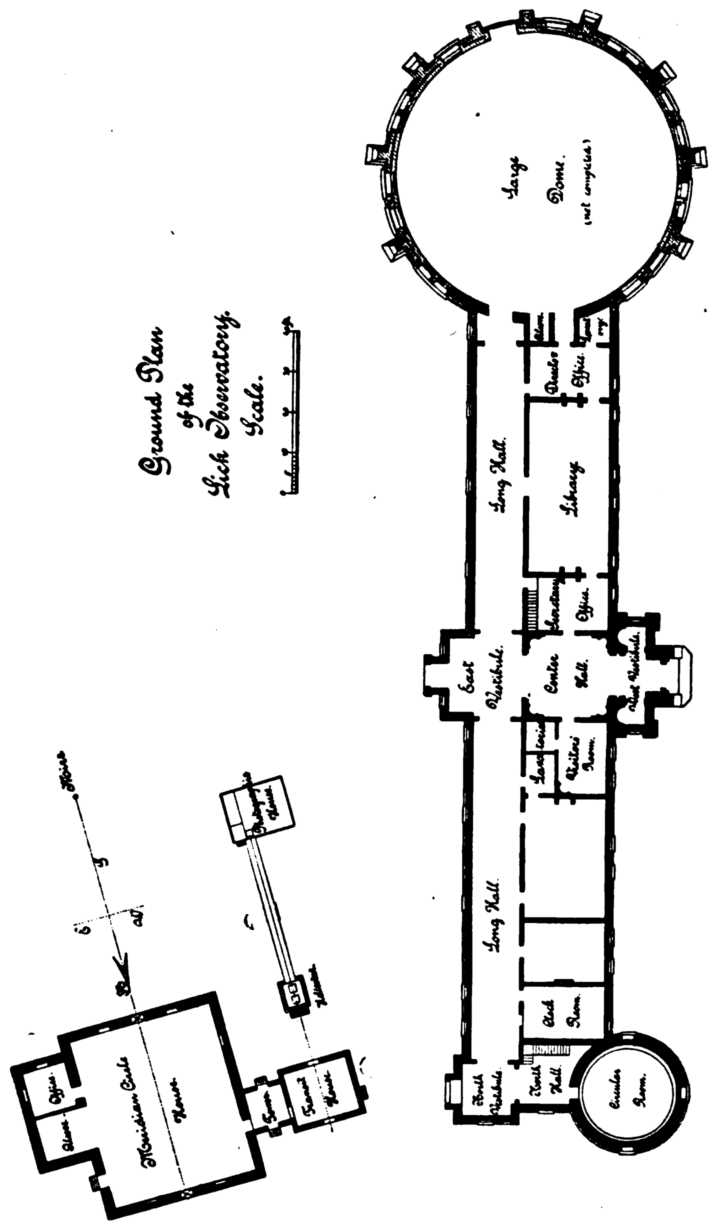
The secret of the steady seeing at Mt. Hamilton lies in the coast fogs. These roll in from the sea every afternoon in summer, rising 1,500 to 2,000 feet. They cover the hot valley and keep the radiation from it shut in. There are no fogs in the day time and few in the winter. Volume I. (before referred to) contains meteorological observations which throw much light on this and similar questions. I must simply refer to them in passing.

In 1879 Capt. Floyd and Mr. Fraser visited Professor Newcomb and myself in Washington and the plans for the Observatory were drawn. These are practically the same as those discussed in 1874.

The plans have proved to be entirely adequate and have been closely followed in most essential respects. Improvements have been made wherever it was possible, and many ingenious devices and details have been worked out by Capt. Floyd, or by Mr. Fraser, or by others under their direction. The plans for the buildings will be best understood by consulting cut on the following page.

At the south end of the Observatory is the 75-foot dome. At the north end is the 25-foot dome. They are connected by a hall, 191 feet in length. On the west is a series of study and work rooms. For the next twenty years there will be space in these rooms and in the hall for all the work of the Observatory. When it is necessary a second row of rooms can be built on the east side of the hall. I do not see any possible expansion of the Observatory which can not be provided for by such additional rooms, and by separate detached observing rooms in the immediate vicinity.

* SIDEREAL MESSENGER, Sept., 1887, p. 233.


Ground Plan
of the
Lick Observatory.
Scale.
Large
Dome.
Long Hall.
Library
Office
East
Vestibule.
Center
Hall.
West Vestibule.
Visitors
Room.
Long Hall.
Clock
Room.
Circular
Room.
North
Vestibule.
North
Hall.
Meridian Circle
House.
Office.
Transit
House.

The building is of brick, painted. It has a slate roof. Tin was found to be better and has been used for the other buildings. Although the building is one story (with a shallow air space beneath), there is a great deal of floor room on the principal floor and in the low attic. The roof is also utilized by platforms and galleries.

THE DOME FOR THE THIRTY-SIX-INCH REFRACTOR.

The computations for the strength of the arches and of the walls of this dome were made by Prof. Bull, of Madison, Wis., in 1885, and forwarded to the Lick Trustees.

The contract for the dome proper was awarded to the Union Iron Works of San Francisco, in 1886, and the dome was finished in place in October, 1887. The details of plans were thoroughly worked out by Mr. Dickie, of the Union Iron Works, and by Mr. Fraser.

No adequate notion of the design can be had without woodcuts which I have no way of producing here. It may suffice to say that the outside diameter is 75 ft. 4 in.; the inside 71 ft. It stands on a smooth cylindric wall of brick 3 ft. 2 in. thick at base, 2ft. 3 in. at the top. This wall has few openings in it.

The original design of the brick cylinder, drawn by Prof. Bull from my sketches, is indicated on the plan of the buildings previously given. It provided for thorough ventilation and for rapid cooling off of the large masses of brick. This is a very important point and it is not yet certain that it has been secured by the modification actually adopted.

The dome itself is admirably constructed by the makers. The moving parts weigh 199,000 pounds, and can be set in motion by a pull of less than 200 pounds. That is, one pound can move 1,000. The usual motive power is obtained from a water engine which will rotate the dome 360° in less than nine minutes.

There are several novel features in the construction; perhaps the most important is the system of expansion bedplates for the track. The diameter of the dome changes one-half an inch in the extremes of temperature, and the track is given a smooth and oiled surface to slide upon (in and out).

The guide rollers are placed on the outside of this dome instead of on the inside, as is usual. The shutter is a modification of the centre pintle shutter described by me in *Silliman's Journal*, in 1873. The modification is an admirable one and consists in placing the pintle eccentrically, so as to keep the shutter as near the dome as possible. Most of the bearings of axles in the dome are anti-friction (ball) bearings.

The shutters weigh	16,000 lbs.
Total weight of cupola	174,000 "
" " " live ring	25,000 "
" " " moving parts	199,000 "
" " " metal in dome	269,000 "
" " " elevating floor	50,000 "
Total number of rivets and bolts	250,000 "

The observing slit is nine and one-half feet wide. As far as can be known now, the dome is an entire success.

THE ELEVATING FLOOR.

A very ingenious plan was proposed by Sir Howard Grubb to the Lick Trustees for placing the observer at a proper height (any where from zero to thirty-seven feet above the floor). The idea was to have a portion of the floor move bodily up and down, like an elevator. This plan was adopted by the Lick Trustees and the floor has been built by the Union Iron Works. It is entirely satisfactory in every respect but one. My recommendation to the Lick Trustees was that the floor should move at the rate of four feet per minute. The motive power provided (a three-cylinder 8×6 water engine) requires ten times as long. It is probable that this speed can be materially increased by changes in the hydraulic arrangements, and if not the motive power can be replaced by steam or electricity, should the present speed be found materially too slow.

The moving floor is 61½ ft. in diameter and weighs 50,000 pounds, which is nearly all counterpoised. By suitable changes it is certain that the ingenious plan of Sir Howard Grubb can be made available and convenient. The speed actually required can hardly be definitely fixed until a series of observations have been made.

THE DOME FOR THE TWELVE-INCH EQUATORIAL.

This dome is a hemisphere 25 ft. 6 in. in diameter, made of thin plates of nickle-plated copper secured to a light framework of wood. The slit for observation is 3 ft. wide and extends beyond the zenith. The shutter is part of a cylinder tangent to the sphere of the dome, and was made by Warner & Swasey in 1887. The mechanism for revolving the dome is novel, simple and efficient, and is the invention of Capt. Floyd and Mr. Fraser. An endless rope passes around the outside of the dome just above the base-plate, over guiding pulleys and down around a grove in a two-foot wheel placed in a recess in the wall of the room below. This wheel is rotated by a crank geared in the proportion of 3:1, and the friction of the rope on the outside is sufficient to turn the dome. To give the dome a complete revolution requires forty-one turns of the crank, and it can easily be effected in less than two minutes. The approximate weight of the dome is eight tons.

MERIDIAN CIRCLE HOUSE.

The Meridian Circle house, completed in 1884, from drawings made from my plans by Professor Comstock, is 43×38ft. with a wing 27×11ft. on the east. The walls are double throughout. The outer frame carries a louvre work of galvanized iron, which completely prevents the sun from striking any part of the building proper. The inner walls are of California redwood, and between these and the outer walls is an air-space twenty-four inches wide, which extends completely around the building. The ceiling is also of redwood. It is sixteen feet above the floor, flat in the centre of the room and arched over to connect with the side walls. A very large air-space above the ceiling communicates with the room itself and with the air-spaces of the walls. On the west the room opens into a ventilating tower two stories in height, which also adjoins and is connected with the house for the meridian transit instrument, which lies still further to the west. The design of this construction is to keep the temperature of the two houses and of their air-spaces precisely the same as that of the external air, and it is probable that this object has been practically attained. The upper room of the ventilating tower ought to furnish an admirable exposure for meteorological instruments.

The wing on the east side projects eleven feet from the main building, and contains an office room for the observer and an alcove to receive the glass house which protects the instrument when not in use.

The slit for observation is 3 ft. 4 in. wide. At the north and south it is closed by double shutters 20 ft. high, and overhead by four shutters, each 25 ft. long and 2 ft. wide, hinged at the side of the slit and opening outward. These shutters were devised by Mr. Fraser, are perfectly weather-tight and very convenient in use. They are the best that I have seen.

THE TRANSIT HOUSE.

The Transit house adjoins the Meridian Circle house on the west. It is built of iron with a wooden lining, after the manner of the Meridian Circle house, but the air spaces are smaller. The room measures 18 feet in an east and west and 14 feet in a north and south direction. The roof is arched, and the central opening is covered by a curved shutter, which is controlled by levers inside on the plan of Sir Howard Grubb. Sliding shutters on the north and south allow the instrument to point to the northern horizon and to the object glass of the photoheliograph which serves as a south collimating lens.

PHOTOGRAPHIC LABORATORY.

This is in a small wooden house with brick foundation, 16 ft. in an east and west and 12 ft. in a north and south direction, situated 60 ft. north of the Transit house.

The tube of the photoheliograph telescope enters the building 2½ ft. to the east of the centre.

The laboratory is 13×12 ft. It is lighted by two windows, one of which is of red glass, in the west end. Both are provided with shutters. On the north is the brick pier which supports the plate-holder of the photoheliograph. A room on the second floor of the main building next to the 75-foot dome is also fitted for photography.

THE DWELLING HOUSES.

The astronomer's dwelling consists of a brick building 63×60 ft. and three stories high, situated on a level bench of ground excavated for the purpose to the eastward of the Observatory and about 22 ft. below the summit. A long flight of steps leads up from the plateau on which the cottages are situated to the principal entrance.

The building contains two distinct and precisely similar dwellings, which, however, may be made to communicate when desirable by doors in the partitions. The floors of the third story and the summit plateau are on the same level, and are connected by a bridge, which gives easy access to the Observatory.

SHOPS, BARNS, AND QUARTERS FOR ASTRONOMERS AND WORKMEN.

The cottages are situated on the saddle of the mountain connecting the Observatory and middle peaks, where a level place was cleared for the purpose. At the foot of the flight of steps leading up to the astronomer's residence is a large double cottage containing eleven rooms, formerly occupied by the superintendent. One large cottage and two smaller ones are but a short distance off, with sheds for poultry, etc. A little further along is a large barn with stables, and north of this a long, low house which has been used by workmen.

On the Observatory plateau, east of the main building is a low brick building containing a carpenter shop and separate rooms for oil, paints, a blacksmith's forge, etc.

As no one of the astronomical instruments has been thoroughly studied, the accounts which can now be given simply serve to accompany an enumeration of the instruments available.

Perhaps this is the best place to say that since 1886 Mr. Keeler has been employed by the Trustees in carrying on a time-service for California, etc. This extends as far east as Ogden and El Paso, and will shortly include Oregon, etc. Observations by Mr. Burnham, Professor Todd, Professor Comstock, Mr. Keeler and myself have thoroughly tested all the instruments except the large telescope.

Mr. E. D. Preston, of the U. S. Coast Survey, has determined the force of gravity at the mountain by pendulum observations.

TWELVE-INCH REFRACTOR BY ALVAN CLARK & SONS.

The objective and tube of this instrument were originally made by Alvan Clark & Sons for Dr. Henry Draper, and were mounted in his private observatory at Hastings-on-the-Hudson.

The objective is of the very finest quality. It was disposed of by Dr. Draper in 1879, in order that he might replace it by the photographic objective of 11 inches aperature, now at Harvard College Observatory. The objective was in the hands of the Messrs. Clark until September, 1880, during which time a substantial mounting was fitted to it. It was mounted at the Lick Observatory, in October, 1881.

THE SIX-AND-ONE-HALF-INCH EQUATORIAL.

(Objective by A. Clark & Sons; mounting by Warner & Swasey.)

In ordering the Repsold Meridian Circle it was stipulated that the three objectives of equal size which belonged respectively to the circle and to the two collimators, should be made by Alvan Clark & Sons. The north collimator is to remain always in position. The south collimator will be used in connection with it for determination of the horizontal flexure by the method of opposite collimators, but can be replaced for determinations of collimation by the south *mire*, about eighty feet distant.

Its objective thus becomes available for other purposes, and Messrs. Warner & Swasey have provided a portable mounting for this objective. It is the work of a few minutes to detach the collimator objective in its cell and to adapt it to the tube of the six-inch mounting. The cast iron column of this mounting is hollow and contains the driving clock and weights. It can be taken apart just below the clock for greater convenience in transportation when the instrument is used on eclipse or other astronomical expeditions.

The driving clock has several features of interest. The double conical pendulum is so hung that its period of revolution is very nearly independent of the height of the balls, which always assume the position proper to their velocity of rotation, although the retarding friction increases continually as the balls diverge. The performance of this clock is very satisfactory. A similar clock, with the addition of an electric control, is provided for the 36-inch refractor.

FOUR-INCH COMET-SEEKER BY ALVAN CLARK & SONS.

The objective has an aperture of four inches and a focal length of about thirty-three inches. The rays from the objective fall on a reflecting prism midway in the tube and are bent into a horizontal plane. The observer has only to move his eye in azimuth while the telescope tube is moved in altitude, in order to cover the whole sky. The motion in altitude is effected by means of a crank. The instrument was ordered on the recommendation of Professor Newcomb in 1880, and delivered in 1881.

PHOTOHELIOGRAPH BY ALVAN CLARK & SONS.

The Photoheliograph is mounted due south of the Transit house. The Transit instrument serves to determine the position of the axis of the Photoheliograph; and conversely the Photoheliograph is used as a south collimator for the Transit.

It is essentially of the same form as those employed in the U. S. Transit of Venus expeditions of 1874 and 1882 which have been described (with plates) in the "American Observations of the Transit of Venus, 1874, Part I."

It was used by Capt. Floyd and Professor Todd to observe the Transit of Venus in 1882.

THE SIX-INCH REPSOLD MERIDIAN CIRCLE.

This instrument was ordered in 1882 and delivered in 1884. Previous to its dispatch to America it was thoroughly inspected by Prof. Auwers and by Prof. Krueger who were kind enough to do this at the request of the Lick Trustees. In a letter of May 6, 1884, Professors Auwers and Krueger say that: "The Meridian Circle ordered of the Messrs. Repsold is in its construction in every way suited to be the chief instrument in an observatory of the first class."

No description of the instrument and of the mounting need be given until after a series of observations shall have been begun and far advanced by its aid. Professor Comstock and myself observed with this instrument in 1886.

DECLINOGRAPH.

In April, 1885, Dr. Johann Palisa, of the Observatory of Vienna, kindly undertook to have a declinograph made which would fit either the 12-inch or the 6-inch equatorial. This instrument was delivered in 1886.

In 1885 it was my plan to carry the S. D. as far south as practicable and the declinograph was designed to aid in this.

As this great task is now in the able hands of Dr. Thome at Cordoba and of Dr. Gill at the Cape, the Lick Observatory has abandoned its original plan in this regard.

FOUR-INCH TRANSIT AND ZENITH TELESCOPE, COMBINED, BY FAUTH & CO.

This instrument was ordered, on the recommendation of Professor Newcomb, in 1880, and delivered in 1881. The aperture is 4.1 inches. It is essentially of the same pattern as the Meridian Circle of the School of Science at Princeton, New Jersey, by the same makers. It was mounted in October, 1881, and has since served for time determinations. In 1885 it was remodeled by the makers.

The objective (which is a very excellent one, by Alvan Clark & Sons) received a new cell. The eye-end was changed so that the micrometer can be used either in R. A. or Z. D. A sensitive level was added. In this way the instrument becomes a zenith telescope also, and can be used for an independent determination of the latitude by Talcott's method.

The piers were originally iron frames; they have been built solid with brick.

The east Y is movable in azimuth. The west Y is movable in level.

UNIVERSAL INSTRUMENT BY REPSOLD.

A universal instrument, by Repsold, was ordered in 1884 and delivered in 1885. Its telescope tube is broken at the middle where a reflecting prism sends the rays through the axis to the eye. Its aperture is 2.15 inches; the horizontal circle reads by two microscopes to 2″. The vertical circle reads by two microscopes to 2″. The circles are 10 inches in diameter. This instrument may serve for special investigations on the refraction; and it is a very perfect geodetic instrument. Together with the six-inch equatorial and a chronometer it constitutes an outfit which can be packed in a few hours and which is very suitable for astronomical expeditions. All these instruments pack readily into boxes of convenient size and shape.

CLOCKS.

There are two dead-beat clocks by Hohwu; two gravity escapement clocks by C. Frodsham and Dent; a mean time clock for time-service work by Howard (dead-beat); several chronometers by Negus and a thermometric chronometer by C. Frodsham. It was originally intended to have a fine clock in each observing room, but a set of controlled clocks (Gardner's pattern) has replaced the finer clocks which are now in the clock room.

CHRONOGRAPHS.

There is a Fauth chronograph in the transit room, one in the meridian circle room and a Warner & Swasey chronograph in each dome.

MINOR INSTRUMENTS.

The Messrs. Repsold have furnished the Observatory with a level-trier of refined construction.

An engine for measuring photographs, scales, etc., has been made by Stackpole & Bro. from designs by Professor Harkness. It is similar to the one constructed for the U. S. Transit of Venus Commission.

For use in connection with the measuring engine, Professor W. A. Rogers, of Harvard College Observatory, has provided a standard bar 20½ inches long, containing a half-yard divided into inches and tenths, with two inches at one end minutely sub-divided.

A delicate spherometer, by Fauth & Co., is provided, beside resistance-coils, galvanometers, a disk photometer, small spectroscopics, spare prisms, eye-pieces, etc.

The most important of the minor instruments are the filar micrometer for the 36-inch, by Fauth & Co., the duplex micrometer, by Grubb, and a very powerful and convenient star-spectroscope made by Brashear from designs by Mr. Keeler.

Plans for a large solar spectroscope have been worked out by Professor Langley and myself, but the instrument has not been ordered as yet.

THE THIRTY-SIX-INCH TELESCOPE.

The visual objective is 36 inches clear aperture and 678 inches focus. One second at the focus is therefore about $\frac{3}{1000}$ of an inch. The image of the sun is about six inches in diameter. The photographic lens is more than 34 inches in aperture and about 48 feet focus.

The history of the objective is as follows: The flint disc was obtained from Feil in April, 1882. After nineteen failures, the crown was successfully cast in September, 1885. In 1886 a third (photographic) crown lens was purchased also from Feil, which was cast at the same time with the successful crown disc for the visual objective; it broke in the hands of the Clarks in 1886.

In 1887, the Trustees of Yale University kindly consented to sell their 27-inch flint disc to the Observatory for its cost to them, but the Messrs. Clark reported to Captain Floyd that this lens was of glass too yellow for a photographic corrector, and their liberal offer was not accepted by the Trustees. In 1887, Mr. Alvan G. Clark went to Paris and procured the crown glass from Feil, which has been worked into a third lens. The glasses have been thoroughly investigated by Professor Hastings and his results will be printed shortly.

The visual objective was completed by the Clarks and delivered in 1886, so that it has waited for a year for the dome and mounting.

The mounting is by Warner and Swasey and all the details of its construction have been worked out by them except those of the eye-end, which were drawn by Professor Bull, of Madison, from sketches by Professor Langley and myself.

The tube is nearly cylindric in shape, with a suitable port for access to the photographic focus. The counterpoising is arranged so that the photographic lens can be put on and taken off safely and quickly.

There are three regular finders 6, 4 and 3 inches in aperture. In addition to these, the 12-inch equatorial can be quickly attached as a pointer for photographic work should the controlled driving clock not prove satisfactory.

The following mechanical movements are provided:

An observer at the eye-end can

1. Clamp in declination.
2. Give slow motion in declination.
3. Read the declination circle (two verniers).
4. Clamp in right ascension.
5. Stop the clock.
6. Give slow motion in right ascension.
7. Read right ascension circle (one microscope).

An assistant on *either* side of the balcony below the axes can

8. Clamp in declination.
9. Give rapid motion in declination.
10. Give slow motion in declination.
11. Give quick motion in right ascension.
12. Give slow motion in right ascension.
13. Clamp in right ascension.
14. Stop or start the driving clock.
15. Read the right ascension circle (two microscopes).
16. Read a dial showing the nearest quarter degree of declination.

The original design of the makers allowed everything which is now done by an assistant on the balcony, to be done by a person on the floor.

The distance from the base of the iron pier to the centre of motion is 37 feet exactly, and to the lowest position of the (movable) floor is 35 feet 11 inches, leaving a clearance of 7 feet 10 inches for the eye-piece, or of about 3 feet 7 inches for the star spectroscope.

The eye-end is so arranged that the micrometer can be quickly removed, and two steel bars inserted in bearings. These bearings are part of a jacket around the eye-end. This jacket revolves smoothly 360° in position-angle. Spectroscopes, photometers, enlarging cameras, etc., can be readily attached to these bars. In this way this telescope mounting is made entirely convenient for micrometric, photographic or spectroscopic work. It is, in fact, three mountings in one. It is as yet too soon to pronounce any opinion on the telescope and mounting. The Clarks declare the objectives to be essentially perfect, and the mounting has been inspected by Capt. Floyd, Professor Newcomb, and Mr. Burnham, and pronounced satisfactory in every respect.

METEOROLOGICAL INSTRUMENTS.

The Observatory is not primarily destined for a meteorological station. Its very exceptional situation, however, creates a responsibility on its part to engage to some extent in making meteorological observations, and a suitable outfit for this purpose has been obtained.

A self-registering rain-guage, a self-registering barometer (Draper's pattern), and a self-registering wind-guage (U. S. S. S. pattern) are provided, together with two mercurial barometers (by Green and by Roach), and a number of standard thermometers (by Green).

SEISMOMETERS.

A complete set of apparatus for the registration of earthquake movements has been provided by the Cambridge Scientific Instrument Co., from designs by Professor Ewing. The separate instruments are as follows:

(1.) A Horizontal Seismograph, with clock and driving plate. The clock is started by an electric contact at the beginning of the earthquake, and the two rectangular components of the horizontal motion are registered side by side on a moving plate.

(2.) A Vertical Motion Seismograph, to register the vertical movement of the surface of the earth on the same plate.

(3.) A Duplex Pendulum Seismograph, to give independent records of the horizontal motion on a fixed plate, the pencil being free to move in all azimuths.

(4.) A chronograph attachment which is set in motion at the beginning of a shock, and records the time of its occurrence by one of the standard clocks. It also marks the clock seconds upon the revolving plate of No. 1.

A catalogue of earthquake shocks in California from 1769 to 1887 has been compiled by me, and arrangements looking to a systematic registration of such shocks in various parts of California have been made.

CORPS OF OBSERVERS.

The Regents of the University of California have taken a most liberal view of the scope of the Observatory, and have provided for a corps of observers consisting, beside myself, of Messrs. Burnham, Schaeberle, Keeler, Barnard and Hill. A machinist and two laborers will also be employed. The work which has already been done by the astronomers is the best evidence that the instruments will be assiduously and intelligently used. The work which the Observatory will undertake can also be inferred from the list of the observers. It is hoped to extend the special facilities which the Observatory affords to distinguished observers of this country and abroad who are not officially connected with the establishment.

In this sketch, which is already too long, I have been obliged to pass over many things of real importance, and to merely mention obligations of the Observatory to individuals, which ought to be set out in full.

My object in what is here written has been to show the condition of the Observatory as regards its fitness for work, leaving to the more popular accounts which have appeared in various places, the history of the successive steps by which the desolate summit of a mountain 4,300 feet high has been turned into the site of one of the most important Observatories in the world. From the inception of the plan until now, this history will reflect credit on all who have been concerned in the work. Mr. Lick made the most splendid gift of the whole world to a noble science. The successive Boards of Trustees were composed of the best citizens of the state. The President of the present Board has given the best ten years of his life to make the Observatory a success, and he has been most ably assisted.

Astronomers all over the world have given their time and their advice generously without compensation.

The Regents of the University have agreed to maintain the Observatory in the most liberal and intelligent manner. They have provided a corps of astronomers who will do credit to the opportunity afforded to them. The press and the public of California have been most friendly to the undertaking.

We have now come to the final stage where results are to be looked for, and I can promise for myself and for my colleagues that we will spare no pains nor labor in that regard.

THE PLACE OF ASTRONOMY AMONG THE SCIENCES.*

PROFESSOR SIMON NEWCOMB.

When the astronomer of to-day contemplates the works of those who have gone before him and beaten the path for his footsteps he has every reason to be proud of the noble army which he passes in review. He studies the work of Possidonius, who several years before the Christian era stated the difference in latitude between Rhodes and Alexandria in Egypt: and who determined the magnitude of the earth within a limit of accuracy which we are hardly able to esti-

* Continued from page 20, January, 1888.

mate because we do not know how long were his measures of length. He also studies the work of Hipparchus, who first applied mathematics to celestial calculations, and showed how by trigonometry the motions of the planets could be investigated.

The astronomer of to-day remembers with sympathy the works of the Arabs, who, when Christendom was involved in darkness, kept burning the light of science, dim and feeble as their light was.

He is grateful to Copernicus who first demonstrated that the earth revolves around the sun and not the sun around the earth. He is grateful to Tycho Brahe, who built an observatory on one of the Danish Islands, and made the observation with which Kepler determined his famous laws of elliptical motion, and thus paved the way for a still further advance. He sympathises with poor Galileo, who, standing before the inquisition, was compelled to abjure the doctrine that the earth revolves on its axis and goes around the sun. He remembers him not only as the expounder of the Copernican system, but as one of the mathematical physicists who first made known the laws of motions which were still further to be used in the geometry of the heavens.

Then comes Newton, who, with a grasp which no mind has ever exceeded, shows how the laws of Kepler could be traced back to the laws of gravitation. His method of calculation is, of course, very far behind his age, but no less does he consider it worthy of his study: as the great warrior or king of to-day may yet consider worthy the doings of his forefathers.

He then thinks of La Place who, with his marvelous analysis shows how the theory of gravitation not only explains the motions of the heavens as we now see them, but can trace back the consequences of gravitation through hundreds of thousands of years, and show the various changes which went through the planetary organs long before man came upon the earth.

We must not forget in this connection the painstaking men of to-day who are, after all, only working on lines which have been gradually opening up to us for 2,000 years. None of the men whose work I have passed in review lived in vain. The most striking feature in the history of astronomical research is that the work of every generation and age in astronomy has been absolutely necessary to the study of that which followed it. This is not true in any other science. The chemist has nothing to borrow from the alchemist; he rejects all the alchemist's methods and ideas. The same is true in physics. The physicists began by rejecting all the ideas of the older physicists. But it is not so in astronomy.

To illustrate how this is: Suppose that from the earliest ages the earth had been enveloped in clouds—as it is probable from the results of the most recent observations the planet Venus is enveloped. So far as we can tell it is probable that the planet Venus is entirely surrounded by clouds so dense that no part of the solid body of the planet can be seen through them; the result is that the inhabitants of that planet (if there are any) can never see the heavens. If, then, we had been so situated on this earth, then we should never have had a sight of the heavens—never have had any knowledge of the existence or motion of the planets. We could, indeed, have inferred that a luminary went around the earth and worked out day and night; we could have worked out all the laws of physical motion on the earth, so far as the earth alone is concerned. Now, supposing that having done this, and these clouds had cleared away, and showed to our view for the first time the sun, moon and planets revolving in all their majesty, what would we have thought of the blue vault of heaven? We would have said: "This azure firmament is a solid globe which encircles the earth on which we live." Thus we should have had the system of the older astronomy as the very first thing to be presented to us. Then we should have found after a time that this revolution was attended with very singular inaccuracies, with a springing motion back and forth, and that springing motion would have next engaged our attention; and the conclusion would be,—here was an epicycle, one body revolving in an orbit which is carried around the earth day by day. That would have been the Ptolemaic school. But it could not have taken us five hundred years to go a step further; the very next generation would have discovered that this exceedingly complicated epicyclic motion could be explained by the theory that the earth and these planets all revolved around the sun. But the same difficulties would have been met in receiving this theory as in the theory of Copernicus. It would have taken us a whole century even to admit it. Then, after a while, some Newton would arise to show that all phenomena are explainable by the laws of motion.

It has been sometimes said that astronomy was cultivated in the interest of astrology. I say there is no foundation in astronomical literature for any such opinion. In not one of the writings of the astronomers of antiquity or the Middle Ages have I ever found a sign of the belief of astrology. The astrologers borrowed their idea from the astronomers, and not the astronomers from the astrologers.

I have thus sought to present to you the two-fold aspect with which we may look at the scientific research of to-day. We have a literature requiring a skilled mind, and a science requiring long study, minute analysis, and all the other qualities which belong to the trained specialist; it is useful in many ways besides, in guiding the traveler on sea and land, by telling time. We have the work of astronomers as part of a great whole embodying those principles which are common to all the sciences; carrying the imagination through the universe, expanding our ideas of the world and its Creator, and calling forth our interest in generations yet unborn.

The actual, practical work of the observatory belongs, of course, to the useful class. And now, without entering into long details, it may not be inappropriate if I give a few hints respecting the details of establishments of this kind.

As you look upon our little building here, the first idea which strikes you is that it is an exceedingly modest establishment. You may, perhaps, doubt whether it will be looked upon with anything but pity by the astronomers of the world. Let me quote what was said by an eminent German. He said "The work was inversely as the magnitude of the institution. The really good work came from the small ones. The great ones did very little." (Applause.) The reason is not very far to seek. The observatory, after all, is nothing more than an instrument for the uses of a workman. If the workman is not efficient, your instrument is useless. He must not only be efficient, but must know what to do and be provided with the means and incentives to do it. It was said that a skillful observer could do better work with a spy-glass attached to a cart wheel than an unskillful one with the very best appliances. The one motto which ought to be inscribed in every scientific institution of to-day is, that there is no such thing as mediocrity in scientific work; everything you do is worthless except the best. The observer may produce very little, but whatever it is it must be the best of its kind. He must, therefore, avoid doing too many things. I would like to tell you of the work of every kind which the astronomer of to-day is waiting to have done. The reason he is waiting is not from any lack of instruments, but rather from the lack of skilled observers ready and willing to devote themselves to small fields. There have been many failures from attempting to do too much, but none in attempting too little,—providing the little is not in the quality. When we read of researches such as those of the great Herschel, we are apt, perhaps, to picture to ourselves a gentleman comfortably seated at his telescope, through which he is looking at distant sidereal systems, giving free play to his imagination as he reflects over the possible inhabitants of some heavenly sphere. As a matter of fact we should have found him at the top of a ladder, standing on a platform, exposed to the wintry blasts of heaven, and, perhaps, impatiently waiting for a passing cloud to clear away.

The actual work of making observation is but a small portion of the work of an astronomer. He has to reduce his calculations, and few men find that interesting. Then there must be much matter carefully written up for the press, and the astronomer must show in his writings that he is acquainted with the work of his predecessors in paths similar to his own. Then must follow a long and careful examination of his work to show that it is all correct before submitting it to the judgment of his colleagues.

If the public are disappointed at not seeing brilliant discoveries coming from all the observatories, we must remember that what are called discoveries are not the main work of the scientific man of to-day. It would be too much to say with confidence that the age of great discoveries in any branch of science has passed by: yet, so far as astronomy is concerned, it must be confessed that we do appear to be fast reaching the limits of our knowledge. True, there is still a great deal to learn. Every new comet that appears must be found by some one, and I do not grudge the finder the honors awarded him. At the same time, so far as we can see, one comet is so much like another that we cannot regard one as adding in any important degree to our knowledge. The result is that the work which really occupies the attention of the astronomer is less the discovery of new things than the elaboration of those already known, and the entire systemization of our knowledge. A few illustrations of this may not be out of place.

Last spring there met at the Observatory of Paris an international congress of astronomers and photographers. They met for the purpose of devising a method by which the stars of the heaven should be photographed. It may surprise you to know that of the millions of stars which are seen through the telescope we know no more individually than of the thousands of men who marched in the armies of Xerxes. They are not catalogued, and should one disappear from the heavens we should never know it. The greatest catalogue of stars yet numbers but about 30,000. With the most powerful telescope about 10,000,000 are actually visible. We see, then, that scarcely more than three per cent of the stars which can be seen belong to our knowledge. Only a small portion of them are found on the star maps, much less on the catalogue. Now, it is proposed by photographing the heavens to make a picture of the constellations as they are to-day, which shall perhaps include several millions of stars. This is a work in which it is eminently proper that the observatory should take part. But it will take very costly appliances and a whole corps of men working for many years.

The great discoverer, Sir Isaac Newton, introduced what we may call the mechanics of the heavens. Until the discovery of the spectroscope and the methods of photographing the heavenly bodies the astronomer had to work upon the same lines his predecessors had worked upon. Now the two sciences are coming together in closer and closer union. The new science of physical astronomy has been established within the last thirty years. The study of the stellar spectrum is a worthy one and quite within the reach of a very modest instrument. I inquired of a specialist in this branch the other day if it was known whether the spectrum of the star Sirius changed as it went through the various stages of light. He said nothing certain was yet known on the subject. The determination of that required a very careful observer with all the best appliances at his command, and no one as yet had devoted the necessary attention to the subject.

It is the fashion to-day to dispose very lightly of the question "*Cui bono?*" when it refers to the value of scientific appliances. We take the value of all scientific work for granted, and look with a feeling akin to compassion upon a man who even seems to question it. I cannot entirely sympathize with this sentiment. Every inquiring person should know what benefit we expect to gain from scientific research. It is one of the vices of our time to take things for granted. Undoubtedly the science of the world has paid for itself many times over even in material benefit. It lies at the bottom of our civilization. Moreover it has got to be what it is by entirely ignoring the distinction between the useful and the useless. Now, you remember about a year ago one of the distinguished orators of our country defined a university as an institution where nothing useful was taught. We must understand that in this paradox the word useful was used in the sense of the ordinary man and not in the sense of the man of science. It was used probably in the same sense in which it is used in many regions of our country, where the people see nothing useful in any study for their children beyond the three fundamental branches of reading, writing and arithmetic. What I think Mr. Lowell really meant is that a university is a place where those things which the uneducated man considers useless are taught.

Now, it must be confessed that the distinction between the useful and the useless is entirely ignored in every form of scientific research. The astronomer takes as much interest in a map of the moon as of the earth; yet the knowledge of the lunar surface may never be of any benefit to mankind. Every addition to knowledge is a point gained, no matter whether any useful application can or cannot be made from it. One of the paradoxes of science is that all the useful branches which have been gained came by following out the apparently useless. What more so than Galvani when he took the legs of a frog and showed how curiously they twitched under the actual contact with metals. Probably the men of his day thought he was simply playing; and yet, out of those little experiments have grown our science of electricity. The steam engine grew out of experiments on the boiling of a tea-kettle and the power of steam. The fact is, however, that it is impossible to say in advance whether any branch of knowledge will be useful or not. We do not know until we have found out what application may possibly be made of it. It seems almost as if nature withheld her choicest secrets from those who had only the useful in view. She seems to say, "You are investigating me in too low a state of mind. I will give my secrets only to those who investigate from a love of nature herself."

I suppose that if the pages of all our scientific literature of to-day were to be carefully scanned fifty years hence, or even if they were scanned to-day by experts in each of the separate branches, the verdict might be that only a small portion of the work they contain is really valuable knowledge. Not only does every work require a special aptitude, but one must be well acquainted with the sciences of the day in order to know what he ought to do and what to leave undone. An investigator going on unaided may obtain results already known, or hardly worth the publication. This tendency is also all the stronger because the whole spirit of modern investigation is in the highest degree a liberal one. We have no priesthood of science; we say to the world: find out all the knowledge you can, and publish it if you can; all that we ask for is the right to reject it if we find nothing at all in it; but we do not wish to dampen any future efforts of the kind.

The knowledge of the littleness of our place in the universe has done more for mankind, has been better for us, than any gratification of our material wants. A few centuries ago the appearance of a comet struck every one with terror; in the simple thought that we now look upon the celestial visitor with no feeling but admiration for its beauty, we have something which more than compensates for all the money and labor we have expended upon observatories and instruments. Are you not thankful to the astronomers that we have a better idea of our place in the universe? There are other indirect benefits: as in every large city we open public squares and parks where the poor of the community may enjoy the fresh air of heaven, so it is good in the busy competition of our business life to have some moral breathing places which shall be free from those taints which affect this struggle for existence. He who enters an observatory or a museum finds an establishment all the attributes of which are placed freely there for him, without price placed at the disposal of mankind. Men like Agassiz and Faraday and Joseph Henry were animated with a love for nature for her own sake—they did not care for the honor of being known as inventors, they never applied for a patent for any of their discoveries, they made no restriction of their use, they had no other motive than that of helping the world.

I have thus sought in my imperfect way to show you a few of the aspirations which animate the astronomer. The motto which he may well recite is:

> "What need my Shakespeare for his honor'd bones
> The labor of an age in piled stones;
> Or that his hallowed reliques should be hid
> Under a starry-pointed pyramid?
> Thou in our wonder and astonishment
> Hath built thyself a lasting monument.

We can say with Horace, "Here is a monument more enduring than bronze."

A NOTE ON THE DISTRIBUTION OF THE STARS.*

W. H. S. MONCK, DUBLIN.

For the MESSENGER.

Having thus noted the mode of departure from uniformity as regards star magnitudes, I tried to ascertain the direction of the departure as regards right ascensions. I used the Harvard catalogue only for this purpose, the Oxford one being arranged in a manner inconvenient for the purpose. Treating the Harvard catalogue as complete up to magnitude 5.9 I found that the number of stars brighter than that magnitude were thus estimated in R. A. (from the North Pole to latitude 30° S.):

* Continued from page 25, January, 1888.

Limits.	No. Stars.	Limits.	No. Stars.
0h to 1h	108	12h to 13h	86
1h to 2h	116	13h to 14h	94
2h to 3h	115	14h to 15h	97
3h to 4h	147	15h to 16h	122
4h to 5h	169	16h to 17h	113
5h to 6h	174	17h to 18h	116
6h to 7h	159	18h to 19h	158
7h to 8h	132	19h to 20h	160
8h to 9h	106	20h to 21h	128
9h to 10h	91	21h to 22h	131
10h to 11h	84	22h to 23h	129
11h to 12h	89	23h to 24h	115

The influence of the Galaxy is here at once apparent. If the Galaxy was a band of uniform thickness the portion of it comprised in any hour of right ascension would be greatest at the points where it cuts the equator, and would then gradually diminish until it reached its greatest northern or southern declination, after which it would increase again. The influence of the Galaxy would therefore be most perceptible at the points where it meets the equator, and least so at distances of 6*h* in R. A. from these points. But as the Harvard catalogue does not include stars with a greater southern declination than 30°, the most southerly portions of the Galaxy are excluded from the list, and hence the minimum at this point falls much below the minimum corresponding to the greatest northern declination of the Galaxy. This minimum, in fact, gives what I may call the non-gallactic average, which seems to be about 87 stars above the 5.9th magnitude for each hour of right ascension. The excess of other hours over this appears to be due to the galaxy.

This enables me to make a rough estimate of the degree of comparative density of stars of this magnitude inside and outside of the limits of the Galaxy. At 87 stars for each hour of R. A., the total number of stars would be 2,088. The entire number in the table is 2,936, showing an excess of 848 due to the Galaxy. If we assume that the Galaxy covers one-tenth of the portion of the heavens included in the catalogue (which of course is only a rough estimate), the non-gallactic mean would give 209, while the actual number seems to be $209 + 848 = 1,057$. According to this estimate stars whose brightness exceeds 5.9 are about five times as numerous in the direction of the Galaxy as elsewhere.

The force of gravity varying like light according to the inverse square of the distance, and the light which we receive from the stars comprised in any subdivision constantly increasing (at least up to the 5.9th magnitude), it seems reasonable to infer that the sun is probably not under the gravitational control of a small number of comparatively near stars, but of a great number of fainter ones. Since the stars between 4.8 and 4.9 give us more light on the whole than those between 1.8 and 1.9 (as is proved by their relative numbers), it seems probable that we are also more influenced by their attraction. And the great excess of stars in the Galaxy I think indicates that if the sun is moving round a centre, that centre must be sought for somewhere in the Galaxy. The point towards which the sun is moving is approximately known, and if we could assume that the orbit is nearly circular, we would find for its centre two alternative points in the Galaxy both distant by 90° from the point in Hercules towards which the sun is moving. And if one of these points was situated in an unusually thin, and the other in an unusually dense, portion of the Galaxy, there would be some reason to think that the latter contained the true centre of the solar system. But that the sun's orbit is nearly circular is an assumption for which there is very little evidence. Among the measured double stars eccentric orbits preponderate, and the great differences in the proper motions of stars whose distances from the common centre (if there be one) cannot be very different, renders the prevalence of circular orbits round this common centre improbable. Our own visitors from exterior space (if such they be), the comets and meteors, usually describe very eccentric orbits round our sun. The centre of the solar system, moreover, may not improbably lie in the rich southern portion of the Galaxy which is not embraced in the Harvard catalogue.

The following seems to me the most probable explanation of the facts respecting star distribution which have been enumerated. The nearer stars are non-gallactic, though some of them no doubt lie in the direction of the Galaxy. These non-gallactic stars are pretty equally distributed over the sky. Some of the gallactic stars, however, owing to their great masses and high temperatures, become confounded, even from the first, with the nearer non-gallactic stars. As we descend in the scale of magnitudes the gallactic intruders become more and more numerous until at last we reach the average magnitude of the nearer gallactic stars, and may consider ourselves as dealing with the surface of a sphere which cuts into the Galaxy itself. At this point it is probable that the density of the stars ceases to increase, and that their distribution for some distance further accords pretty nearly with the law of uniformity; after which we begin to cut through the Galaxy in parts, and to reach a region beyond it where the density of the stars again diminishes. I think it is certain that the light of all the stars from the zero of the scale up to the 200th magnitude is not ten times as great as that of all the stars from zero to the 20th magnitude; but this may be due to some medium in space (perhaps dense flights of meteors) which intercepts or absorbs a sensible portion of the light of very distant stars. If no light is lost, even what I call the non-gallactic average cannot be maintained to infinity; but it seems likely that photometry has hitherto merely grazed the outer limits of the Galaxy, and that when it is carried two or three magnitudes lower what I have called the gallactic average will be found to have been exceeded.

In conclusion I may remark that the law as to the number of stars in R. A. will in this instance (and I believe in all other cases) become more apparent by taking the hours in pairs at distances of twelve hours from each other. The figures arrived at by this process are as follows:

Limits.	No. of Stars.
0h to 1h and 12h to 13h	(Minimum) 196
1h to 2h and 13h to 14h	210
2h to 3h and 14h to 15h	212
3h to 4h and 15h to 16h	269
4h to 5h and 16h to 17h	282
5h to 6h and 17h to 18h	290
6h to 7h and 18h to 19h	(Maximum) 317
7h to 8h and 19h to 20h	292
8h to 9h and 20h to 21h	236
9h to 10h and 21h to 22h	222
10h to 11h and 22h to 23h	213
11h to 12h and 23h to 24h	201

NOTE.—If we can rely on Argelander's catalogue as based on the ratio of 2.512 for each magnitude, the increasing density of the stars continues down to at least those of the 9th magnitude. The figures given by Sir Robert Ball in his "Elements of Astronomy" from Argelander are as follows: 1st magnitude, 20 stars; 2d, 65; 3d, 190; 4th, 425; 5th, 1,100; 6th, 3,200; 7th, 13,000; 8th, 40,000, and 9th, 142,000. The theoretic value of 2.512 is here exceeded in every instance save that of the stars of the 3d and 4th magnitudes; but neither the Harvard nor the Oxford catalogue sustains this exception.

The maximum interval here contains the two intersections of the Galaxy with the equator, and the minimum interval contains the poles of the Galaxy. Both increase and decrease are continuous, though the rate varies.

STANDARD DIMENSIONS IN ASTRONOMICAL AND PHYSICAL INSTRUMENTS.*

BY J. A. BRASHEAR, ALLEGHENY, PA.

In a paper read before the Franklin Institute by Mr. George M. Bond, the present secretary of Section D., the following words were quoted from Mr. Forney's report to the Master Car Builders' Association, on standard bolts and nuts:

"It is worthy of note that a remedy for the evil complained of by the Master Car Builders, that nuts, made by some firms, would not screw on bolts made by other firms, at first baffled the ability of the most prominent manufacturers of tools in the country, and to provide an adequate remedy it was necessary to secure the assistance of the highest scientific ability in the country, which was supplied through the co-operation of the professor of astronomy of the oldest and most noted institution of learning in the land. The man of science turned his attention from the planets and the measurments counted by millions of miles, to listen to the imprecation perhaps of the humble car repairer, lying on his back and swearing because a ⅝ nut a trifle small would not screw on a bolt a trifle large."

We all know this professor of astronomy and the noble work he has done in the way of giving us standards of the highest accuracy, which in turn have been carried out into practical mechanism by some of the honored members of the American Association, especially by Mr. Bond of the mechanical section.

Paradoxical as it may seem, though the astronomer has furnished the most accurate standards for the mechanician, thus facilitating the construction of interchangeable machinery all over the world, the astronomer himself has yet to put

*From the Proceedings of the American Association for the Advancement of Science, Vol. XXXVI.

up with an eye-piece that is just a little too large for a sliding tube that is just a little too small; or, in other words, that branch of science, which has furnished the standard for all other work, is without any standard for the construction of its own instruments.

How many of the parts of an astronomical or physical instrument should be made interchangeable, I am not now willing to say, but every worker with the telescope, spectroscope, or other instrument for physical research, will bear me out in this fact: that there is a sore need of standard dimensions in many of the parts of our apparatus. Indeed, our President, Professor Langley, was one of the very first to call my attention to the matter, and suggested that it would be a very excellent plan for the Association to appoint a committee to discuss, and, if possible, decide upon some standard dimensions of the more important parts which should at the earliest date be made interchangeable. I might urge many reasons in support of standard dimensions in many of the parts of our astronomical and physical instruments, but it is not necessary, as the day has passed when we are satisfied with anything but interchangeable parts in modern machinery; therefore we should not be satisfied with anything less for our astronomical and physical instruments.

As an illustration of what is needed, I have constructed four spectroscopes within the past year for six-inch aperture telescopes. The diameter of the tail piece of these telescopes has varied from two and one-half inches to six inches, requiring a new pattern to be made for every clamp that holds the spectroscope to the telescope.

We have indeed only to look at the great variety of eye-pieces and their varied diameters for which we are constantly called upon to make adapters, so that they may be used with any degree of pleasure, to see how far we are from the ideal astronomical or physical instrument. We shall, in all probability, have to call to our assistace the "mandrel drawn" tube makers to give us standard tubes; and perhaps the founder to give us a standard metal, but we should make a move in the matter, and everything will come out right. These very mechanicians, to whom the astronomer has furnished the data, have given us standard reamers, standard guages, and every facility for making our own work standard, and so we are without a subterfuge, without a valid excuse for doing our work in a "haphazard" way.

I should hope that whatever parts of our instrument we make of standard dimensions, that the basis should be a decimal system, preferably the metric; indeed, is it not possible that these standards might be made international as they should most surely be? The greater then the value of the metric basis.

This paper is only suggestive, but I trust will serve to call attention to a fault in the construction of our apparatus that is not in accord with the progress in other lines of mechanical art.

FIRST OBSERVATIONS OF SATURN WITH THE 36-INCH EQUATORIAL OF LICK OBSERVATORY.

BY JAMES E. KEELER.

For the MESSENGER.

The great telescope of the Lick Observatory was first directed to the heavens from its permanent home, on the summit of Mt. Hamilton, on the evening of January 3, 1888. A few observations of stars were then made for the partial adjustment of the object-glass, but rapidly thickening clouds prevented anything like a satisfactory test of its qualities. The next clear night was on the 7th, but the dome could not be turned, as the non-congealing solution, which will fill its "liquid seal," has not yet been provided, and everything had been frozen solid by a week of severe weather. It was consequently possible to observe an object only during its passage across the slit, but as this is sufficiently wide for half an hour's steady observation, no inconvenience was felt beyond the necessity of a little waiting.

Captain Floyd, Mr. Alvan G. Clark, Mr. Ambrose Swasey and myself were present at the trial. We observed a number of bright stars and doubles as they crossed the opening, and at about nine o'clock, the great nebula in Orion. Here the great light-gathering power of the object-glass was strikingly apparent. Only the central part of the nebula could be seen in widest field which could be used (power 312), but months would have been required to record satisfactorily all the intricate details which were there brought to view.

The opening in the dome was directed a little toward the east of south. The definition had been steadily improving, and when Saturn passed across the slit at a high altitude and entered the field of the eye-piece he presented probably the most glorious telescopic spectacle ever beheld. Not only was he shining with the brilliancy due to the great size of the objective, but the minutest details of his surface were visible with wonderful distinctness. Most of these I had repeatedly seen before with smaller instruments, but merely seeing an object, when every nerve is strained, and even then with half a doubt as to its reality, is very different from seeing the same object glowing with abundance of light and visible at the first glance.

How greatly the beauty of the view, even as a spectacle, depends upon sharpness of definition, was strikingly shown two nights later, when, although the sky was remarkably clear, the seeing was bad, and the view of Saturn was disappointing even to novices, the brilliancy of the image not compensating for its blurred and indistinct appearance.

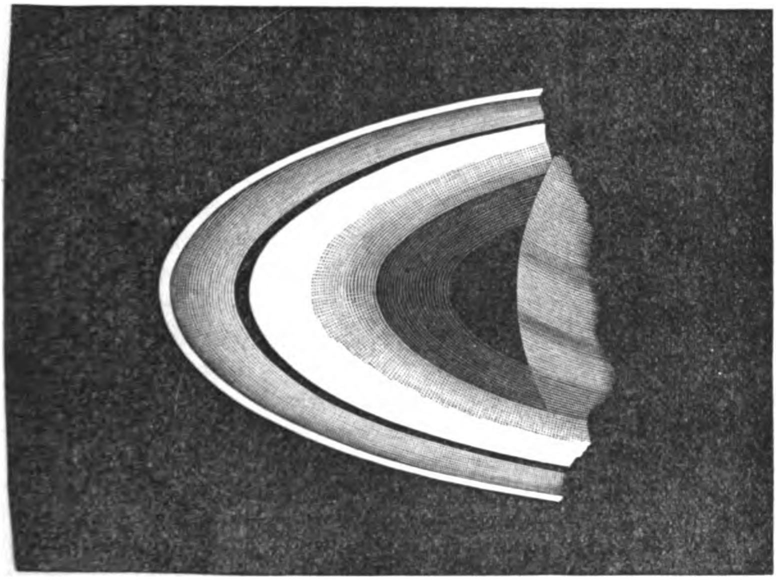
After each of our party had taken his turn at the eye-piece, there remained some time for a more careful study of the details.

The outlines of the rings with a power of 1,000 were very sharply defined. The inner edge of the inner ring did not shade off gradually into the guage ring as often represented, although its brightness was there much diminished, but the line of separation was distinct, and I even thought that it was marked by a fine black division. The great aperture of the object glass brought out the guage ring with remarkable distinctness: It appeared uniform in tint, without spots or markings of any kind. Between its inner edge and the planet the background was perfectly dark.

The inner ring appeared as usual, with a shading increasing in depth toward its inner edge, suggesting an annular concentric structure, although presenting no definite markings.

The object of greatest interest to me was the outer ring. It is usually drawn with a division at about one-third of its width from the outer edge, sometimes fine and sharp and sometimes broad and indefinite. Many drawings which I have examined place this line or shade near the centre of the ring. In a series of drawings which I made with the 12-inch equatorial of this observatory, from a careful study of Saturn during the finest nights of the past summer, the outer ring is represented with a faint broad shading in the centre, diminishing gradually toward the edges, which are therefore relatively bright.

The 36-inch equatorial showed, at a little less than one-fifth of the width of the ring from its outer edge, a fine but



SATURN'S RINGS AS SEEN WITH THE THIRTY-SIX-INCH EQUATORIAL, Lick Observatory, Jan. 7, 1888.

distinct dark line, a mere spider's thread, which could be traced along the ring nearly to a point opposite the limb of the planet. This line marked the beginning of a dark shade which extended inward, diminishing in intensity, nearly to the great black division. At its inner edge the ring was of nearly the same brightness as outside the fine division. No other markings were visible.

It is easy to see how, with insufficient optical power, this system of shading could present the appearance of an indistinct line at about one third the width of the ring from its outer edge. The broad band alone would make it appear near the centre of the ring, and the effect of the fine line, itself invisible, would be to displace the greatest apparent depth of shade in the direction of the outer edge. Two nights after the observations just described I re-examined Saturn very carefully with the 12-inch equatorial, but could not perceive the narrow line, although I was then aware of its existence, and the definition was excellent. The appearance of the outer ring was exactly as represented in my earlier drawings. While I would not assert that the present structure of the ring as seen with the great telescope has existed for any great length of time, and has eluded the grasp of smaller instruments, I am confident that there has been no change during the past year.

There was no irregularity in the outline of the shadow of the planet projected on the rings, although Saturn was so nearly in opposition that the shadow was very narrow, and this peculiarity could not be so well noted as at other times. I have often noticed the distortion of Saturn's shadow when observing with the 12-inch equatorial, with a low power or on a poor night, but it always disappeared on employing a sufficiently high power, or with improvement in the definition. I have never been able to convince myself that it is anything more than a purely optical phenomenon.

The instrumental means at command on Mt. Hamilton have given me an excellent opportunity for testing the comparative efficiency of large and small telescopes under identical circumstances. The observatory possesses three equatorials, with object glasses of 6½, 12 and 36 inches clear aperture, all of Alvan Clark and Sons' best make. Objections have justly been made to the use of different apertures on the same telescope, and to comparisons of different telescopes when not made by the same person. My own eyesight is far from being acute, and I would not compare my observations with those of another person using even a much smaller instrument, but conclusions drawn from experiments made by the same observer, under the same circumstances, with instruments of the highest degree of excellence, differing only in size, are certainly valid. According to my experience, there is a direct gain in power with increase of aperture. The 12-inch equatorial brings to view objects entirely beyond the reach of the 6½-inch telescope, and details almost beyond perception with the 12-inch are visible at a glance with the

36-inch equatorial. The satellite of Neptune is to me always a difficult object with the 12-inch telescope, but it was very conspicuous with the great equatorial on the night of Jan. 9th, and if there had been another satellite of only one fourth or one fifth the brightness of the one already known, it could not have escaped detection. The great telescope is equal in defining power to the smaller ones, and has in addition the immense advantage of greater light-gathering power, due to its superior aperture.

Of course great size carries with it certain disadvantages. The telescope cannot be turned rapidly from one part of the sky to another, and observing is necessarily slow work, even with the most perfect mechanical appliances. It can however be employed on the work for which it is best suited, work entirely beyond the power of small instruments, while for these will remain fields of labor in which they will never be superseded by large ones.

FOR STUDENTS AND YOUNG OBSERVERS.

Interesting Phenomena for February.

Mercury is in the constellation of Pisces during most of the month of February. On the 13th at 4 o'clock in the morning it will be in conjunction with the moon; on the 16th it will be in perihelion, and at 3 o'clock on the morning of the 17th it will be in greatest eastern elongation from the sun, its distance being 18°7′. The planet will not be in favorable position for naked eye observation, because so far in south declination. If clear to the horizon, it may however be seen for a few minutes near the time of the date last mentioned above.

Venus is in Saggitarius, near the star Pi, on the 16th. It is still very brilliant. During the last two months this planet has been unusually conspicuous in the southeast during early morning hours. Its great brightness has led many people to think that it was the Star of Bethlehem, so called, chiefly because some popular journals have been persistently claiming that such a star was now visible, and that it could be seen in the eastern morning sky. To persons unacquainted with the face of the sky, it may be said, that there is now no unusual star visible, and that astronomers do not know anything about the Star of Bethlehem. The phenomena given in the New Testament, which no one disputes, have, however, never been satisfactorily explained on scientific grounds, for the probable reason that they were miraculous.

Venus will be in conjunction with the moon February 8th, and will enter the descending node February 27th.

Mars is among the small stars of Libra, a few degrees northwest of the star Kappa. He will be in conjunction with the moon February 2d, being at that time 2°51′ south.

The Minor Planets now number 271, the last being discovered by Knorre of Berlin October 16th. A charming little book giving full information about the minor planets has just been published by the J. B. Lippincott Publishing Company of Philadelphia, written by Professor Daniel Kirkwood of Bloomington, Ind. Notice of it elsewhere is more fully given. Since this book was published two of the recently discovered asteroids have been named: No. 268 is Adorea; 270 is Anahita. Nos. 269 and 271 are yet without names.

Jupiter is south and east of Beta Scorpii, and will move eastward during the month less than three degrees in right ascension. He will be in conjunction with the moon February 5th, being then 4°2′ south. The planet reaches quadrature, *i. e.* ninety degrees from the sun in right ascension, February 23d. Its apparent diameter is steadily increasing because the earth is approaching the planet, which will continue to be the case until the middle of the month of June, after which time the earth will pass by it and leave it behind.

Saturn is, for this month, a beautiful object for early evening observation. It is in the constellation of Cancer and makes nearly a right triangle with Pollux and Procyon. It slowly retrogrades during the month, and comes to opposition with the moon February 24th, being 1°22′ south. Readers of the MESSENGER will especially enjoy Profesor Keeler's article in this number which gives detailed view of the great planet as seen through the 36-inch lens of the Lick Observatory.

Uranus is near Mars, being half a degree eastward and one degree north. Its motion is westward and northward. It will be in conjunction with the moon February 1st, the planet being then 4°29′ south.

Neptune is in Taurus, almost directly south of the Pleiades about six degrees. Its motion is slowly north and east. It reaches the point of quadrature with the sun February 15th.

The following table will also assist those who have small telescopes, and wish to know of the positions and motions of the planets for the month of February:

	R. A.	Decl.	Rises.	Transits.	Sets.
	H. M.		H. M.	H. M.	H. M.
MERCURY.					
February 5	22 08.0	−12°47′	7 66 A. M.	1 06.4 P. M.	6 17 P. M.
February 15	23 02.0	− 5 20	7 40 "	1 21.2 "	7 02 "
February 25	23 14.6	− 1 26	6 58 "	0 54.4 "	6 50 "
NEPTUNE.					
February 5	3 41.6	+17 54	11 24 A. M.	6 39.2 P. M.	1 55 A. M.
February 15	3 41.6	+17 55	10 44 "	5 59.9 "	1 16 "
February 25	3 42.0	+17 57	10 05 "	5 20.9 "	12 37 "
SATURN.					
February 5	8 17.5	+20 14	3 48 P. M.	11 14.3 P. M.	6 41 A. M.
February 15	8 14.4	+20 25	3 04 "	10 31.9 "	5 59 "
February 25	8 11.8	+20 34	2 22 "	9 50.0 "	5 18 "
URANUS.					
February 5	13 04.2	− 6 06	10 23 P. M.	4 00.2 A. M.	9 38 A. M.
February 15	13 03.5	− 6 02	9 42 "	3 20.2 "	8 58 "
February 25	13 02.6	− 5 56	9 02 "	2 40.0 "	8 18 "
MARS.					
February 5	13 41.2	− 7 51	11 06 P. M.	4 37.2 A. M.	10 08 A. M.
February 15	13 49.9	− 8 34	10 39 "	4 06.7 "	9 34 "
February 25	13 55.1	− 8 58	10 06 "	3 32.4 "	8 58 "
JUPITER.					
February 6	16 05.8	−19 56	2 24 A. M.	7 01.8 A. M.	11 40 A. M.
February 16	16 10.6	−20 08	1 50 "	6 27.2 "	11 05 "
February 26	16 14.4	−20 17	1 15 "	5 51.6 "	10 28 "
VENUS.					
February 6	18 38.3	−21 56	5 05 A. M.	9 33.5 A. M.	2 02 P. M.
February 16	19 30.3	−21 10	5 14 "	9 46.1 "	2 18 "
February 26	20 21.6	−19 22	5 17 "	9 57.8 "	2 39 "

Partial Eclipse of the Sun. A partial eclipse of the sun will take place on February 11, but will be visible only in regions south of 30° south latitude. Magnitude of greatest eclipse = 0.502 (sun's diameter = 1).

OCCULTATIONS VISIBLE AT WASHINGTON.

Date.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean Time.	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. 4	γ Libræ	4½	14 28	171	15 03	236	0 35
24	θ Cancri	5½	6 54	89	8 11	283	1 18
25	ψ Leonis	6	15 40	127	16 36	273	0 56

PHASES OF THE MOON.

		Central Time. H. M.
Last Quarter	February 4,	1 25.7 P. M.
New Moon	February 11,	5 52.4 "
First Quarter	February 19,	7 59.2 "
Full Moon	February 27,	5 57.6 A. M.

MINIMA OF ALGOL (β Persei; R. A. 3h 01m, Decl. +40°31′).

	Central Time. D.	H. M.		Central Time. D.	H. M.
February	4	1 52 A. M.	February	18	9 57 A. M.
	6	10 41 P. M.		21	6 46 "
	9	7 30 "		24	3 35 "
	12	4 19 "		27	0 24 "
	15	1 08 "		29	9 12 P. M.

GREAT RED SPOT ON JUPITER—TIMES WHEN ITS ZERO MERIDIAN PASSES THE CENTRE OF JUPITER'S DISK.

	D.	Central Time. H. M.		D.	Central Time. H. M.		D.	Central Time. H. M.
Feb.	2	6 44.5 A. M.	Feb.	12	5 01.4 A. M.	Feb.	22	3 17.9 A. M.
	3	2 35.9 "		13	0 52.8 "		22	11 09.3 P. M.
	4	8 23.0 "		14	6 39.9 "		24	4 56.3 A. M.
	5	4 14.4 "		15	2 31.3 "		25	0 47.6 "
	6	0 05.9 "		16	8 18.3 "		26	6 34.7 "
	7	5 53.0 "		17	4 09.7 "		27	2 26.0 "
	8	1 44.4 "		18	0 01.1 "		28	8 13.1 "
	9	7 31.5 "		19	5 48.2 "		29	4 04.4 "
	10	3 22.9 "		20	1 39.5 "		29	11 55.7 P. M.
	10	11 14.3 P. M.		21	7 26.6 "	March	2	5 42.7 A. M.

PHENOMENA OF JUPITER'S SATELLITES.

	Central Time. D.	H. M.			Central Time. D.	H. M.	
February	4	3 26 A. M.	I Ec. Dis.	February	19	5 37 A. M.	I Tr. In.
		6 47 "	I Oc. Re.		20	1 42 "	I Ec. Dis.
	5	2 48 "	I Sh. Eg.			5 07 "	I Oc. Re.
		3 11 "	II Sh. In.		21	2 17 "	I Tr. Eg.
		4 00 "	I Tr. Eg.			2 48 "	II Ec. Dis.
		5 33 "	II Tr. In.		23	2 37 "	II Tr. Eg.
		5 41 "	II Sh. Eg.		25	1 51 "	III Ec. Dis.
	7	3 38 "	III Sh. In.			3 24 "	III Ec. Re.
		5 24 "	III Sh. Eg.			6 53 "	III Oc. Dis.
	12	2 28 "	I Sh. In.		27	3 35 "	I Ec. Dis.
		3 43 "	I Tr. In.		28	1 58 "	I Tr. In.
		4 40 "	I Sh. Eg.			2 55 "	I Sh. Eg.
		5 47 "	II Sh. In.			4 10 "	I Tr. Eg.
		5 55 "	I Tr. Eg.			5 21 "	II Ec. Dis.
	13	3 12 "	I Oc. Re.		29	1 28 "	I Oc. Re.
	14	5 06 "	II Oc. Re.	March	1	2 45 "	II Sh. Eg.
	18	2 52 "	III Oc. Dis.			2 45 "	II Tr. In.
		4 29 "	III Oc. Re.			5 12 "	II Tr. Eg.
	19	4 21 "	I Sh. In.				

THE CONSTELLATIONS.

At 8 P. M. in the middle of February the vernal equinox is very near the western horizon. There is no bright star at this point. If we draw a line from the north pole to the vernal equinox it will pass very near to five bright stars: Polaris the pole star, γ Cephei, β Cassiopeiæ, α Andromedæ and γ Pegasi. This line is the equinoctial colure or first meridian from which the right ascensions of all stars are reckoned. The last two stars mentioned form the east side of the Square of Pegasus. Passing up toward the zenith from the Square of Pegasus one may trace the constellations Andromeda, Perseus and Auriga, the brightest star, Capella, of the last having just passed the meridian. Starting again with the west horizon, one may trace an irregular line of faint stars toward the east, along the equator for about 30°, to one a little brighter than the rest, then turning an acute angle and extending toward the north point as far as β Andromedæ. This V-shaped constellation is Pisces, The Fishes.

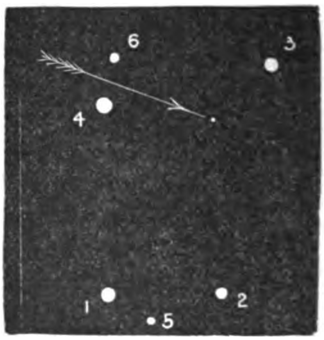
About 5° to the southeast from the point of the V, is Mira, o Ceti, the wonderful variable which, during most of the time, is invisible to the naked eye, but at intervals of about eleven months shines forth with the brilliancy of a star of the second or third magnitude. It is on the average about forty days from the time it becomes visible to the naked eye until it attains its greatest brightness, and it then requires about two months to become invisible. The next maximum will occur about the last of September 1888, although the period is so irregular that the exact date cannot be predicted. The minimum will occur in June. Passing east along the equator we may trace Aries, Taurus, with its two familiar groups the Hyades and Pleiades, Gemini, Cancer, with the planet Saturn, and Leo, the last extending nearly half way from horizon to zenith and marked by the bright star Regulus and the well-known group of the Sickle. On the meridian toward the south stands Orion, rich in objects for telescopes of moderate power. The great nebula in the middle of the dagger is in its best position to be observed. To the east from Orion are the two Dogs, Canes Minor and Major, and between them the One-horned Horse, Monoceros. Toward the north one may see the two Bears, the Dragon, Cepheus and Cassiopeia.

Studies of the stars with the opera glass, and methods of drawing the planets, Jupiter and Saturn, will be given next time.

EDITORIAL NOTES.

We are disappointed, and we are sure that President Holden will be also, in not seeing the leading article in this number illustrated by half a dozen fine cuts of the buildings and instruments of Lick Observatory. He certainly did his part in procuring the engravings, and THE MESSENGER waited ten days for them after they were due. They have not yet reached us. They may be somewhere in the snow drifts of Dakota, or possibly lost under those Northern Pacific banana trees of Montana, that we sometimes hear about. We have also had some apprehensions about this number of THE MESSENGER, coming, as it does, out of a cold wave, that sank us to 46½° below zero, by signal service reckoning in this latitude, lest it should go to our readers trimmed with icicles, or in the halo of thick ice fog.

Clark's New Star in the Trapezium of Orion. Mr. Keeler, of the Lick Observatory, kindly remembers THE MESSENGER with prompt notice of the first known discovery, by the aid of the great 36-inch equatorial. While Alvan G. Clark, was observing the Trapezium of Orion during first trial of instrument last month at Mt. Hamilton, he found an *exceedingly* faint star whose position is shown by the arrow in the above drawing. It was also seen, at the same time, by Mr. Keeler and Mr. Swasey, of Cleveland.



Saturn in the Great Lick Telescope. We give elsewhere, by the kindness of Mr. Keeler, the first view of Saturn, as seen through the great 36-inch lens of the Lick Observatory, at Mt. Hamliton, California, during the early days of last month. The fine drawing of the rings of Saturn furnished us by Mr. Keeler could not be reproduced in its delicate shading, by any procsss within reach, but that of lithographing. Our figure is only an approach in detail. The exquisite finish of the gauge ring to definite inner outline, and the delicate changes of light and the faint traces of line divisions on the surface of the outer rings are the work of an artist's pencil rather than the possible effects of a well guided ruling machine. The drawing referred to represents a magnificent view of the Saturnian rings.

The Olbers Brooks' Comet. I send herewith three views of the above named comet selected from a number of sketches made at the eye-piece of the nine-inch reflector. Figure 1 shows its appearance on the morning of August 29, four days after my discovery of the comet. It was considerably brighter in appearance and the short bushy tail more pronounced. The nucleus was exceedingly diffused. Figure 2 shows the comet's appearance September 17, and a marked change in its form is noticeable.

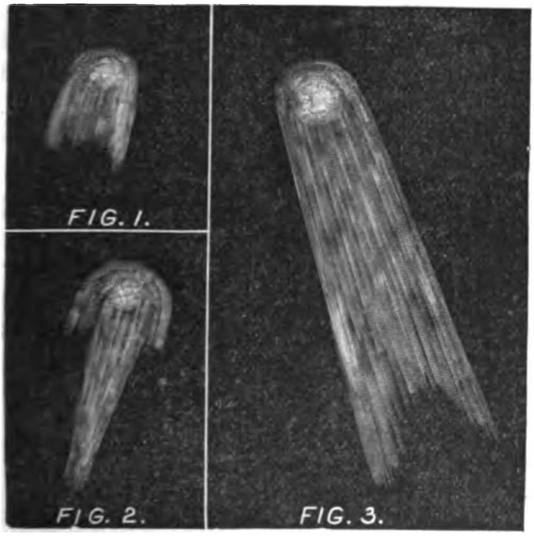


Fig. 3 gives its appearance on the morning of October 14th, about one week after the comet had made its perihelion passage, and was probably about at its brightest at this time. WILLIAM R. BROOKS.

Red House Observatory, Phelps, N. Y., Dec., 1887.

The above note should have appeared last month; it was accidentally passed in arranging for a form already late.

Professor Holden, as Associate Member of the Royal Astronomical Society. My attention has been called to a sentence in a letter from Mr. Richard A. Proctor published in your issue for September last which I would desire to correct as being seriously unjust to Prof. Holden.

On page 261, Mr. Proctor says: "Prof. Holden owes it entirely to me that his name when suggested for a Foreign Associateship of the Society (*i. e.* the Royal Astronomical Society) was not rejected with contempt." As Mr. Proctor's remark conveys such an absolutely erroneous impression, I would solicit the favor of a little space to point out the facts of the case.

On 1884 May 9, Prof. Holden was nominated by the Council of the Royal Astronomical Society for election as Foreign Associate, and his certificate bears the signatures of *eleven* members of the Council, including the names of some most eminent in British astronomy.

Mr. Proctor had not been a member of the Council since February 1879, more than five years before.

On 1884 November 14, Prof. Holden was balloted for by the Fellows, and duly elected. It does not appear that Mr. Proctor was present on that occasion.

In selecting Prof. Holden for the Foreign Associateship, the Council desired to honor a distinguished American astronomer, and it is beyond question that that selection, and his subsequent election by the Society, could not in the remotest manner be considered as due to Mr. Proctor.

Royal Astronomical Society, EDW'D B. KNOBEL,
Burlington House, 1887, Dec. 17. Sec'y R. A. S.

Unjust to Professor Holden. We have also received a private letter from another prominent member and late officer of the Royal Astronomical Society, confirming in general way, the statements made in the above communication from Secretary Knobel. We hasten to mention these things in simple justice to Professor Holden, and to say that we were greatly surprised at the contents of these letters, and cannot now see, for the life of us, how it is possible for a man of Professor Proctor's intelligence and minute acquaintance with the active life of the Royal Astronomical Society to be ignorantly mistaken regarding the facts of Professor Holden's election. It is equally hard to believe that Professor Proctor could carelessly and confidently misconstrue the plain facts in so severe a criticism. In the light of these recent letters THE MESSENGER greatly regrets the publication of what now seems to be both untrue and unjust to Professor Holden regarding his Foreign Associateship to the Royal Astronomical Society.

Professor W. Tempel. We were pained to learn from a private letter of Assistant C. W. Dunn, in the observatory at Florence, Italy, of the recent serious illness of Professor W. Tempel. Later news brings the cheering report that he is somewhat better, though still able to do only a little astronomical work. Friends are apprehensive that recovery at best may be slow.

The Star of Bethlehem. So good a paper as the New York *Evangelist* should read the stars in the sky rightly. Under date of Dec. 22 appears the following note:

> The "Star of Bethlehem," so called from its being coincident with the beginning of the Christian era, is at present visible any clear morning from about half past four. Its brilliancy far exceeds that of any other star. Its last appearance was several hundred years ago, and it will rapidly recede from the earth, not to be visible again for 340 years. Its light is so powerful that even after the sun has passed the horizon it can be seen. Look to the east.

The beautiful star referred to above was undoubtedly the planet Venus, which was at its brightest during the month of December, and to be seen in the south eastern part of the sky in the morning. Near this date it was visible in clear Minnesota skies all day. As for the Star of Bethlehem, astronomy claims to have no knowledge. The latest study of the Christian astronomer leads to the belief that the wonderful star-like appearance at the birth of Christ was a phenomenon wholly miraculous.

Preparations for Photographing the Sky. At a recent session of the Academy of Sciences at Paris, Admiral Mouchez gave the following report concerning the preparations which are being made for the execution of a chart of the heavens by photography:

"The preliminary researches and experiments are being made by the savants who were willing to take them in charge, and I have already received information that ten photographic telescopes conforming to the model of that of Paris, adopted by the congress, are actually in construction. They will all be finished next year or a little later, at the beginning of 1889.

"Here is a list of the observatories to which these telescopes are destined:

FRANCE—Observatory of Toulouse, Observatory of Bordeaux, Observatory of Alger.

SPAIN—Observatory of San Fernando.

BRAZIL—Observatory of Rio de Janeiro.

ARGENTINE REPUBLIC—Observatory of La Plata.

CHILI—Observatory of Santiago.

MEXICO—Observatory of Tacubaya.

AUSTRALIA—Observatory of Sydney, Observatory of Melbourne.

"The first seven are being constructed by the Messrs. Henry, for the optical parts, and Gautier for the mechanical parts; the last three by Mr. Grubb.

"It is possible that other instruments are in construction by other makers, but I have not been informed of any.

"We can count certainly on the coöperation of one or two observatories in England and upon the establishment, at least temporarily, of a photographic observatory in New Zealand, in accordance with the view expressed by the Congress. We can count also on the observatory of the Cape of Good Hope, whose eminent and active director, Dr. Gill, has contributed so much to the progress of celestial photography.

"I have equally good hopes in Russia; the concurrence of its observatory of Poulkova, because of its northern latitude, will be very desirable.

"I have received no news from Italy, Austria or Germany.

"In the United States several observatories seem to desire to take part in the work; but, as yet, I have not received any word of the order of a special instrument. The observatory of Washington will, without doubt be provided.

"We are to-day perfectly certain of being able to begin active work upon the chart of the sky in 1889, with a number of observatories already sufficient to undertake and finish, within the prescribed limits of time, the work of such vast importance, voted by the congress." H. C. W.

Harvard and Oxford Photometry. Before the publication of Professor Pickering's comparison of the Harvard and Oxford Photometries, I was engaged in comparing the same catalogues, and I communicated my results to the Royal Astronomical Society before Professor Pickering's paper reached this country, though my paper was not read until afterwards. As there are some differences between my results and his, the publication of the former may prove of interest to some of your readers. I should premise that I took the stars comprised within certain limits of magnitude from the *Uranometria Nova Oxoniensis* and compared the values in the *Harvard Photometry*, while Professor Pickering adopted the reverse course. This difference in procedure will account for some slight differences in our results, but the differences are, I think, greater than might have been anticipated.

First, Professor Pickering seems to think that though the Pole Star is rated at 2.15 in his catalogue and at 2.05 in the Oxford one (being the standard star in both) the difference of scale is rather apparent than real. On the other hand by comparing the Harvard and Oxford values of a number ot stars of pretty nearly the same brilliancy as the Pole Star, I came to the conclusion that the difference of scale is real, thongh perhaps it would be better expressed by 0.06 or 0.07 than by 0.10 magnitudes.

Second, I found that though this difference in scale steadily diminished, the stars were, on the average, brighter according to the Oxford measurements up to about the 4.30th magnitude, at which point the two scales coincide. Beyond this point the stars are brighter according to the Harvard table.

Third, Professor Pickering finds that after passing the 6th magnitude the stars become again brighter according to the Oxford observations. I did not find this to be the case. Taking the stars rated at 6.00 to 6.10, in the Oxford catalogue, and comparing them with the Harvard values, the latter appears to make the stars brighter on the average by 0.07 to 0.08. Below this point the number of stars comprised within any tenth of a magnitude in the Oxford catalogue were hardly numerous enongh to warrant any positive inference but they rather indicated fluctuations or anomalies than any actual inversion. Thus from 6.50 to 6.60 the stars were brighter according to the Harvard estimate, while from 6.60 to 6.70 they were fainter. But the few stars lower than the 7th magnitude which appear in both catalogues are again brighter according to the Harvard measurements. I concluded that the Oxford measurements made the stars fainter as long as the stars were numerous enough to justify us in striking an average.

I excluded from my computation the Oxford stars (given in the notes, not the text) in which a correction for atmospheric absorption was necessary. These stars exhibit such diversities as to lead me to think that the Oxford correction for absorption is radically erroneous.

May I venture to suggest that Professor Pickering (whose comparisons must have furnished him with the necessary data) will publish a comparison of the two catalogues, subdivided into tenths of a magnitude.

Dublin, Ireland, Dec. 17, 1887. W. H. S. MONCK.

An obvious error crept into my calculation of the relative motion of Sirius and his companion in the January number of THE MESSENGER. I believe I should be more accurate to say that the divergence of the curve obtained from measures of distance from that obtained from angles and epochs amounts in the segment of the orbit, between 60° and 30° to 0.62″. By the table near the bottom of page 26 it will be seen that the approach of the companion toward the centre of the system in passing from 60° to 30° is 11.50″—7.79″ or 3.71″. We must credit Sirius then in the same time with an approach of 0.62″, or one-sixth as much.

The table on page 27 should be reconstructed as follows:

Position Angle.	Dist. comp. as above.	Approach of Comes to center.	Approach of Sirius.	Distance Actual.
60°	11″.50			11″.50
50°	11″.26	0″,24	0″.04	11″.22
40°	10″.04	1″.22	0″.20 + .04	10″.80
30°	7″.79	2″.25	0″.38 + .24	7″.17

This of course makes the companion one-sixth the mass of the principal star, and they are, at the moment of their greatest apparent distance, respectively 9.87″ and 1.65″ from the center about which they both revolve. The semi-axis major in the table of elements needs a corresponding correction.

Such a mistake is decidedly "amateurish," but I will claim at least the credit of having discovered it myself.

NEWTON M. MANN.

Rochester, N. Y., Jan. 24, 1888.

BOOK NOTICES.

The Asteroids, or Minor Planets between Mars and Jupiter, by Daniel Kirkwood, Professor Emeritus in the University of Indiana. Philadelphia: Messrs. J. B. Lippincott Company, 1888; pp. 60.

The astronomy of the Minor Planets is given in full, with varied interesting details, in this small book just published by Professor Kirkwood. The subject matter appears in two parts, the first being a popular statement of the leading historical facts about the discovery of Ceres, Pallas, Juno, Vesta, and Astræa. In this part is given a table of all known planetoids down even to the date of this writing, the whole number, 271. This table contains the date of discovery, the name of the discoverer, the place of discovery and the name and number of the asteroids. The remarks that follow the table are instructive. A second table in the first part gives the elements of the orbits of the planetoids that have been computed, which are arranged in the order of perihelion distance. Part second is given to a discussion of the facts of this table last mentioned. The extent of the zone, the small mass of the asteroids, the limits of perihelion distance, stability of the zone, distribution of its members in space, commensurability of periods, particular perihelion distances, the second order of commensurability, chasms corresponding to the third order, chasms corresponding to the fourth order, relations to certain adjacent objects, the eccentricities, the inclinations, longitudes of perihelia, distribution of the ascending nodes, the periods, the origin of the asteroids, variability of certain asteroids, the average asteroid orbit and the relation of short period comets to the zone of the asteroids are the principal themes discussed in the last part of the book.

This little book deserves to be in the library of every scholar or seacher of science, who is interested in having the best knowledge of the asteroids. It will help the teacher of elementary astronomy to correct and amplify brief or misleading statements of the ordinary text-books on this subject.

Mitchel, F. A.: Ormsby Macknight Mitchel; Astronomer and General. Boston: Houghton, Mifflin & Co.; pp. 392.

This biographical narrative is one of exceptional interest, not only to any one who is fascinated by the well-told story of an eventful life, but also and especially to every one who has any adequate conception of the stimulus given to the cultivation of astronomy in this country by Gen. O. M. Mitchel. It has been the author's aim to give the story, as far as possible, in his father's own words, by copious extracts from his diaries and other manuscripts. But much has necessarily been supplied by the author; yet the book is not a piece of literary patchwork. It is divided into two parts, entitled respectively Science and War. Part II is the record of a truehearted patriot and skillful soldier, who, despite lack of adequate support and the jealousy of his superiors, penetrated by swift and daring moves into the heart of the enemy's country, without leaving behind a sickening trail of desolation. But those interested in astronomy will find Part I replete with interest. Here we read Mitchel's own descriptions of his visits to the leading astronomers of the Old World: he gives pen portraits of them and descriptions of their observatories. The kindness of Sir George Airy and his wife, the courtesy of Arago, the good-heartedness of the bachelor Lamont, and the brusque hospitality and ruined hopes of Sir James South are set forth vividly. The heroic sacrifices and struggles which led to the establishment of Cincinnati observatory are depicted with graphic pen. The reader is also introduced to the charming family life of the subject of the narrative, and learns to admire and love him.

H. A. H.

First Steps in Geometry: A Series of Hints for the Solution of Geometrical Problems, with Notes on Euclid, Useful Working Propositions and Many Examples. By Richard A. Proctor. London: Messrs. Longmans, Green & Co., and New York: 15 East Sixteenth Street, 1887; pp. 179.

There is no doubt but that a working knowledge of geometry is, or ought to be, the principal thing sought by the student, especially after he has acquired some knowledge of geometrical methods and principles. When the author of the book before us says that teachers and books strive to impart readiness in following demonstrations rather than facility in obtaining solutions, he must mean those students who have already acquired some knowledge of geometry, and so have some foundation for independent, individual effort. As pertaining to this stage of advancement, the criticism is just, and to such the book is a help, containing as it does, many pertinent suggestions coming from experience and thought in the solution of quite a range of elemental geometrical problems. The notes on the propositions of Euclid's first two books are useful reading for teacher or student.

THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE,

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

VOL. 7, NO. 3. MARCH, 1888. WHOLE NO. 63.

THE COMPUTATION OF CLOCK CORRECTIONS.

PROFESSOR FRANK H. BIGELOW, RACINE COLLEGE.

For the MESSENGER.

The determination of the correction Δt and rate ρ of a standard astronomical clock becomes a matter of practical experience, rather than that of theoretical method, in the daily work of an observatory. So much refined skill has entered into the construction of the clock, that an observer often feels the instrument is more trustworthy than the man who is the medium of comparison between the time of the stars and the time keeper. In spite of all the care of the computer in the elimination of instrumental errors, there always remains a margin where the exercise of an arbitrary judgment must intervene to decide upon the adopted result.

Let us confine our attention to time-stars near the equator and suppose that every precaution is practiced in the determination of the *c. m. n.* in Bessel's formula, or the A. B. C. in Mayer's formula, there yet remains a series of residual Δt's varying in magnitude as much as two-hundredths of a second. It may be safely asserted that where the observations run throughout the year, the resultant right ascensions of the stars' places will range over about fifteen-hundredths of a second, under favorable circumstances. It was my allotted duty at the Cordoba Observatory to discuss the time corrections, and there were passed in review hundreds of nights and thousands of time-star observations, so that my opinion keeps in view this experience. Three of the years at least—1881, '82 '83, were devoted to this subject of time-stars, while the reductions of the zones and catalogues were in such a condition as to render a further accumulation of circle observations undesirable. Here was an opportunity if ever to reduce all errors to a minimum, as the list comprised for the most part Almanac stars, and the observers or computers were all men long practiced in this work. An evening's observations took in, say six circumpolars and fifteen time-stars. There were a multitude of very accordant results, but likewise divergencies from the arithmetical mean all the way up to six or eight-hundredths of a second, so that it was fair to allow a range of fifteen-hundredths for unavoidable inaccuracies and yet regard the work as standard in every respect.

It is important to decide upon the best method of dealing with this troublesome margin, since all imperfections here go over into the catalogues, or are eliminated only by increasing the number of observations and taking a mean result. In a discussion on "The Rejection of Discordant Observations,"* Professor Asaph Hall criticises the various mathematical methods, and concludes as follows: "The question occurs whether there is any advantage in the discussion of observations by means of these rules over the judgment of an experienced investigator. I think the reply must be negative. For most cases of discordance that occur in practical astronomy the judgment of an experienced astronomer will be better than any arbitrary rule." There are two general methods of dealing with the observations, the first by reducing the several Δt's to one epoch assuming some clock rate for the interval, and by "least squares" obtaining the most probable correction to rectify this mean Δt and arbitrary ρ; the second by plotting the several Δt's on square paper, and drawing some representative line through them which is supposed to show the action of the clock. To the first it should be objected that it avoids a use of judgment, presuming that there was a mathematical uniformity of running in the clock, and thus putting all the burden of error on the observations; and again it does not admit the detection of temporary or accidental changes due to lack of compensation under temperature strains, not of the really poor individual observations that necessarily occur. Good and bad are counted as of equal weight in the resultant values, nor is there any attempt to distinguish between them. The graphic method on the other hand does allow a complete inspection of all the incidents attending the night's work, since it lies in a picture before the eye. But it has the practical difficulty, which fol-

* SIDEREAL MESSENGER, November, 1887.

lows from our premise that variations up to fifteen-hundredths of a second do occur, namely, that it is possible to draw several plausible lines or curves through the scattering points—higher or lower or more or less inclined—and that the practical judgment is puzzled which to select. In case there are two observers, as happens when the work continues six or seven hours, the trouble is increased by the necessity of paying attention to the personal equation. All the judgment needs is some clue to the general truth involved in any instance, in order to discover it exactly, and it is the purpose of this paper to offer a suggestion on this point.

I can best produce the idea by indicating the plan pursued at Cordoba. The Δt and ρ of each night were determined graphically in accordance with the best judgment of the occasion, and afterwards these resultant star places reduced to the beginning of the respective years were collected in long ledgers, containing generally about 16,000 observations annually, and in one instance 27,000. This proceeded from 1873 to 1880, but after 1880 all the computations were revised throughout as to the instrumental and time corrections. As a preliminary each night's work was inspected in the ledger, which implied the comparison of over a hundred star-places with the entries of the same star occurring in other nights and years. It was done only roughly and the variety of circumstance entering into the facts before one was so wide as to forbid any collusion of evidence, so that the information gained could be used to detect the tendency of errors in the original computation. It was laborious and involved much readjustment of figures, but it was a sound system of successive approximation, such as astronomy practices in all departments and is in fact the only approach we have to the ultimate truth in human knowledge.

Besides becoming able to exclude the clearly wrong assumptions of the instrumental errors previously made, and seen to be such with surprising vigor of conviction under the new light, it was perceived that there was a strong tendency to readjust the clock rate of the evening to close agreement with the daily rate. From this it may be argued that the clocks have already surpassed the accuracy of observations; and that further skill in this direction is not necessary. The accidental changes of the clocks should be less discussed, and that of the physical condition of observers more. A second lesson may be learned that a revision of computations by practical judgment is more essential to good results than further improvements in instruments and their use; that this can be done in some degree by an intro-comparison of first computations when they extend over long periods of time, and that consequently the practice of publishing the annual volumes as independent of each other is prejudicial to the highest accuracy of astronomy, since the material is put forth before it has furnished its highest truth. One other conclusion may be ventured, that there is a margin of one-seventh of a second of time that no skill is apparently capable of removing, which must be due to the physico-nervous constitution of observers. It is the measure of the time over which the consciousness and will have only indirect control. The only remedy is to remove the observer wholly, and introduce the electric spark and the sensitive photographic paper in place of the chronograph and human eye. A contrivance attached to the eye end of the telescope, having a rotating and advancing barrel with sensitive paper whereon the emergent pencil of rays from the star makes a continuous trail, except when crossing a wire, and on which trail an electric spark encased in a dark tube with small hole in a point at the pencil struck every second by the standard clock, furnishes the elements of the solution. The efforts being made to overcome this mechanical difficulty ought to be encouraged in every way, as it is the only hopeful method to secure another progressive step in accurate observations.

RACINE COLLEGE, Jan. 3, 1888.

DISTANCE AND CONSTITUTION OF THE SUN.

THE EDITOR.

So many queries about the solar system, or the members of it, have come recently to the attention of those in charge of this journal from various sources, that it is thought best to make a brief statement of the present state of knowledge that astronomy has of the solar neighborhood in which we live.

Naturally we begin with the sun, and the oldest and most important problem which the study of this body offers is the determination of its distance from the earth in terrestrial units of measure. This distance is important because the knowledge of all the phenomena of all the heavenly bodies, except those of the moon; depend directly or indirectly on its value. The problem of the sun's distance is difficult because the data given for determining it are insufficient to enable the astronomer to apply the principles of trigonometry directly to it. He is, therefore, compelled to use indirect methods of solution which, at best, give only approximations to the true distance, arising chiefly from small errors in observation, which, at the present time, seem unavoidable. A familiar illustration will make our meaning clear. The knowledge we have of the sun's distance depends on the accurate measurement of a small angle formed by drawing two lines from a point at the sun to the extremities of the earth's radius. That angle is called the sun's parallax. Ptolemy thought that this angle was 3′ of arc, but we now know that its value is very near 8.80″ of arc, and that the error of this amount from the true angle probably is not more than 0.02″. To measure this small angle has been the astronomer's great trouble since the time of Aristarchus, and he does not yet know its value accurately. His problem is like that of a surveyor attempting to measure a ball, whose real diameter is one foot, at the distance of 4.4 miles nearly; and unless he can determine the diameter of the ball so that he shall not be uncertain in his measure to the amount of 0.03 of an inch, his work will not add any thing useful to present knowledge.

If we suppose the angle of parallax to be known, the computation of the distance of a celestial body is easy. Multiply earth's radius by 206,265 (seconds of arc in the unit radius), and divide the product by the angle of parallax in seconds of arc. The mean equatorial radius of the earth, as given in Clark's Geodesy, is 3963.3 English miles. The sun's distance for a parallax of 8.78″ would be

$$\frac{206{,}265'' \times 3963.3}{8.78''} = 93{,}108{,}000 \text{ miles.}$$

For parallax of 8.80″ = 92,897,000 miles.

For parallax of 8.82″ = 92,686,000 miles.

The range of error in parallax, as here given, is 0.04″, and the change of the distance of the sun in allowing for this error is nearly half a million of miles. If 8.80″ be the assumed parallax, with ± 0.02″ as probable error, then the uncertainty of the sun's distance is still nearly a quarter of a million of miles.

So far astronomers are pretty generally agreed, unless it be in the value of the earth's radius used above. In his excellent work, entitled "The Sun," we notice that Professor Young gives 3,962.72 English miles as the "latest and most reliable determination" (page 22), while he seems to use, Bessel's value of 3,962.80 in obtaining 92,885,000. This may be because the last named value is still in most general use, though less accurate undoubtedly than that of Clarke.

Since the transit of Venus, of 1874, the determination of the solar parallax has not been very much improved. The transit of 1882, so far as known, has given surprisingly discordant results, and probably they will be of very little service in improving our knowledge of the distance of the sun. In the midst of all this uncertainty of late work, in ordinary methods two ways of studying the problem show results almost exactly alike. They are obtained from late improved measures of the velocity of light, and from measures by the heliometer. The parallax from these sources is 8.794″. The Brazilian result of transit of Venus for 1882, by Wolf and André, recently published, make the parallax 8.808″. The American reductions for the last transit are not yet completed.

From the above brief statement of results, it seems that the value of the solar parallax is likely to be a trifle under 8.80″, rather than above it, making the distance of the sun probably very near 93,000,000 miles.

The next most important problem pertaining to the sun is its constitution, which is usually considered under four heads:

1. The central portion, thought to be made up chiefly of intensely heated gases;

2. That part which is seen by the aid of the telescope, called the photosphere, consisting of a "shell of luminous clouds formed by the cooling and condensation of the condensible vapors at the surface where exposed to the cold of outer space" (Young);

3. Outside of the photosphere is a shallow stratum, called the chromosphere, "composed mainly of uncondensible gases (conspicuously hydrogen) left behind by the formation of the photospheric clouds, and bearing something the same relation to them that the oxygen and nitrogen of our own atmosphere do to our own clouds" (Young); and,

4. The corona, which is the beautiful halo seen, with the naked eye, outside of all, during the time of a total eclipse of the sun. This curious halo with all its streamers and rifts is thought to be composed chiefly of an incandescent material, in a far more attenuated state than that of hydrogen, the rarest gas known, because it yields freely in the spectroscope a certain line, 1474 K, which most agree can mean nothing else, although no one knows what the gas or metallic vapor is. Hydrogen is also found in the corona extending to the height of 600,000 miles above the photosphere, and possibly 1,200,000 miles. Suspended in this mixture of vapors and "falling into, or projected from, the sun is a large quantity of solid or liquid material, which is at such a temperature as to be self-luminous. It is this which yields the continuous spectrum, free from dark lines.

Besides these components in the outer envelope, there is present matter which reflects or diffuses light much as our own atmosphere does.

To this is attributed the partial radial polarization of the corona. The streamers and rifts indicate matter repelled, in various quantities, from the sun by forces which may be electrical." (Hastings.)

These are the views advanced by astronomers and physicists, as theories or working hypotheses, until something better or more certain can be known. They are not held as facts by any, because of insufficient proof to establish them as such, and because there are very grave objections to some of them which are at present unanswerable.

For example, the spectroscope shows that the gaseous pressure at the limit of the chromosphere is very small, although that is at the base of an atmosphere from 600,000 to 1,200,000 miles deep, and under the influence of a force of gravity more than twenty-seven times as great as that in action at the surface of the earth.

Optically the atmosphere of the earth ceases at a height of forty-five miles, but bodies at twice that altitude, moving at the rate of twenty-seven miles per second, meet resistance of air enough to render them incandescent almost instantly. But the evidence seems clear that, far within the corona, the resistance to moving bodies is much less than in our atmosphere at a height of sixty miles. The great comet of 1882 passed through the coronal atmosphere within 300,000 miles of the sun, with a velocity one hundred and eighty times that of the earth in its orbit. The comet was not stopped, nor destroyed, nor its orbit disturbed, as subsequent observations showed. The same thing was true, so far as known, of the comet of 1843, which passed still nearer the solar surface. These facts are troublesome to explain on the hypothesis of a coronal atmosphere.

Still further: if the sun be surrounded by a gaseous envelope, its density, as aforesaid, ought to diminish from the solar surface outward to its upper limits; but the fact is, the material of 1474 K line always appears in the spectrum of chromosphere, which would seem to indicate, by its place, that it is as much more dense than hydrogen as is magnesium vapor, or even the vapor of iron. But the evidence of the spectroscope makes this 1474 K material far less dense than that of hydrogen, and this is a contradiction that is very troublesome to the student of solar physics.

In studying the polarization of the light of the corona, it is clear that the amount of polarized light reflected from a particle at the surface of the sun is nothing, "because the luminous source there is a surface with an angular subtense of 180°;" hence polarization of the corona near the limb of the moon ought to be small, farther away, larger. But observation shows that the contrary is true, *i. e.*, the per cent of polarized light increases as the corona is observed nearer the limb of the moon during totality.

These are a few of the difficult questions that stand in the way of accepting the foregoing theories as facts pertaining to, or well grounded knowledge of, the constitution of the sun. They are by no means all, or possibly the most important ones. They are certainly among those that are receiving very general attention at the hands of physicists at the present time.

More particular discussions of the photosphere and the chromosphere of the sun will be considered next time, by the aid of such illustrations as may be procured, for the sake of making the meaning of certain phases of opinion clearer than would be possible without them.

(TO BE CONTINUED.)

THE DISTRIBUTION OF THE STARS.

W. H. S. MONCK, DUBLIN, IRELAND.

For the MESSENGER.

I fear my article on this subject contains a serious oversight which vitiates many of my results, though the new ones derived from the correction may prove interesting to your readers. I was, of course, correct in saying that on the hypothesis of uniform distribution the number of stars which would be cut by, "or lie close to," the surface of any sphere drawn at random round the earth (or sun) as centre would be proportional to the surface, but I tacitly assumed that a star of the 5.1 magnitude (for example) would lie as close to the sphere corresponding to 5.0 magnitude as a star of the 4.1 magnitude would to the sphere corresponding to 4.0 magnitude. This (as some of your able readers will probably have pointed out before this letter reaches you) is not the case.

In fact let r_1, r_2, r_3, r_4 be the radii corresponding to the magnitudes 4.0, 4.1, 5.0 and 5.1 respectively, then if the distribution be uniform the number of stars lying between 4.0 and 4.1 will be to the number lying between 5.0 and 5.1 as $r_2^3 - r_1^3$ to $r_4^3 - r_3^3$, or as $(r_2 - r_1)(r_1^2 + r_1r_2 + r_2^2)$ to $(r_4 - r_3)(r_4^2 + r_4r_3 + r_3^2)$. But it is easily shown that $\frac{r_4^2 + r_3r_4 + r_3^2}{r_1^2 + r_1r_2 + r_2^2} = 2.512$, and therefore the ratio is not 2.512, but $\frac{r_4 - r_3}{r_2 - r_1} \times 2.512$; and since r_4 is to r_3 as r_1 to r_2 (as the change in the intensity of the light proves), we may write this $\frac{kr_3}{kr_1} \times 2.512$, or $\frac{r_3}{r_1} \times 2.512$. But the intensity of the light being inversely as the square of the distance, we get $\frac{r_3}{r_1} = \sqrt{(2.512)}$, and the ratio between the total numbers of stars is (on the hypothesis of uniformity) not 2.512 to 1, but $\sqrt{(2.512)}^3$ to 1 or 3.981 to 1.

Comparing this theoretical result with the figures given by me, it will appear that, with perhaps one or two fluctuations, the number of stars of any magnitude below the second, is always *less* than it would be if the distribution was uniform, the deficiency of stars becoming greater as we descend to lower and lower magnitudes (though the *rate* of thinning appears to diminish). Therefore, *assuming that no light is lost in transmission*, we are traveling through a rich star region which is surrounded by a poorer one; and we are most probably situated *in* the Galaxy, the rich star region to which we belong extending to a considerable distance only in the directions in which the Galaxy extends. I confess, however, that I am more disposed to adopt the theory of a loss of light, whether the ether itself absorbs light, or whether (as seems more probable) a portion of the starlight is intercepted by meteor flights or nebulæ. A particular law of absorption would give results almost identical with those which I originally arrived at, but in the absence of any evidence for such a law I can no longer regard them as shown to be probable.

January 28th, 1888.

GOOD ASTRONOMICAL TELESCOPES.

SIR HOWARD GRUBB.*

A good astronomical telescope, even of small size, is an expensive luxury, and its purchase should not be entered upon without due consideration of the suitability and adaptability of the various forms and constructions to the conditions and surroundings of the intending user.

It is curious to note how differently different people go about starting an astronomical observatory. Some take upon themselves to decide on all points without any previous personal experience whatever, or without consulting any friendly expert; the result being that the instrument, having done its duty as an instructor (*i. e.*, an instructor of the shortcomings of astronomical instruments), finds its way into the market, as a second-hand instrument, in a year or so. Some, again, solicit the advice of their astro-

* From "Astronomy for Amateurs," 1888.

nomical friends all round, but as each of those friends has probably some particular line of work or some particular study most prominently before him (to which he thinks all others should be made subservient), the advice he receives is generally rather perplexing, and if attempted to be followed in its entirety, likely to lead to the production of a kind of second-rate Admiral Crichton of an instrument, suitable to a certain degree for all classes of work but first-rate for none. Others, again, take perhaps the advice of one experienced friend, and this is much better, for if that friend be a man who has done good work, it is likely that he will become possessed of an instrument suitable at least for that one particular line. The worst of all cases and the most unsatisfactory for the instrument maker, is that of the would-be astronomer who comes and says, "Now I want a telescope, and I want to do some astronomical work. I don't know what that work is to be, and even if I did, I don't know what form of instrument would be best suited for it; but please do the best you can for me for so much." The instrument maker is probably unacquainted with the purchaser's position, surroundings, taste, and qualifications, etc.; in fact, every factor which should be taken into account in deciding such a question; ten to one, he, with the best intentions, advises some unfortunate course, which the amateur gets thoroughly sick of very shortly, and the result is dissatisfaction on all sides.

It the amateur would take the trouble to consult a few good reliable works on the subject, so as to be able to take an intelligent view of the subject, he will find that after a little he will be able to communicate to the instrument maker his special desires, and discuss with him the applicability of the various forms to his special purpose. It is with a view to aid amateurs in this matter that the present remarks are offered.

The Mounting. In the present day it may be assumed that any one who possesses an astronomical telescope, except of the smallest size, will not think of mounting it on any other form than the equatorial. It is the only form in which the heavenly bodies can be followed by a uniform motion of the instrument around one axis. If the axis be placed in any other position, it is not possible to follow the object without a double motion, and that varying in a most complicated manner; nor is it possible to apply clock-work, except with the most complicated contrivances. The superiority of the equatorials for astronomical purposes has always been recognized since their first introduction, but up to late years it was not possible to procure these, except of great complexity and corresponding expense. Now, however, when really practical little tools suitable for mounting small instruments can be obtained at prices quite as low as the simplest alt-azimuth, that difficulty is removed, and no one probably will think in the future of using anything but an equatorial for astronomical purposes. [There are cases, however, in which the alt-azimuth (provided with circles) has its advantages. One of the most successful discoverers of comets at the present time uses such a mounting, as more suited to that particular class of work.] Of the various forms of equatorials, also, it will hardly be necessary to treat in this chapter, as it is only intended that the remarks here made should have reference to refractors up to 8″ in diameter, and reflectors to 12 or 25, and there is for these sizes really but one type of equatorial usually used by the instrument makers of this country, *i. e.*, the so-called (but misnamed) German form. The other two distinctive types—the old English divided polar axis (such as the Greenwich refractor) and the biforked polar axis (in which the telescope is swung between a pair of jaws forming a prolongation of polar axis above upper bearing) need not be discussed, as they are not practically procurable.

The first and most important point to look to is the stability of the instrument. This depends on various conditions. Suppose the foundation, or pillars, or whatever the instrument be mounted on, to be sufficiently firm, the stability depends on the porper proportioning and constructtion of the axes and their bearings, and the general strength of the body or frame-work. It may be asked what size and length should the axes be in proportion to the diameter of objective or special size or form of telescope, etc. This is a question it would be almost impossible to answer, as so much depends on the construction and arrangement of the parts.

A rough, but fair test of the stability, however, may be made thus: Turn the telescope to a star (a polar star preferable if there be no clock-work), and put a high power on telescope, say 200 for a 3-inch objective, and try if you can focus satisfactorily and comfortably without causing the image to dance about in the field. If the image is unsteady in the field, it will be impossible to focus satisfactorily, and the stand is defective.

It may be asked, how am I to specify to an instrument maker the degree of stability necessary, or how am I to know before hand that the instrument he recommends me will have the requisite stability? To this the best answer is: Go to an instrument maker of repute, and tell him you want an instrument of such size for star-gazing, or for micrometrical work or spectroscopic work, as the case may be, and you may be perfectly sure that he will not risk his reputation by recommending you anything unsuitable.

Quite apart from stability there is a certain quality of rigidity which is very desirable. This is generally not so much a matter of mere strength of axes, etc., as of proper construction and arrangement of the clanps and slow motions. Every mounting to carry a 4″ or over refractor ought to be provided with clamps and slow motions in right ascension and declination, and if these be not properly constructed there is want of rigidity and definiteness of position of the instrument.

To test this, point instrument as before on a star, clamp both right ascension and declination: now press finger with a few pounds pressure against side of rack tube, trying it up, down, right and left. On application of each successive pressure the star will be seen to move slightly in the field (for no instrument is absolutely rigid), but on releasing the pressure the image ought to return to almost the same place as before.

The clamping handle should clamp very decidedly and promptly, a quarter turn of handle should suffice to clamp or unclamp, and, when clamped, the telescope should be quite firm and not movable except by considerable force.

The slow motions should work with as little "back lash" or "loss of time" as possible—*i. e.*, after working in one direction, if the handle be reversed the motion of the instrument should respond almost at once to the reversed motion of the handle.

There are several forms of slow motion used. For declination, generally a screw working into a sector, or what is called the German form, a screw bearing directly upon a clamp which is kept in good contact with it by a spring, is suitable for small, light instruments. For right ascension movement, the slow motions are generally either of the form of a tangent screw of some kind, or a differential gearing in clock shaft which, when worked in one direction or other, causes a temporary acceleration or retardation of rate at which clock drives endless screw. Whatever be the form used, if the instrument stands the test given above, it is sufficiently good; but if a differential gearing be used, see that it is of a form in which the additional wheels only come into use when the slow motion handle is turned. Some of the differential slow motion introduce several wheels directly into the clock train; there is no necessity for this, and every wheel added between governors and clock train is a disadvantage.

Another point to be considered about equatorial mounting is its general convenience. Some mountings have inconveniences attending them which are never discovered till they come to be used; but here again it is necessary to trust, to a great extent, to the instrument maker. Any instrument maker of experience has of course had all matters of convenience and inconvenience brought prominently and constantly before him; his business is to grapple with these matters, and they may generally be safely left to him. A few points may, however, be mentioned:

See that the telescope has, to as large extent as possible, circumpolar motion—*i. e.*, that up to as high an altitude as possible the telescope can be allowed to follow a star without requiring reversal when the star passes meridian. In some instruments the clock and other parts of apparatus are so placed that when the telescope has followed the star from E. to meridian, or just a little beyond, it (the telescope) comes against some part of the stand or clock, and the whole instrument has to be reversed to other side of pier, and the observation re-commenced. This is often very vexatious, as it is just the best possible position for observing. There is no difficulty in arranging matters so that any star up to 75° or 80° altitude can be observed without necessary reversal of instrument. Another convenience resulting from this, that there is thus generally a possibility of a choice of two positions in observing any star up to that altitude, *i.e.*, with telescope E. or W. of Polar axis, if star be near meridian; or above or below Polar axis, if star be E. or W. See also that if motion of telescope is liable to be stopped near meridian by some portions of instrument, that it be not likely to be so stopped by any delicate part, such as clockwork, etc. This is another great convenience.

All clamping handles and slow motion arrangements should be convenient to hand of observer while he is in a position for observing.

Circles should be clearly but not too finely divided. In the smaller instruments, in which accurate determinations of position are rarely wanted, it is a mistake to employ circles too finely divided. It is rarely that the vernier in right ascension circle is ever used; generally the zero point is quite sufficient. Amateurs have not often the means of knowing the time so accurately, or the facility of calculating the refraction so conveniently, that they require to set the right ascension circle nearer than to fifteen seconds of time.

For very small telescopes of simple but efficient construction, some makers use circles printed on paper, which are clearly and easily read, and quite as accurate as the ordinary class of metallic circles on the less expensive stands, and can be replaced when required at a cost of a few pence.

On the better class of instruments various convenient appliances are added by different makers for different purposes.

Readers, by which the circles can be read from eye-end of telescope, etc., these are just so many labor-saving contrivances, very useful and very convenient, but without which it is quite possible to do the very best work.

In equatorial instruments, as well as in most mechanical instruments, there are two totally different classes of "cheap" instruments.

There is the instrument which is cheap because it is inferior in every way, badly designed and constructed and clumsily made. This is dear at any price. But there are also instrumetns sold at low prices by good makers which are cheap; not because they are inferior in any way, but because they have been simplified down, and all unnecessary work and finsh dispensed with. They do not profess to do as much as the other class of instruments. But what they do they do well, and they can have such additions made to them from time to time as the purchaser may desire.

Except in very small instruments, it is much better that the endless screw driven by clock-work gears into teeth cut on a long radius of sector than into teeth on an entire circle, which must necessarily have a short radius. For any given error in screw or bearings, the effect or motion of insturment will be in the inverse ratio of radius of toothed circle.

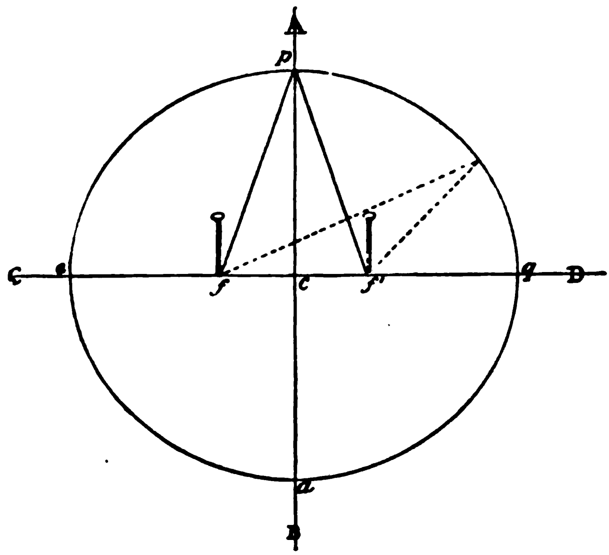
For large equatorials, those 5″ or over, it is better that the clock-screw have a square and not a V thread.

(TO BE CONTINUED.)

FOR STUDENTS AND YOUNG OBSERVERS.

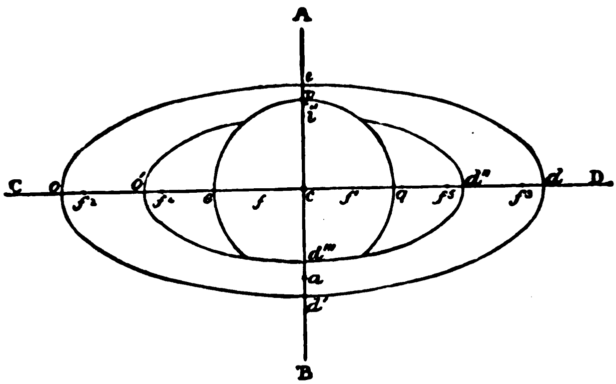
DRAWING THE PLANETS.

Suppose we next try to draw the outline of the planet Jupiter, as seen in a small telescope. The accompanying figure will indicate how this is to be done. For the month of



February the average equatorial diameter of the planet is 37.49″; the polar diameter is found by multiplying the equatorial diameter by .939, or it is directly given in Nautical Almanac. If 17″ = 1 inch, *eq* will equal 2.20 inches.

Then from the centre *c*, where the two diameters cut each other, we take the distance *ce*, or *cq*, in the compasses and placing one leg on *p* or *a*, move them about until the other touches the line *cq* in the points *f* and *f'*. Into these two points, technically called the *foci* of the ellipse, we stick two pins, and round these tie a loop of thread of such length that when stretched tight by a pencil, the point shall touch either *a*, *e*, *p* or *q*. *f p f'* represents this thread in the figure, and if it be kept tightly stretched, as the pencil is carried round, the curve *f e a q* will be the correct elliptical outline of Jupiter to the adopted scale. The accompanying figure is a little larger than the numbers given above call for, being drawn for another date.



The description of the outline of Saturn and his rings only involves a repetition of this process. The successive steps will be understood by a study of the figure below.

The polar diameter of Saturn for the middle of February is a little more than 19″; its equatorial diameter is in the ratio of 1 : 0.895, being therefore 21.3″. If the equatorial diameter be taken as one inch, then 0.895 of one inch will be the polar diameter. Make *e q* one inch, and *p a* 0.895 of an inch, and construct the elliptical outline of the planet precisely as before. Now looking at page 481 of the Nautical Almanac, we find the outer major axis of the ring for February is 46″, and the outer minor axis is 16.08″. These values correspond to *o d* and *i d* respectively. On the same page we find the factor to be multiplied by line *o d* to obtain the major axis of the inner ellipse of the inner ring = 0.66. The minor axis of the inner ellipse of the inner ring is found by multiplying its major axis by 0.43, which serves fairly well to indicate the apparent relation of the axis as seen at the present inclination of the rings. Perhaps enough has been said to show how the three ellipses can be drawn and to give some knowledge of the sources of information if the young observer have not the means of measurement connected with his small telescope.

It may be asked if it be advisable to pursue the above methods night after night, or week after week, in the study of the planets. Certainly not; for the outline of Jupiter is very nearly invariable, and Mars and Saturn vary so slowly that one drawing will last for many weeks. If such drawing be transferred to stencil plate, which is inexpensive to cut in outline, it will be of ready use for the observing book from night to night in the study of details. Good observers are known to follow this plan. These suggestions are taken from Capt. Noble's excellent little book entitled "Hours with a Three-inch Telescope."

Interesting Phenomena for March.

Mercury will be at inferior conjunction on March 3, about 4° north of the sun's centre. He will be stationary in right ascension on the 16th; at descending node of his orbit on the 21st; in conjunction with Venus on the 27th; at greatest elongation west 27°49′ on the 30th; and in aphelion on the 31st. The conjunction with Venus would be an interesting phenomenon to observe, since the planets will be only 2′ apart, and in some latitudes the parallax may bring them still closer together; but unfortunately it occurs below the horizon of observers in the United States. During the middle of the month of February Mercury was quite a conspicuous object in the clear western sky of Minnesota an hour after sunset, so that the most casual observer could hardly fail to notice him. During the latter part of March he will be in favorable position for observation in the morning.

Venus will be in conjunction with the moon on the 9th at 3*h* 36*m* P. M., and will be occulted to observers in the South Pacific ocean. She passes this month from Capricorn into Aquarius. Her phase increases from 0.828 to 0.892, while the diameter of her disk decreases from 13.0″ to 11.6″.

Mars is in Virgo, and not in Libra as stated last month, and will be stationary on the morning of the 4th. After that he will slowly retrograde for a couple of months. He will be in conjunction with the moon, south 2°35′ on the 28th at 8.15 P. M. Mars is approaching opposition, and is now in good position for observation. His phase increases during the month from 0.945 to 0.994, and his apparent diameter from 12.4″ to 16.0″.

Jupiter is in the foot of Ophiuchus, almost directly north of Antares (α Scorpii). He will be in conjunction with the moon on the 21st, and after that will slowly retrograde toward β Scorpii. He will be in conjunction with the moon, —3°47′ on the 4th at 4:36 A. M., and again on the 31st at 0.36 P. M., —3°32′.

Saturn still continues to retrograde in the constellation of Cancer until the 30th, when he will be stationary. He will be in conjunction with the moon on the 22d at 9:45 P. M., being then 1°20′ north of the moon's centre. The elevation of the plane of Saturn's rings above the earth will be at its maximum for this year at the end of this month, being 21° 12′ on March 20th. On the same date the major and minor axes of the outer edge of the outer ring will be 43.76″ and 15.83″ respectively. Ordinarily five of the satellites of Saturn may be seen with an eight-inch telescope, the brightest being Titan, the next Japetus, then Rhea, Dione and Tethys, nearly equal in brightness.

Uranus and *Neptune* move so slowly that their change of position from month to month is scarcely noticeable without a telescope. The latter will soon be lost in the advancing sunlight. The former may be observed for several months yet.

	R. A.	Decl.	Rises.	Transits.	Sets.
	H. M.		H. M.	H. M.	H. M.
NEPTUNE.					
March 5...........	3 42.4	+17°59′	9 28 A. M.	4 46.0 P. M.	12 04 A. M.
15.........	3 43.1	+18 02	8 49 "	4 07.4 "	11 26 P. M.
25.........	3 44.1	+18 06	8 10 "	3 29.0 "	10 48 "
SATURN.					
March 5...........	8 09.9	+20 41	1 42 P. M.	9 12.7 P. M.	4 43 A. M.
15.........	8 08.4	+20 46	1 01 "	8 31.9 "	4 03 "
25.........	8 07.7	+20 48	0 20 "	7 51.8 "	3 23 "
URANUS.					
March 5............	13 01.5	− 5 49	8 23 P. M.	2 03.5 A. M.	7 44 A. M.
15..........	13 00.1	− 5 40	7 42 "	1 22.8 "	7 04 "
25..........	12 58.6	− 5 30	7 00 "	12 42.0 "	6 24 "

MARS.

	R. A.	Decl.	Rises.	Transits.	Sets.
	H. M.		H. M.	H. M.	H. M.
March 5	13 56.2	− 9 02	9 30 P. M.	2 58.1 A. M.	8 26 A. M.
15	13 52.9	− 8 44	8 47 "	2 15.4 "	7 44 "
25	13 44.7	− 8 04	7 57 "	1 28.0 "	6 59 "

JUPITER.

March 6	16 17.0	−20 23	12 40 A. M.	5 18.5 A. M.	9 57 A. M.
16	16 18.5	−20 25	12 02 "	4 40.6 "	9 19 "
25	16 18.6	−20 25	11 23 P. M.	4 01.4 "	8 40 "

VENUS.

March 6	21 06.8	−16 57	5 13 A. M.	10 07.4 A. M.	3 02 P. M.
16	21 55.4	−13 31	5 08 "	10 16.7 "	3 26 "
26	22 82.6	− 9 27	4 58 "	10 24.3 "	3 50 "

MERCURY.

March 6	22 43.6	− 4 26	5 58 A. M.	11 44.1 A. M.	5 30 P. M.
16	22 26.5	− 8 29	5 18 "	10 47.7 "	4 17 "
26	22 44.6	− 9 01	4 59 "	10 26.4 "	3 54 "

OCCULTATIONS VISIBLE AT WASHINGTON.

Date.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean Time.	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.
Mar. 5	μ Sagittarii	4	13 55	159	14 28	224	0 33
5	15 Sagittarii	5½	14 18	63	15 10	319	0 51
26	b Virginis	5½	10 52	109	12 07	310	1 15
29	ξ¹ Libræ	6	11 30	95	12 36	319	1 06
30	49 Libræ	6	15 16	77	16 23	322	1 07
April 2	33 Sagittarii	6	12 15	126	13 07	249	0 52
2	ξ² Sagittarii	3½	14 04	37	14 40	336	0 36

PHASES OF THE MOON.

		Central Time. H. M.
Last Quarter	March 4,	9 25.9 P. M.
New Moon	March 12,	10 21.0 A. M.
First Quarter	March 20,	2 43.4 P. M.
Full Moon	March 27,	4 07.5 P. M.

GREAT RED SPOT ON JUPITER—TIMES WHEN ITS ZERO MERIDIAN PASSES THE CENTRE OF JUPITER'S DISK.

D.	Central Time. H. M.	D.	Central Time. H. M.	D.	Central Time. H. M.
March 2	5 42.7 A. M.	March 12	3 58.5 A. M.	March 22	2 13.8 A. M.
3	1 34.0 "	12	11 49.7 P. M.	22	10 05.0 P. M.
4	7 20.8 "	14	5 36.7 A. M.	24	3 52.0 A. M.
5	3 12.3 "	15	1 28.0 "	24	11 43.2 P. M.
5	11 03.7 P. M.	16	7 14.9 "	26	5 30.1 A. M.
7	4 50.7 A. M.	17	3 06.2 "	27	1 21.3 "
8	12 41.9 "	17	10 57.4 P. M.	28	7 08.2 "
9	6 28.8 "	19	4 44.4 A. M.	29	2 59.5 "
10	2 20.2 "	20	12 35.6 "	29	10 50.6 P. M.
10	10 11.5 P. M.	21	6 22.6 "	31	4 37.6 A. M.
				April 1	12 28.7 "

MINIMA OF ALGOL (β Persei; R. A. 3h 01m, Decl. + 40°31′).

Central Time.	D.	H.	M.		Central Time.	D.	H.	M.	
March	3	6	01	P. M.	March	18	2	06	A. M.
	6	2	30	P. M.		20	10	55	P. M.
	9	11	39	A. M.		23	7	44	"
	12	8	28	"		26	4	33	"
	15	5	17	"		29	1	21	"

PHENOMENA OF JUPITER'S SATELLITES.

Central Time.	D.	H. M.				D.	H. M.		
March	6	2 36	A. M.	I Sh. In.	March	21	3 44	A. M.	I Ec. Dis.
		3 50	"	I Tr. In.		22	12 50	"	I Sh. In.
		4 48	"	I Sh. Eg.			1 58	"	I Tr. In.
		6 02	"	I Tr. Eg.			3 02	"	I Sh. Eg.
	7	12 32	"	III Tr. In.			4 10	"	I Tr. Eg.
		2 05	"	III Tr. Eg.		23	1 29	"	I Oc. Re.
		3 21	"	I Oc. Re.		24	2 18	"	II Ec. Dis.
	8	12 30	"	I Tr. Eg.			11 41	P. M.	III Oc. Re.
		2 51	"	II Sh. In.		25	11 31	"	II Tr. In.
		5 18	"	II Sh. Eg.			11 49	"	II Sh. Eg.
		5 21	"	II Sh. Eg.		26	1 57	A. M.	II Tr. Eg.
	10	2 01	"	II Oc. Re.		29	2 43	"	I Sh. In.
	13	4 28	"	I Sh. In.			3 47	"	I Tr. In.
	14	1 12	"	III Sh. Eg.			4 55	"	I Sh. Eg.
		1 50	"	I Ec. Dis.		30	12 06	"	I Ec. Dis.
		4 22	"	III Tr. In.			3 18	"	I Oc. Re.
	15	12 09	"	I Tr. In.			11 23	P. M.	I Sh. Eg.
		1 09	"	III Sh. Re.		31	12 26	A. M.	I Tr. Eg.
		2 21	"	I Tr. Eg.			4 51	"	II Ec. Dis.
		11 40	P. M.	I Oc. Re.			11 13	P. M.	III Ec. Re.
	16	11 44	"	II Ec. Dis.	April	1	1 50	A. M.	III Oc. Dis.
	17	4 29	A. M.	II Oc. Re.			3 18	"	III Oc. Re.
	21	3 22	"	III Sh. In.					

New Minor Planet (*272*) was discovered by Charlois of Nice, Feb. 4. 4808 G. M. T.; right ascension 10*h* 1*m* 10.8*s*; declination + 19° 20′ 22″. No. (271) discovered by V. Knorre, of Berlin, has been named Penthesilée. No. (269) the last found by Palisa has not yet been named.

Total Solar Eclipse of 1887. The preliminary report (unofficial) of the total Solar Eclipse Expedition of 1887, in charge of Professor David P. Todd, of Amherst College Observatory, has been recently received. That part which pertains to Astronomy for substance has already been reported.

Period of Algol. S. C. Chandler, Jr., of Cambridge, Mass., is making a thorough study of the period of Algol, a portion of his paper having already appeared in the last number of the *Astronomical Journal.* We also notice that Professor Oudemans, of Utrecht, is engaged in deducing new elements of Algol.

EDITORIAL NOTES.

A New Comet was discovered by Sawerthal, Feb. 18.6059, having right ascension 19*h* 11*m* 32.85*s*; declination south 56° 03′ 44″; daily motion, 6.9*m* east and 1° 15′ north. The nucleus of the comet, at the time of discovery, was of the seventh magnitude in brightness, and well defined. The comet was visible to the naked eye having a tail two degrees long. When first seen, it was in the constellation of the Telescope, and on the first day of March it will be in the south part of Sagittarius, moving, apparently, almost directly towards the sun. At that time it passes the meridian about 3° above the horizon in latitude 45° north, in light, hence not then visible so far north. It promises to be an interesting object on account of size and rapid motion.

Elements of Comet 1886, IX. The following elements were computed from observations made by Professor Frisby at the U. S. Naval observatory, 1886, Oct. 7, Nov. 3, Dec. 1 (see *Astron. Journ.*, vol. vii, pp. 8 and 31):

T 1886, Dec. 16.49674
ω 86° 19′ 54.4″ }
Ω 137 22 19.9 } Mean eq. 1886.0
i 101 36 25.5 }
$\log q$ 9.821770
Middle place } $d\lambda \cos \beta = -2.9''$
$o - c$ } $d\beta = +3.6$

W. C. WINLOCK.

Professor G. E. Curtis, of Washburn College, kindly remembers THE MESSENGER with advance sheets of his report of Lieut. Lockwood's astronomical observations on the north coast of Greenland while connected with the Lady Franklin Bay Expedition, May 1882. These sextant observations were made by Lieut. Lockwood on his sledge journey to Lockwood Island and were reduced by Sargent Israel, astronomer to the expedition, after his return to Fort Conger. Professor Curtis' work has been to review the reductions, correct arithmetical errors and arrange them for publication. As shown by these observations the latitude of the farthest point north reached by Lieut. Lockwood was 83° 24′, the highest on record.

Publications of Lick Observatory. The first volume of the Publications of the Lick Observatory has been received. Its size is about that of the Cambridge volumes, and it contains 312 pages. It is an exceedingly interesting publication because it gives so much of the detailed history of the great observatory from the first, that has been omitted from nearly all popular articles about it in the past. One of the first things to catch the attention is the report of Professor Newcomb on the result of his trip to Europe in 1875 to confer with the leading men of science in England, France and Germany deemed by him best able to give information as to the probable limit of available size that a refractor could be made; and also to ascertain what optical firms could be prudently entrusted with the construction of such an instrument, larger than any then existing. An abstract of this will be given later.

We were a little disappointed not to find, in this connection or elsewhere in this volume, the report of the committee whose duty it was to make an examination of the optical qualities of the 36-inch lens which was tested last summer at Cambridgeport. It doubtless will be given to the public later.

Then follow the report of S. W. Burnham on the advantages of Mt. Hamilton for an observatory site, and his discoveries and observations while there; the description of the instruments; a history of the work done during the last five years; full meteorological record with interesting summary; a set of twenty tables of reduction for the latitude of Mt. Hamilton, which cover the following points: Transit factors A. B. C. D., transit factors for all B. J. stars with variations of factors with the time, extension of Pulkowa refraction tables to barometer pressure of 25 inches, auxiliary table for computing refractions, zenith distances, parallactic angles, etc., Differential refractions in R. A. and Decl., parallax in R. A. and Decl., hour angles and azimuths in the horizon, zenith distances, interpolating for the Sun's place, diurnal aberration in R. A. and a dozen other tables on kindred subjects useful in general observatory work. The volume indicates a wise and judicious beginning for a work of unexampled range and magnitude in the future.

Cincinnati Zone Catalogue. Publication No. 9 of Cincinnati Observatory, which we have just received, contains the results of a series of zone observations made with a three-inch Buff and Berger transit instrument during the years 1885, 1886 and the first half of 1887, and gives a good example of the work which may be done with an inferior instrument in the hands of an assiduous and careful observer. The region covered by the zones is from declination —18°50′ to —22°20′. Within these limits 4,050 stars have been observed, including nearly all of the stars down to the 8.5 magnitude, and a considerable number of fainter ones. The observations were made by the director of the Observatory, Professor J. G. Porter, assisted until June, 1886, by Mr. H. C. Wilson, the observers taking alternate zones in declination.

The positions of the stars depend upon those of zero stars observed in each zone, differences of right ascension being observed by transits recorded by chronograph and differences of declination by bisections with a micrometer wire. An eye piece magnifying thirty times and giving a field of 50′ diameter was employed. The zones were taken only 15′ apart in declination, so that generally each star was observed three times in different parts of the field of view. Professor Porter gives as the probable error of a single observation, derived from 342 stars chosen at random, $\pm 0.123s$ and $\pm 1.84''$. A list of 201 zero stars precedes the zone catalogue. The places of these zero stars were taken from the most recent catalogues, none depending on observations made earlier than 1875, excepting a few taken from the Greenwich nine-year catalogue.

The arrangement of the catalogue is convenient and compact, giving in a single line on one page the reference number, magnitude, right ascension and declination for 1885.0, precession, number and epoch of observations in both R. A. and Decl., and references to earlier catalogues. Professor Porter has done a valuable and laborious work in comparing his places of the stars with those found in the earlier catalogues, and, as a result, has appended to his catalogue a considerable list of errata in Lalande, Oeltzens-Argelander and Lamont's Zones, and also a list of seventy-five proper motion stars, most of which are new. It is interesting to notice that more than half of these are from 8. to 9. magnitude.

Lunar Eclipse at St. Paul. Notwithstanding the unfavorable weather in this vicinity on the 28th ult., two of the phases of the lunar eclipse of that date were visible here; these phases being "middle of eclipse" and "ending of totality." At this place the moon rose at 5:10 P. M., central time, and as the "middle of eclipse" occurred ten minutes thereafter, the moon was at an altitude of only a little more than 1° at the time of this phase. Owing to an obstructed horizon, I was unable to see it until about thirty minutes after the time of the greatest obscuration. The moon had then attained an altitude of nearly 5°, and notwithstanding the fact that it was wholly immersed in the earth's shadow, the lunar disc was very distinctly visible and shone with a dull red light; this light was bright enough to render the irregularities of the moon's surface very apparent, the lunar elevations being noticeably bright, while the lowest portions were only faintly discernible.

Although the "coppery line" on the disc of the totally eclipsed moon is not a rare phenomenon, being noticeable, to a greater or lesser extent, at, probably, every total lunar eclipse, yet its intensity on this occasion, when the moon was so near the horizon and the twilight was considerable, seems to me worthy of remark. If there had been a clear view of the horizon, I think that the totally eclipsed moon would have been visible to me at the moment of its rising. The striking aspect of this phenomenon was probably due to an extraordinary translucency of the atmosphere at all points on the earth in the vicinity of which the surface of the "cone of the shadow" was tangent to the surface of our globe; for the phenomenon is caused simply by the reflection, from the lunar disc, of those rays of sunlight which have been reflected and refracted and thrown thereon by their passage through a zone of atmosphere surrounding the earth in the vicinity of all the points of tangency.

The "ending of totality" was observed at 6:09 P. M., at which time the moon's limb appeared as a pretty well defined bright point, the penumbra being not particularly noticeable. This point developed rapidly into a beautiful crescent, which, in the course of about five minutes, attained the dimensions of the illumined portion of the moon when the latter is between two and three days old. About this time, when the area of the luminous crescent was to the area of the unillumined part of the lunar disc, as one to eleven, the "coppery line" disappeared, probably by reason of the irradiation from the crescent, just as the "ashy light" near the time of the new moon disappears as the moon's age increases. This disappearance of the "coppery line" was probably hastened by meteorologic causes, for shortly afterward clouds intervened, quickly obscuring the lunar disc, and precluding any further observations. S. J. CORRIGAN.

St. Paul, Minn., Feb. 14, 1888.

Five Views of Saturn. On Wednesday evening, February 1st, having just shown a party of visitors through the Chabot Observatory, I was joined by Mr. E. E. Barnard, of the Lick Observatory, and Mr. Charles Bucrkhalter, my colleague at the Chabot, and as the night had appeared to be exceptionally fine we all went into the dome to study Saturn. The eight and one-half-inch Clark equatorial was used with powers ranging from 200 to 450 diameters, with fine results, and every detail shown on Trouvelot's drawing in the Harvard collection was easily made out. The "dusky ring" was distinct all around, and decidedly brighter at the *following* ansa. The shadow of the planet was seen on *both sides* of the ball, (Saturn being near opposition), that on the *preceding* side amounting only to the merest black dot, exactly at the "Cassini" division. The markings on the ball were beautifully distinct, and the cold steel tinge at the south pole very perceptible. But the most interesting detail to all of us was the undoubted visibility of the "Encke division." It was very plainly seen at the *preceding* ansa, and only glimpsed at the *following*; but was traced for some little distance at either side and gave the impression of being—not an absolute division, like the well-known separation between the A and B rings,—but more like a marking or "belt" on the surface. And it was very decidedly not in the centre of the A ring, but at the most, only one-third of the distance from the outside. The whole view was grand.

On the succeeding evening I found the atmosphere not quite so good, and all these features less remarkable; the "Encke division" was not well seen. The dusky ring was on this occasion decidedly brighter at the *preceding* ansa.

Oakland, Cal., Feb. 3, 1888. CHAS. B. HILL.

Total Solar Eclipse, Jan. 1, 1889. The belt of totality in the solar eclipse on January 1, next, traverses California, where, at that season, favorable atmospheric conditions for observations may be anticipated with some degree of confidence.

The central line meets the American coast at Point Arena, traversing the state of California in the direction of Pilot Peak, which is also close upon the central eclipse. At Point Arena totality commences at 1*h* 30*m* 33*s* local mean time, or at 1*h* 45*m* 13*s* Pacific standard time, and continues 2*m* 3*s* according to the elements of the *Nautical Almanac*, the sun at an altitude of 25°. At Pilot Peak totality commences at 1*h* 45*m* 54*s*, local mean time, or at 1*h* 49*m* 46*s* Pacific standard time and continues 1*m* 57*s*, with the sun at an altitude of 23°. Between these points the central eclipse crosses the track of the Central Pacific railroad, or rather branches of that line, north of Colusa. Probably any observers proceeding from Europe for the observation of this phenomenon will not care to locate themselves east of the Sierra Nevada, the duration of totality of course diminishing with decreasing westerly longitude, and the sun's altitude also becoming less, so that in 105° 29′ W. and 46° 39′ N., close on the central line, the total eclipse begins at 3*h* 4*m* 14*s* local mean time, and continues 1*m* 25*s*, with the sun at an altitude of only 9°. The main line of the Central Pacific appears to be again crossed near Oreana.

At Mendocino totality commences at 1*h* 29*m* 47*s* local mean time, and continues 1*m* 45*s*. At San Francisco and its suburbs, Alameda, Oakland and Berkeley (the seat of the University of California, now presided over by our associate Professor Holden), the eclipse, though very large will not be total. At San Francisco the magnitude is 0.987, and it is to be regretted that the Lick Observatory on Mount Hamilton is not within the shadow; the greatest eclipse there at 1*h* 45*m* local mean time, magnitude 0.974.

J. R. HIND, in *Monthly Notices*.

An interesting article on the photographic outfit for astronomical work, at Harvard College Observatory, appears in the Boston Daily *Globe* (Feb. 12), in which are given cuts of the new instruments, buildings, and a general view of the Observatory grounds.

Sun Spots and Auroræ. On the 13th of December at 1:30 P. M. standard time of 120 meridian, I observed with the 6⅛-inch equatorial refractor of this observatory, using a sun prism and power of 40, a large spot south of the equator about one 20th of the diameter of the sun from his west limb. It was new to me, but the weather had been unfavorable for several days previously. The spot exhibited great activity. The night of the 13th showed a brilliant auroral display in the northeast. It lasted from 9:30 P. M. until 2 A. M. This is an unusual phenomenon in this region of the country. On the morning of December 14, at 11 o'clock, I noticed a large spot and nine small ones just coming from the east limb of the sun in about the same latitude as the first spot. The latter was more indistinct and nearer the limb. The coincidence of these spots with the auroral display here is further emphasized by the sudden rising of one of those dry, dessicating winds from the north which are nearly always accompanied by much electric disturbance in the atmosphere. It rose at the hour of the disappearance of the aurora, and blew with great force until 7:30 A. M. In Southern California this wind was very high and did much damage. FRANK SOULE.

Students' Observatory,
University of California, Dec. 16, 1887.

The eclipse of the moon, January 28, was not observed at Carleton College Observatory. The sky was overcast with thick clouds during its entire period. The disappointment of observers here was somewhat relieved by receiving a cable message from Paris by kindness of Mr. Appel, of Cleveland, saying that the eclipse was splendidly seen at that place.

Any person desirous of disposing of a good second-hand transit instrument, astronomical clock or Chronograph may possibly be assisted in the sale of the same by corresponding with the publisher of this journal.

Errata. I notice two misprints in my article in the January No. of THE MESSENGER. In p 24, line 11 from bottom, "he" should be "we," and line 3 from bottom "$(2.611)^3$" should be "$(2.512)^3$" W. H. S. MONCK.

National Academy of Sciences. Volume II of the Memoirs of the National Academy of Sciences contains four papers, whose titles are: Report of the Eclipse Expedition to Caroline Island, May, 1883; Experimental Determination of Wave-Lengths in the Invisible Prismatic Spectrum, by Prof. S. P. Langley; On the Subsidence of Particles in Liquids, by Prof. W. H. Brewer; On the Formation of a Deaf Variety of the Human Race, by Prof. Graham Bell.

The first two are themes of great interest to science generally, and each has received careful attention during recent years. The full discussion of Professor Hastings' theory of the solar corona will be read by the mathematician, as well as the student of solar physics, with profit. The volume, as a whole, reflects credit on those in charge of its preparation and the National Academy of Sciences.

The New Spectroscope for Lick Observatory. Some time ago we were informed that the new spectroscope for Lick Observatory had been completed and tested in a preliminary way. Soliciting information from Mr. J. A. Brashear, the maker, of Allegheny City, Pa., he kindly informed us that he had made some observations with it on the solar spectrum, using the fine grating that was ruled by Professor Rowland and that he had never seen the B group so beautifully separated into its components as he saw it in this spectroscope.

Lunar Eclipse at Baltimore. The recent total eclipse of the moon (Jan. 28) was very well observed here. The air was very clear. The illumination during the whole of totality was very considerable, and the moon was very easily seen by the casual observer.

Several small stars were occulted at the end of the total phase, the sunlight came on in beautiful contrast. The refracted light during the total phase seemed to be variable, and was decidedly so in local distribution. J. R. H.

Comet 1887 IV (Barnard May 12). Mr. Frank Muller, of the Leander McCormick Observatory at the University of Virginia, gives notice that he is planning to compute a definitive orbit for Comet 1887 IV, and asks the favor of all unpublished observations as soon as possible.

Professor P. Tacchini, of the Observatory at Rome, has recently favored THE MESSENGER with several volumes of the Memoirs of the Italian Society of Spectroscopy, of which he himself is an honored member.

By kindness of Librarian Lancaster, of the Royal Observatory of Brussels, the Annual for 1888 is received.

Professor Mary W. Whitney has been chosen to supply the place of Professor Maria Mitchel, during the leave of absence of the latter from Vassar College. Miss Whitney has studied at Harvard College Observatory.

We have recently learned, through a friend, of the equipment of an astronomical observatory for Bucknell University at Lewisburg, Pa. Mr. William Bucknell, of Philadelphia, is the generous donor. The observatory has a fine ten-inch Clark equatorial, a Fauth three-inch transit, a Waldo clock and other smaller instruments.

Markings on Mercury. At a late meeting of the Liverpool Astronomical Society, Mr. Denning, of Bristol, presented a paper on the planet Mercury, setting forth particularly studies of surface markings in 1882 especially. These light and dark tracings were so pronounced, as to suggest an analogy to those of the planet Mars. Professor Schiaparelli, of Milan, has made interesting observations of Mercury which seem to confirm those of Mr. Denning.

Pulkowa Observatory. The last *Observatory* has a report of work at Pulkowa during the last year. The transits were 3767, zenith distances, 1130, each involving two observations in reversed positions of the instruments, Professor Struve considering this the most satisfactory method of obtaining fundamental declinations, and preferring the transit circle only for differential measures.

Solar Parallax. We notice in *Bulletin Astronomique* for February, p. 65, an account of the application of a new method of discussion to the results of the Transit of Venus Observations obtained by the French expedition 1874, by M. Obrecht. He obtains for the solar parallax $8.80'' \pm 0.06.''$

Later reports from Professor W. Tempel, of Arcetri, are a little more favorable respecting his health and recovery.

Mr. E. E. Reed, of Camden, N. J., is about to erect an astronomical observatory with a six-inch equatorial. He is a gentleman of fine scientific scholarship, and he proposes to do practical work in astronomy.

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*Pons-Brooks Comet.** Messrs. Schulhof and Bossert request observers, who have unpublished observations of the Pons-Brooks comet to kindly forward them to the Observatory of Paris.

BOOK NOTICES.

Astronomy for Amateurs, a Practical Manual of Telescopic Research in all Latitudes Adapted to the Powers of Modern Instruments. Edited by John A Westwood Oliver, with the assistance of T. W. Backhouse, J. Rand Capron, W. F. Denning, T. Gwyn Elger, W. Franks, J. E. Gore, Sir Howard Grubb, E. W. Maunder and others. Illustrated. London: Messrs. Longmans, Green & Co., publishers. New York, 15 East Sixteenth Street. 1888; pp. 316.

This book supplies a real need and it will be welcomed by a large class of amateurs in the United States. This class consists mostly of young people who will certainly be helped by a plain statement of practical and useful work that inexperienced observers like most of them may soon learn to do well, who have the aid of small telescopes. This class is large and needs assistance and direction. The preliminary chapter is by the editor, who speaks directly to amateur workers, stating the useful fields of work open to them. These are, the sun, moon, planets, comets, double stars, variable stars, star colors, stellar distribution, zodiacal light, meteors and auroræ.

The chapter on the telescope is written by Sir Howard Grubb, one of the most noted of instrument makers in the world. It covers the ground well. E. W. Maunder, late editor of the *Observatory*, prepared the chapter on the sun, in which is found useful information on the measurement of sun-spots, methods of observing and recording the same, besides other things that the amateurs may do in the study of the sun. The chapter on the moon is presumably by the editor who brings out well the essentials for the young

*Bulletin Astronomique.

observer. The late useful information here given can not fail to interest the professional reader. The field of work chosen will easily hold the attention of the young observer and give him methods of study used by good observers at the present time. A full chapter on the planets appears which was prepared by W. F. Denning, also another on comet-seeking by the same author, who has been favorably known, on both sides of the water, for years, in the study of meteors. Our own Mr. Burnham of Chicago has the honor of contributing the chapter on double stars, rightly enough, if the best living authority on this subject is desired. This chapter is a reprint, with some modifications, of the matter which was published in THE SIDEREAL MESSENGER in numbers 2 and 3 of Vol. I.

The mode of computing the orbits of double stars is by J. E. Gore, who also contributes a valuable chapter on variable stars. W. S. Franks writes the chapter on the star colors, T. W. Backhouse on stellar distribution and J. Rand Caprore that on the auroræ.

The mention of the names of these writers is assurance for something good, and the book is a timely one.

The Essentials of Plain and Spherical Trigonometry. By Webster Wells, S. B., Associate Professor of Mathematics in the Massachusetts Institute of Technology. Messrs. Leach, Shewell & Sanborn, publishers, Boston and New York.

The salient points in this new book to which the attention of teachers should be called are (1) the proofs of functions of 0°, 90°, 180°, 270°. The mode of proof is by rectangular coördinates, and proper at this stage of the student's advancement, because he ought to have used such proofs in infinitesimal analysis in algebra.

2. The functions of negative arcs are carefully explained by figures and proofs clearly obtained.

3. The proofs of the fundamental formulæ for any angle are made to depend on the definitions of the functions, and generalized by the use of rectangular coördinates. Other new points are the discussion of the line values of trigonometric functions of any number of degrees, the proofs of formulæ for sines and cosines, the *ambiguous case* and considerable interest pertaining to the spherical triangle. The new points are generally improvements.

THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE,

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

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ON THE ADJUSTMENT OF A SEXTANT.

PROFESSOR GEORGE C. COMSTOCK.*

For the MESSENGER.

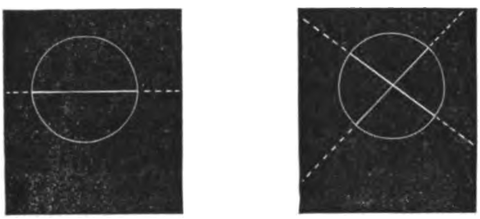
My attention has recently been called to the needlessly crude character of the methods commonly given for the adjustment of a sextant. As an example of these I may cite the method of adjusting the index glass given by *Chauvenet's Spherical and Practical Astronomy*, Vol. II., Articles 82 and 102. "Set the index near the middle of the arc; then placing the eye very nearly in the plane of the sextant and near the index glass, observe whether the arc seen directly and its reflected image in the glass appear to form one continuous arc, which will be the case only when the glass is perpendicular." * * * "By the method of adjusting the index glass given in Art. 82 it may easily be placed within 5′ of its true position."

To test the truth of this assertion I detached from its mounting the index glass of an excellent sextant belonging to the Washburn Observatory and secured it in place in such a manner that by turning a coarse micrometer screw the inclination of the mirror to the plane of the sextant could be altered at will, one revolution of the screw changing the inclination by 74′. Numerous experiments with this apparatus showed that by following the method above given the probable error of a single setting of the index glass made by turning the micrometer screw was about ±4′. This can not, however, be taken as a measure of the accuracy of the above method of testing the adjustment, since the to and fro motion imparted to the mirror by means of the micrometer screw very materially assists in determining the position in which the direct and reflected portions of the limb seem to form a continuous arc. Having determined from the mean of forty settings of the mirror, the micrometer reading at which the

* Director of Washburn Observatory, Madison, Wis.

mirror was perpendicular to the plane of the sextant, I found from experiment that if the micrometer were set anywhere within a quarter of a revolution of this reading, the eye could not detect any error in the position of the mirror, but that it could readily detect it when the micrometer was set half a revolution wrong. When the micrometer was set from fifteen to eighteen divisions wrong (1 div. = 1′.6) the eye was not satisfied with the appearance of the two parts of the arc, but was unable to determine which way the mirror ought to be moved to correct the error.

I think we may conclude from these experiments that the method of making this adjustment given by *Chauvenet* and most other writers upon the theory of the sextant, may easily be in error by as much as 20′. For many purposes for which a sextant is used an error of this magnitude in the adjustment is quite insignificant, but if the greatest precision attainable is desired the adjustment must be more carefully made. The following method is unexceptionable as regards accuracy and when all the adjustments of the instrument are to be tested is perhaps as convenient as any other.



Let the sextant be placed upon a table, or other firm and level support and let an auxiliary mirror be placed approximately perpendicular to the sextant telescope at a distance of from ten to twenty feet from it. The first step in the adjustment is to make this mirror perpendicular to the plane of the sextant. Prepare two sights by fastening threads across circular apertures in pieces of card board as in the accompanying diagram. These pieces of card board must be so fastened to wooden or metalic bases that when placed in an upright position on the arc of the sextant the centers of the apertures shall be as nearly as possible on a level with the top of the silvered part of the horizon glass. Place these sights on the sextant arc as far apart as possible and in such a position that by sighting through the apertures the image of the one nearest the auxiliary mirror may be seen reflected from it.

Then holding the eye in the line determined by the cross threads let an assistant turn the mirror until the image of the aperture in the front sight is bisected by the horizontal thread. This operation as well as all the following ones, will be facilitated by throwing a beam of reflected sunlight upon the sextant. I interchange the sights and repeat the operation in order to eliminate any want of parallelism between the line of sight and the plane of the sextant. The mean of the two positions of the mirror thus found will be perpendicular to the plane of the sextant, and if the operations have been carefully performd the error of its position ought not to exceed 1′ or 2′ as I have found by repeated experiment.

The adjustments of the sextant can now be very easily made by the use of this mirror.

I. To adjust the index glass: Tie a white thread around the middle of the index glass and turn the glass until it is parallel to the mirror which has just been adjusted. If the index glass is perpendicular to the plane of the sextant a ray of light proceeding from the thread to the mirror will be reflected back to the index glass and then to the mirror again, etc., producing a series of images of the thread, and if the eye be held in the plane passing through the real thread and its first image all succeeding images should be hidden behind the first one. If not so hidden they will form a series upon one side of it and the index glass must be adjusted until the images coincide. It is evident that this is a very delicate test and the accuracy of the adjustment is limited only by the accuracy with which the auxiliary mirror can be placed perpendicular to the plane of the sextant.

II. To adjust the horizon glass: This is best done by bringing into coincidence the images of a distant object seen directly and by reflection from the sextant mirrors. For an approximate adjustment the image of one of the sights seen in the auxiliary mirror may be used.

III. To adjust the line of sight of the telescope: Bring into the field of view the reflected image of one of the sights placed upon the arc of the sextant and by turning the adjusting screws which secure the telescope collar in place, bring the image of the aperture in the sight midway between the cross threads of the telescope. In making this adjustment it will be well to use the highest power eye-piece and the threads in the field of the telescope must, of course, be placed approximately parallel to the plane of the sextant.

The angle which the line of sight of the telescope makes with a perpendicular to the horizon glass, called β by most writers, is one of the constants which enter into the theory of the sextant. Its value may be found to a sufficient degree of approximation in connection with these adjustments. Place one of the sights on top or in front of the horizon glass and turn the whole sextant about until the image of this sight reflected from the mirror is seen midway between the cross threads of the telescope, which must now be placed perpendicular to the plane of the sextant. Set the index glass approximately parallel to the auxiliary mirror and place against the front of the glass a piece of paper folded so as to present a sharply defined vertical edge. A series of images of this paper will be formed in the mirror. Let the eye be placed in the plane passing through the edge of the paper and its first image and turn the index glass until the other images in the mirror are just hidden behind the first. The reading of the vernier corrected for index error equals 2β as may be seen by constructing a figure representing the position of the index and horizon glasses, the auxiliary mirror and the line of sight of the telescope corresponding to the observation, and the position of the index glass when parallel to the horizon glass.

ON THE NEBULAR HYPOTHESIS OF LA PLACE.

GEORGE W. COAKLEY.*

The bases of La Place's theory of the formation of the solar system are to be found in certain propositions which he has rigorously demonstrated in his "Mechanique Celeste," together with certain numerous relations among the elements of this system, which are the results of observation.

Almost the whole of the second volume of the "Mechanique Celeste," consisting, in Bowditch's translation, of 990 large quarto pages, is taken up with the mathematical investigations of the attractions of bodies of various forms, at rest or

* Professor of Mathematics and Astronomy in the University of the City of New York.

rotating on their axes. The attractions of all their parts for each other, or for any external or internal particle, are considered. The form of equilibrium of the surfaces of the earth and other planets, and of the sun, is the subject of minute and extensive investigation.

La Place's theory of the tides, both in the waters that cover the earth and its atmosphere, form a part of this same investigation. In the course of these investigations La Place establishes the *great principle* of the *constancy of areas*, described by the radii drawn to all parts of a revolving body, whether that body be solid, liquid or gaseous; or any combination of these three states of matter.

This principle may be stated as follows:

Suppose any body to revolve around an axis, passing through its centre of gravity; and suppose a plane to be drawn through the centre of gravity perpendicular to this axis. Call this plane the equator of the rotating body; then, if radii be drawn from the centre of gravity to every particle of the rotating mass, and if these radii and particles be considered to be projected perpendicularly upon the plane of the equator, the rotation of the body will carry each of these projected radii over a certain area in a given time. But as long as the mass of the rotating body remains the same, provided it is subject to the action of no external force, then, however the form of the body may change, the *sum of the products of all the particles by the projected areas which they describe in that given time*, will remain *constantly the same*. If also there be any external forces acting on the body, but directed always towards the centre of gravity, the constancy of these areas will still be maintained. This constancy, however, will not be maintained if the external variable forces be directed towards *several different centres*; nor will the sum of the areas be the same if the *mass* of the rotating body be *increased* or *diminished*.

If no change takes place in the form or size of the rotating mass, especially in the absence of external forces, then the body will have a constant, uniform motion about its axis. There are cases, moreover, where the axis is continually changing within the mass, and other cases where the axis is fixed and unchangeable within the mass. This last, or stable axis of rotation, occurs especially when the body rotates around the *shortest axis* that can be drawn through it.

These principles are rigorously demonstrated in the "Mechanique Celeste" and in other works.

For a statement of the Principle of Constant Areas in a mathematical form, and some deductions from it, see the concluding part of this article in subsequent number.

If a body have no rotation, supposing its parts to be of a yielding nature, like those of a liquid or a gas, or even a semi-liquid; then, in obedience to the mutual attraction of its particles, the body must take on a perfectly spherical form. For it is evident that the resultant of the attractions of all its parts will produce a pressure towards the centre of gravity, which pressure from opposite sides towards that centre will be in proportion to the depth, or to the distance from the centre. Hence one portion of the body's surface cannot be further from the centre than its diametrically opposite portion. If they were at different distances, the opposite pressures would be unequal, and the gaseous, liquid, or semi-liquid mass would yield in the direction from the greater pressure, or greater elevation, towards the side where the elevation and constant pressure were less. Moreover, as such masses transmit pressure equally in all directions, it is evident that the bounding surface of the body can be no other than that of a sphere.

If, however, such a body have at first a very slow rotation around an axis, a new force will arise from this rotation, tending to change the form of its bounding surface. La Place, and the older writers on mechanics, called this new force the *centrifugal force.* I shall apply to it the same name.

The force arises, as is well known, from that property of the inertia of matter, which makes it, if in motion, constantly strive to continue that motion in a straight line. When, therefore, any particle of a rotating mass is carried in a circle about the axis of rotation, it strives by its inertia to leave the circumference of that circle, and fly off in a tangent, endeavoring thereby to increase its distance from the axis. This is the centrifugal force which counteracts a part of the gravitation and pressure towards the centre, and thus changes the form of the body's bounding surface from that of a sphere to that of a spheroid or ellipsoid, whose axes are more or less disproportionate according to the amount of the centrifugal force, or according to the velocity of rotation on the axis. On the other hand, when such a rotating mass has a given ellipsoidal figure of equilibrium, in accordance with a given velocity of rotation, and consequent centrifugal forces, should it by any means be made to rotate more slowly, or should the centrifugal forces be diminished by any causes, then the tendency of the pressures towards the centre will begin to renew their sway, and to impress upon the rotating mass a form approaching more nearly that of a sphere.

To appreciate the strength of La Place's theory, it will be necessary to look more closely into the subject of centrifugal force. It is demonstrated by all writers on mechanics, including La Place, that, in a rotating mass, the value of the centrifugal force exerted on a unit of the mass situated at the distance r from the axis, may be measured by the square of the velocity at that distance, divided by the radius. If, therefore, the angular velocity of rotation be denoted by ω, the velocity at the distance r from the axis will be $r.\omega$. Hence the centrifugal force, f, at the distance r from the axis, exerted on the unit of mass at that distance is

$$f=\frac{(r.\omega)^2}{r}=\frac{r^2\omega^2}{r}=r.\omega^2.$$

Hence, as long as the angular velocity of rotation remains the same, the centrifugal force exerted on each unit of the body's mass will be proportional to the distance of that unit from the axis of rotation. If, therefore we consider especially the different units of mass at or near the surface of the rotating body, it is evident that their centrifugal forces will increase as they are nearer the equator of that body, and that those forces will diminish for the parts more remote from the equator, because the distances from the axis increase toward the equator, and diminish as the parts recede from the equator. Moreover just at the equator the centrifugal force is directly opposed to the gravitation and pressure towards the centre, while the direction of the centrifugal force is more and more oblique to that of gravity, and therefore less effective in opposing it, as the parts of the surface are more removed from the equator of the rotating body. This is easily shown by a very simple mathematical investigation, upon which, however, it is hardly necessary to enter in this paper.

The most interesting case of a rotating body, the one in fact which undoubtedly led La Place to form his celebrated hypothesis, is the one which he investigates in the second volume of the "Mechanique Celeste," Book III., Chapter vii. The chapter is entitled "On the Figure of the Atmosphere of the Heavenly Bodies."

He supposes a body like the earth, or Jupiter, or the sun, to have a more or less dense nucleus, surrounded by a rare, elastic atmosphere of any extent possible. The nucleus he considers either solid, or so dense compared with the atmosphere as to be relatively solid, and to contain by far the greatest amount of the body's mass. The form of the nucleus, for convenience, he takes to be already reduced to that of a spheroid differing but slightly from that of a sphere, but the form of the atmosphere's bounding surface he leaves to be determined solely by the play of the centrifugal and gravitating forces resulting from any given mass and velocity of rotation that the body can have. This investigation is begun upon the 519th page of the second volume, or a little after the middle of the volume of nearly 1,000 pages. But to follow the demonstration completely presupposes a familiarity with not only about all of the previous 500 pages, but also with most of the first volume as well. It is rather too much mathematics to compress within the limits of this paper.

Nevertheless the equation of equilibrium which La Place demonstrates for the surface of the atmosphere of such a rotating body is simple enough; and the subsequent use he makes of it is so important to the right appreciation of his celebrated hypothesis, that I must ask you to allow me to state and explain, but not to prove it.

In Bowditch's translation it is the equation marked number [2120]; and is as follows:

$$c = \frac{2}{r} + \frac{n^2}{M} . r^2 \sin^2 \theta.$$

I have, however, replaced La Place's *a*, in this equation by its value $\frac{n^2}{M}$, deduced in Bowditch's note.

The meaning of the equation is this; La Place has previously proved that the figure of equilibrium of the atmosphere is an ellipsoid of revolution with its shortest axis coinciding with the axis of rotation. Suppose, then, a section of this surface to be made by a plane passing through the axis of rotation. The section will be a curve, an ellipse, of which the above is the equation. c is a constant introduced by integration, the value of which is yet to be determined. r is the variable radius drawn from the centre of gravity, or from the ellipse, to any point of the section on the surface of the atmosphere. θ is the variable angle which this radius makes with the axis of rotation. M is the mass of the rotating body, including the atmosphere. n is the angular velocity of rotation, the same which has previously been denoted by ω.

To determine the constant, c, La Place supposes the radius, r, to be drawn to the point where the axis of rotation meets the surface of the atmosphere, and denotes the length of this radius by R. This, of course, is the polar radius of the elliptical section of the atmosphere. This radius, R, makes with the axis of rotation the angle $\theta = o$. Making these substitutions in La Place's equation, the value of his constant, is obtained, namely

$$c=\frac{2}{R}$$

Replacing c by this value, his equation becomes

$$\frac{2}{R}=\frac{2}{r}+\frac{n^2}{M}.r^2 sin^2\,\theta. \quad [2123] \text{ of Bowditch.}$$

If now we suppose $\theta=90°$, r will become the *equatorial radius*, for which La Place puts R'. Hence, as $sin.\ \theta=1$, the equation [2122] becomes

$$\frac{2}{R}=\frac{2}{R'}+\frac{n^2}{M}.R'^2.$$

Hence,

$$\frac{n^2}{M}.R'^2=\frac{2}{R}-\frac{2}{R'}=\frac{2(R'-R)}{RR'}, \text{ or } \frac{n^2}{M}.R'^2=2\left(\frac{R'-R}{R}\right).$$

which is the form in which La Place puts his next equation.

(TO BE CONTINUED.)

ASTRONOMICAL PHOTOGRAPHY.*

The application of photography to astronomical research is rapidly transforming its destinies. The more closely the exquisite sky prints recently taken at Paris and elsewhere are studied, the more opulent of promise they appear. Their pictorial beauty is the least of their merits. In the eyes of the astronomer their eminent value lies in their capability of exact measurement. Upon this basis of fact rest anticipations which to unaccustomed ears sound exaggerated, but which the future will, unless we are much mistaken, amply justify. We can have no hesitation in admitting that what has been done, not by chance, but on system, can be done again. Results already obtained can be repeated and multiplied. It needs no more—although much more will probably be accomplished—to ensure a new birth of knowledge regarding the structure of the universe.

The scientific importance of Daguerre's invention was perceived from the outset. In formally announcing it to the Academy of Sciences, August 19, 1839, Arago characterized it as a "new instrument for the study of nature," the manifold uses of which must baffle, and would assuredly surpass, prediction. "En ce genre," he added significantly, "c'est 'sur l'imprévu qu'on doit particulièrement compter."† And it is indeed the unforeseen which has come to pass. Arago himself, with all his readiness to admit incalculable possibilities, would have been staggered by a forecast of the work now actually being done.

Celestial photography, as was natural, made its first essay with the moon. The broad, mild face of our satellite, diversified with graduated lights and intense shadows, formed a

* From January "Edinburgh Review," being a review of the following articles:

1. La Photographie Astronomique a l'Observatoire de Paris et la Carte du Ciel. Par M. le Contre-Amiral E. Mouchez. Paris: 1887.

2. An Investigation in Stellar Photography conducted at the Harvard College Observatory. By Edward C. Pickering. Cambridge, U. S.: 1886.

3. First Annual Report of the Photographic Study of Stellar Spectra conducted at the Harvard College Observatory. By Edward C. Pickering, Director. Cambridge, U. S.: 1887.

4. The Applications of Photography in Astronomy. Lecture delivered at the Royal Institution, Friday, June 3, 1887. By David Gill, LL.D., F.R.S. (The Observatory, July and August, 1887.)

5. Die Photographie im Dienste der Astronomie. Von O. Struve. (Bulletin de l'Academie Imperiale des Sciences de St. Petersbourg, Tome xxx. No. 4: 1886.)

† Comptes Rendus, tome ix. p. 264.

tempting subject for the nascent art. At Arago's suggestion, accordingly, Daguerre exposed one of his sensitive plates to the lunar rays, but with a disappointing result. Nothing worthy the name of a picture made its appearance. Professor J. W. Draper, of New York, however, obtained early in 1840 some little prints, not altogether characterless of the lunar surface, after which the subject dropped out of sight during ten years. It was resumed at Harvard College Observatory by George P. Bond, one of whose lunar daguerreotypes attracted deserved attention at the Great Exhibition of 1851. The light employed to produce them was concentrated by a telescope fifteen inches in aperture, equatorially mounted, and kept fixed by a clock-work movement upon the moving object to be depicted.

Bond's pictures marked the close of the first or tentative period in celestial photography. In 1851, the collodion process was introduced by Frederick Scott Archer, and rapidly superseded all others. Daguerreotypes, lunar, solar and terrestrial, began to assume an antiquarian interest and aspect.

Collodion is a colorless, semi-viscous fluid produced by dissolving gun-cotton in a mixture of alcohol and ether. Spread upon glass, it forms a transparent membrane rendered susceptible to the action of light by impregnation with salts of silver. The 'sensitiveness' of these substances is due to their possessing a molecular equilibrium so delicate as to be overturned by the quick ethereal impacts of the vibrations of violet light. The metal they contain, thus partially released from the bonds of chemical combination, is ready to attract further deposits; and the opportunity of exercising this power of appropriation is afforded by the processes of development.* A photograph is hence a picture painted in metallic silver under the regulating influence of light.

Mr. Warren De la Rue was the first to turn Archer's improvement to account for astronomical purposes. He began his photographic work towards the close of 1852 with a thirteen-inch reflector of his own construction which gave him successful pictures of the moon, one inch across, in ten to thirty seconds. Some taken later with improved means bore enlargement to eight inches, and clearly showed details

* Some kinds of development merely complete the "reducing" process begun by the action of light, without adding any fresh metallic supplies.

representing an actual area on the moon's surface of about two and a half square miles. The distribution of light and shade in them differed so notably from that perceived with the eye as to afford hints (it was thought) towards a science of lunar geology, formations of different epochs being distinguished by their varying powers of reflecting the actinic rays.* The marked deficiency in chemical power of the so-called "seas," in especial, suggested that they might in reality be plains clothed with vegetation, the vital needs of which were supplied by a dense, low-lying atmosphere.

Mr. De la Rue showed further that, by the stereoscopic combination of two photographs taken at opposite phases of the moon's libration, something might be learned as to the relative age of lunar craters. The deep furrows diverging from Tycho, for instance, were perceived to run right through some craters, but to be overlaid by others.† Obviously, then, the dislocated craters were already in existence when these clefts opened, while the unaffected ones were of later production. With the improved photographic methods now in use, it is quite possible that the real position in Jupiter's atmospere of the great red spot adhering to his southern belt may in this way be determined; perhaps even indications derived as to the nature of the mysterious Martian canals.‡

The immediate followers of De La Rue in lunar photography were two gifted Americans, Dr. Henry Draper and Lewis M. Rutherford of New York. The moon, as seen with the naked eye, is about one tenth of an inch in diameter, that is to say, it is just covered by a disc of that size held at the ordinary distance for clear vision.§ One of Draper's pictures, taken with a fifteen-inch silvered glass reflector, Sept. 3, 1863, and subsequently enlarged, showed it as three feet across, or on a scale of about sixty miles to the inch. The spectator was virtually transported to a point 600 miles from the lunar surface.

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* Report British Association, 1859, p. 145.

† Monthly Notices, vol. xxiii. p. 111.

‡ The rotation of the planets gives the differences in the point of view requisite for obtaining stereoscopic relief. Photographs taken at intervals—for Jupiter of twenty-six, for Mars of sixty-nine minutes—combine with the proper effect. De la Rue, "Report Brit. Ass." 1859, p. 148.

§ H. Draper, "Quart. Jour. of Science," vol. i. p. 381.

Reflectors possess the great advantage of being perfectly achromatic. Undulations of all wave lengths are collected by them at a single focus. In refractors, on the other hand, there is always a certain amount of dispersion. Opticians have to choose which rays to unite, leaving the others to shift for themselves. They in general, of course, bestow exclusive attention on those of greatest visual intensity. Ordinary achromatics have hence no sharp chemical focus. Rutherford, however, took the more rapid vibrations alone into account in calculating the curves of an object glass of eleven inches designed expressly for photographic use. He thus set the example of deliberately constructing a telescope totally unserviceable to the eye. By its means were obtained in 1865 lunar photographs which marked the culmination of the art in its second or "wet-collodion" stage.

Yet the result, striking as it was in some respects, somewhat disappointed expectation in others. The details of structure were not so distinctly given as to serve for a criterion of future change; nor has any lunar photograph yet taken shown the crispness of the best telescopic views. The reason is obvious. Atmospheric shiverings which the eye can to some extent eliminate, produce their full effect on the sensitive plate. The resulting picture is the summation of a multitude of partial impressions due to evanescent distortions and displacements of the image.

It was perhaps owing to a sense of partial failure that lunar photography fell into neglect during twenty years. Now, at last, there are signs of revived interest in it. Recent improvements afford great advantages for its cultivation. Owing to the high sensitiveness of modern plates the images thrown upon them can be strongly magnified, while the time of exposure is still kept extremely short. The MM. Henry have accordingly adopted the plan of photographing the moon in sections, six or eight of which cover the visible hemisphere and are united to form a map one and a half to two feet in diameter. A repetition of the process at intervals will test the occurrence of variations in lunar topography extending over not less than one and one half square miles.

The finest telescope in the world for the purposes of moon-portraiture is undoubtedly the giant refractor of the Lick

Observatory in California. With an aperture of three, and a focal length of fifty feet, it gives a direct image of the moon six inches in diameter, negative impressions of which may be enlarged with advantage to perhaps twelve feet. But the third lens, by which the correction of this superb instrument can be modified at pleasure to suit the actinic rays, has yet to be provided; and perfect glass discs of thirty-six inches are not to be had for the asking. They may be bespoke a long time before they are forthcoming.

The sun can now be photographed in the inconceivably short space of the one hundred thousandth part of a second!* A short exposure, followed by a long and strong development, gives the best results; and it is difficult to see how those obtained by M. Janssen at Meudon during the last eight or nine years can be much improved upon. It might, however, be found possible to work on a larger scale. Advantage for the exhibition of details would probably be derived from the use of a solar image more highly magnified than has hitherto been customary.

The historical starting point of solar photography is a daguerreotype taken at Paris by MM. Foucault and Fizeau, April 2, 1845. The attempt, though not unsuccessful, remained isolated for a number of years. The eclipsed sun was the subject of the next experiment. Busch and Berkowski of Königsberg obtained a slight but distinct impression of the corona during the total eclipse of July 28, 1851. But the triumph of practically establishing the value of photography as a means of investigating the solar appendages was reserved for Mr. De la Rue and Father Secchi. By the comparison of photographs taken at various stages of the eclipse of July 18, 1860, the status of the "red protuberances" was settled forever. The advance of the moon *over* them proved beyond cavil that they belong to the sun.

The camera is an encroaching instrument. So surely as it gains a foothold in any field of research, so surely it advances to occupy the whole, either as adjunct or principal. Telescopic and direct spectroscopic observations during solar eclipses are now altogether subordinate in importance to photographic records of them. Fleeting appearances likely either to escape or to mislead the eye during the lapse of

* Janssen "Annuaire du Bureau des Longitudes," 1883, p. 809.

those counted and crowded moments, are stored up for leisurely interpretation; and the whole working power of the mind can thus be devoted to the collection of materials for subsequent discussion. The discovery of a comet close to the sun, May 17, 1882, is a picturesque incident of eclipse photography. "Tewfik," as the object was named in compliment to the reigning Khedive, made its first known appearance to terrestrial spectators during the seventy-four seconds of total obscurity at Sohag. It was caught with beautiful distinctness on Dr. Schuster's plates of the corona, and its place was measured from them; but for lack of previous or subsequent observations, it must forever remain unidentified.

But we must hurry on, lest time fail us to describe the latest developments of this marvelous art. They are due to improvements of a fundamental kind in photographic processes. Collodion-plates can practically only be used in a wet state. This narrowly limits the time of exposure. Moreover, the preparation of each plate must immediately precede and its development immediately follow exposure—conditions which inconveniently hamper the operations of the astronomical photographer. In 1871, however, gelatine was by Dr. R. L. Maddox substituted for collodion, silver bromide being exclusively used as the sensitive substance. The advantages of the new process were quickly perceived and improved. Gelatine is not, like collodion, a merely neutral vehicle. It possesses a reducing power of its own which steps in as an auxiliary to that of light. Hence the extraordinary rapidity of the "gelatino-bromide" plates now universally employed. Chief among their recommendations to "astrographers" are the faculties of keeping indefinitely, and gaining five fold sensitiveness by drying. They can thus be prepared at leisure, exposed with constantly accumulating effect for an unlimited period, and developed when convenient.

Their singular adaptation to the exigencies of celestial research was first perceived by Dr. Huggins, who used "dry plates" in his experiments on photographing stellar spectra in 1876; and his advice and example were followed, a few years later, by Draper and Gould in America, by Common and Janssen in Europe. The change has proved of the highest moment to science.

We have heard much lately of the power and promise of the "new astronomy," and celestial physics have indeed, in our day, entered upon a splendid career. Like "England's great Chancellor," it "has taken all knowledge to be its province." No truth regarding the material universe is indifferent to it. It assimilates every variety of information. Scarcely an experiment can be performed in a laboratory without directly or indirectly promoting its interests. The labors of electricians, meteorologists, geologists, mineralogists, chemists, are all made available. No science can be its rival, because each one is its colleague and ally. The results have been commensurate with this vast extension of resources. Knowledge, ample and assured, has been accumulated of a kind which, previous to the middle of the present century, appeared to the profoundest thinkers for ever unattainable. Undreamt-of analogies between celestial and terrestrial phenomena have been disclosed. Above all, boundless prospects of future discovery have been thrown open, and the keenest stimulus to persistent effort has thus been supplied.

The new astronomy has accordingly found eager and numerous votaries in all its various branches. Yet its popularity seemed attended by a twofold danger. The majestic elder astronomy—the astronomy of Hipparchus, Bradley, and Bessel, of Newton, Leverrier, and Adams—might, it was to be feared, suffer neglect through the predominant attractions of its younger, more versatile, and brilliant competitor; or its lofty standard of perfection might become lowered through the influence of workers more zealous than precise, recruited from every imaginable quarter, inventive, enthusiastic, indefatigable, but unused to the rigid requirements of mathematical accuracy.

Both these perils have been happily averted. The prospect has suddenly cleared and brightened. The new astronomy has submitted to bear the yoke of the old. The old astronomy has adopted the new methods, and is even now anxiously fitting them to its own sublime purposes. It has enlarged its boundaries without departing one iota from its principles. By an effort which shows it to be still young and elastic, it has seized the key of the situation, and now stands hopeful and dominant before the world.

This union of the two astronomies has long been in remote preparation. Artists and experimenters innumerable have unconsciously urged it on. It has been promoted by improvements in the manufacture of glass, in the shaping of lenses, in the grinding, polishing, and silvering of mirrors, by the growth of intimacy with the peculiarities of salts of silver, and by the growth of skill in their employment for the purposes of light portraiture. The meeting last year at Paris of an International "Astrophotographic" Congress marked its accomplishment. This event will undoubtedly prove to be of the "epoch-making" description. Future ages will look back to it as the beginning of great achievements. To have been concerned with it will in itself be counted as giving a title to fame. Circumstances concurred to bring it about just at the right moment.

Stellar photography originated with a daguerreotype of Vega (α Lyræ) taken at Harvard College July 17, 1850. The oval shape of an image of Castor obtained about the same time indicated its duplicity; but these impressions were very faint, and none at all could be derived from objects of inferior lustre, such as the pole-star. Then the collodion process was introduced, and with its aid the younger Bond, in 1857, extended the depicting powers of the camera to stars of the sixth magnitude. Still more significantly, he demonstrated the applicability of photography to the astronomy of double stars by executing upon prints of *Mizar* in the Tail of the Great Bear a set of measures which proved superior in accuracy to those of the ordinary visual kind. He also led the way in photographing what are called "star-trails." When Vega, the clock being stopped, was allowed to "run" upon the plate by its own diurnal motion, its passage remained marked by a fine line. The principle of "trails" has been turned variously to account in recent investigations.

Rutherford reached the limit, in this direction, of what was possible to be done with wet plates. In and after the year 1864 he secured photographs of a number of clusters, including stars down to the ninth magnitude, from one of which Dr. Gould deduced places for nearly fifty Pleiades, agreeing so closely with Bessel's, of a quarter of a century earlier, as to put beyond doubt the extreme minuteness of the relative motions of those stars. When it is added that quantities of $\frac{1}{500000}$ of an inch were measurable on Rutherford's negatives, it becomes clear that the era of observations "of precision" by photographic means was fast approaching.

With the introduction of dry plates it may be said to have arrived. They were indeed indispensible, no less for charting than for exploring the skies. Photography is of service for these purposes just in proportion to the number of faint stars it can register. But here length of exposure is all-important; and long exposures are impossible with plates subject to change by evaporation.

Impressions on the sensitive plate are cumulative as well as permanent. Those on the living retina are neither. The maximum effect of a luminous object on the human eye is produced in one-tenth of a second. Beyond that limit there is continual effacement and renewal. Were it not for this faculty of rapid obliteration, we should see, with the strangest results of visual confusion between time and space, not what we were actually looking at, but what had met our eyes some short time previously. A vast gain in penetrative power would, however, ensue upon a very moderate extension of the time during which the eye can collect impressions. By lengthening it to one second the brightness of visual images would be nearly decupled, and the whole heavens would appear, like the Milky Way, dimly luminous with minute stars.*

This retentive power is possessed, in an eminent degree, by a sensitised gelatine film. No limits have, so far, been set to the time of useful exposure. Successively, as the rays continue to impinge upon it, all the orders of the stars, all the secrets of the sky, disclose themselves to its patient stare. It has thus become possible to photograph stars too faint to be seen with the same optical aid. Some of those sprinkled over the Orion nebula, in Mr. Common's beautiful picture of it, were probably beyond the reach of direct observation with the 36-inch mirror employed; and Dr. Draper at the time of his death in 1882 was making arrangements for exposing plates during nearly six hours, by which he hoped to

* Janssen "Annuaire," p. 809. Paris: 1883.

get notified of the existence of stars sunk in depths of space hopelessly inaccessible to telescopic vision.*

But the decisive impulse towards the greatest astronomical undertaking of this century came otherwise. The Royal Observatory at the Cape of Good Hope was, in 1882, unfurnished with any photographic appliances. The activity reigning there was of a rigorously orthodox kind. The ample programme of work in course of execution included nothing for which Halley or Maskelyne would have been unprepared. "Astrophysical" tendencies, of whatever description, were absent from it. Nor did any such exist in the mind of the Royal Astronomer. Dr. Gill belonged to the strict school of Bessel; in the use of the heliometer he was Bessel's legitimate successor. His leading title to distinction at that time was a masterly determination of the sun's distance, for which the opposition of Mars in 1877 had given the opportunity; and he was engaged upon a set of measures for stellar parallax of unsurpassed excellence, and now of standard authority. His energetic administration was mainly directed towards promoting the interests of practical astronomy in the southern hemisphere; and he was far from suspecting that in the camera an instrument was at hand more rapidly effective for the purpose than the transit or the heliometer. He was not, however, slow to avail himself of it.

The splendid appearance, at the Cape, of the great comet of 1882 challenged photographic portrayal; and Dr. Gill employed for that end the apparatus, and profited by the experience, of Mr. Aldis, a local artist. An ordinary portrait-lens, of only two inches aperture and eleven focus, was attached to the stand of the Observatory equatorial, the telescope itself serving as a guide to the small corrections needed of the clockwork following motion during exposures lasting from half an hour to two hours and twenty minutes. A series of pictures resulted, one of which was exhibited by Dr. Gill in the course of his lecture at the Royal Institution, cited, from its importance to our present subject, among our authorities. They were remarkable, not only for the strength and fidelity with which their principal subject was

* Rayet, "Bulletin Astronomique," tome iv. p. 320.

represented, but for the accessory wealth of stars they displayed. The entire background was thickly strewn with them. Forty or fifty, down to the ninth magnitude, shone across the interposed film of the comet's tail.

The sight of the Cape photographs set the whole astronomical world upon the business of stellar chartography. They emphasized the advantages to be derived from the use of lenses of short focus and wide field, giving small, bright images of tolerably extensive sky landscapes.* To Mr. Common they "came as a revelation of the power of photography" for star-charting purposes; and he proposed to Dr. Gould, then (in 1883) at Cordoba in South America, a joint photographic survey of the whole heavens, which it was not however found practicable just then to undertake. Investigations of relative stellar brightness by photographic means were almost simultaneously executed by Professor Pickering at Harvard and by Mr. Espin in Lancashire; and Mr. Roberts of Liverpool began, and has made considerable progress with, a detailed chart of northern stars.

But by far the most important of these preliminary enterprises was that of completing, in the southern hemisphere, the great northern star-census executed by Argelander at Bonn above a quarter of a century ago, and lately extended by Schönfeld to twenty degrees south of the equator. The "Durchmusterung," comprising in its two sections nearly 458,000 stars, may be described as the roll-call of the stellar army. Stars not entered in it have no official existence; should they fade and vanish the fact cannot be attested; should they brighten into conspicousness we are obliged to regard them as "new" for lack of previous acquaintanceship. Whatever is known of the distribution of the stars in space is founded on this grand enumeration, which was, besides, an essential prelude to more refined measurements.

A corresponding enrollment of southern stars was one of the most pressing needs of astronomy; and it is now, by novel means, in course of being supplied by Dr. Gill. His photographic "Durchmusterung" will extend from the limit of Schönfeld's zones to the south pole, and will include all stars brighter and many fainter than the ninth magnitude.

* Mr. De la Rue showed experimentally in 1861 that such instruments were the most proper for mapping the stars. "Report Brit. Ass." 1861, p. 95.

The requisite number of plates will probably have been secured in two or three years; while the catalogue derived from their measurement, through the disinterested labors of Professor Kapteyn of Groningen, may be completed in five or six. It will give the places (exact to one second of arc) and magnitudes of thirty per cent more stars per square degree than are contained in the Bonn Catalogue, and will furnish "working lists" for still more accurate determinations for about the epoch 1900.*

But we have not yet exhausted the results of the comet-pictures of 1882. Thirty-six years have elapsed since Chacornac began, at the Paris Observatory, the laborious task of charting ecliptical stars to the thirteenth magnitude. His object was the detection of asteroids, by obtaining an individual acquaintance with the small stars strewing their route in the sky; but he died in 1873, leaving the work only half finished. For its completion the resources of the newer astronomy had to be called into play.

His successors were MM. Paul and Prosper Henry, two brothers united by a rare community of tastes and endowments, inseparable in their labors, scarcely distinguishable by fame. In ten years they constructed sixteen additional maps out of a total of seventy-two; but they were arrested by encountering, where the ecliptic crosses the Milky Way, a throng of minute objects, totally unmanageable by the ordinary methods. The perplexity in which they found themselves was dissipated by a glance at the starry background of Dr. Gill's comet. They determined to have recourse to photography; their stars should henceforth register themselves. From that hour visual star-charting became a thing of the past.

The unmistakable success of some preliminary experiments earned for their scheme the warm approval of Admiral Mouchez, Director of the Paris Observatory, the title of whose valuable little book heads this article; and the construction of the largest photographic telescope yet seen was officially sanctioned. In May, 1885, an instrument on a somewhat novel plan, the optical part by the MM. Henry, was mounted in the garden of Perrault's edifice. It consists of two telescopes, one adapted for chemical, the other for

* Auwers, "Monthly Notices," vol. xlvii. p. 455.

visual use, enclosed in a single rectangular tube. The photographic objective is of thirteen inches aperture and eleven feet focus, its curves being computed to enable it to take in a wide area of the sky without sensible deformation of the images. Their complete immobility in the field is secured by a skilful use of the guiding telescope. During the time of exposure the eye of the operator is never removed from it, and incipient deviations are checked by his hand.

The results of the employment of this apparatus by the MM. Henry were summed up by Admiral Mouchez before the Academy of Sciences, January 18, 1887.

"At the Paris Observatory," he stated, "we now easily obtain, with exposures of an hour, plates upon which thousands of stars down to the sixteenth magnitude are portrayed with the utmost nicety and distinctness over an area of six or seven square degrees. That is to say, the limit of visibility with our best telescopes under the sky of Paris is considerably overpassed, and we have even obtained many seventeenth magnitude stars doubtless never anywhere directly observed. The stellar images, varying in diameter proportionately to magnitude, afford useful data for photometric determinations.

"Objects other than stars, invisible in our most powerful instruments, sometimes appear on the plates. Such is the Maia nebula in the Pleiades, depicted like the tail of a brilliant little comet attached to the star, yet heretofore undetected, notwithstanding the exceptional amount of attention bestowed upon the Pleiades group. Unknown bodies, in sufficiently rapid movement to become sensibly displaced in an hour—minor planets, for instance, comets, the problematical trans-Neptunian planet, or undiscovered satellites—may reveal their existence by imprinting the line of their route among the fixed stars, as Pallas has been observed to do.

"The distinct visibility, on a photograph submitted to the Academy, of the interval of 0″.4 between the rings of Saturn, gives a prospect of securing impressions of double stars at that apparent distance. The satellite of Neptune has been photographed in every part of its orbit, even when it is only 8″ from the planet.*

"With the consideration before us that the stars below the sixteenth magnitude have thus been photographed amid the turbid atmosphere of Paris, it becomes difficult to imagine the prodigious quantity of new objects which would be disclosed on the plates of the MM. Henry could they be exposed under the pure skies of the tropics, or at so favourable a station as the Pic du Midi. Stars of the eighteenth magnitude would then not improbably emerge to view, showing a penetration of the heavens to depths never before sounded. Such plates would doubtless, at a little distance, like the firmament itself in serene tropical nights, assume a uniformly nebulous aspect. We hope then to apply photography not only to the regular prosecution of celestial chartography, but to researches on double stars, and to explorations in search of unknown heavenly bodies."†

* No visual observations of Neptune's satellite have ever been made at Paris.

† Mouchez, "La Photographie Astronomique," p. 37.

Specimens of the Paris photographs were soon in the hands of astronomers in all parts of the world. They were received with admiration not unmixed with incredulity. They seemed too absolutely perfect to be wholly genuine. Abundant evidence was however at hand to show that their extraordinary precision was really the fruit of unparalleled skill, and this conviction, once attained, was decisive of the future of astronomy.

On one of the plates, covering an area of about four square degrees in the constellation Cygnus, where 170 stars had previously been identified, some 5,000 were clearly imprinted. Wolf's great map of the Pleiades, founded on laborious servations extending over several years, contains 671 stars; photographs taken in a few hours by the MM. Henry supplied materials for charting 1,421 stars of the same group down to the sixteenth magnitude with an exactitude unattainable by visual means. The significance of such results was not to be mistaken. They pointed to a great task, the execution of which was felt to be imperative so soon as it had become possible; and Dr. Gill gave expression to a universal sentiment when he proposed, June 4, 1886, an International Congress for the purpose of organising a photographic survey on a grand scale of the entire heavens.

Fifty-five delegates of fifteen different nationalities took part in the deliberations of the memorable assembly which met at Paris, April 16, 1887. They were concluded in nine days, and were as harmonious as they were prompt. Enthusiasm for a great end secured unanimity as to the means; differences of opinion vanished as if under the pressure of some supreme crisis. The upshot of the meetings was to set preparations on foot for the charting of over twenty millions of stars! So far have we got by the aid of photography.

The co-öperation of ten or twelve observatories in both hemispheres can be reckoned upon, and the work will be executed upon an identical plan with instruments similar in every respect to that of the MM. Henry. About ten thousand plates (duplicated to avoid accidental errors), each exposed during a quarter of an hour, will record the positions of all the stars in the sky to the fourteenth magnitude—the prescribed limit of faintness. This part of the undertaking can scarcely occupy less than five years. For the orientation of each plate, a single "star-trail" (necessarily running along a parallel of declination) will suffice. The *absolute* places of the imprinted stars will be deduced from accurate measurements of their situations relative to certain "standard stars," of which a sufficient number will be found on every plate.

But there is to be a catalogue as well as a chart, and, in Dr. Gill's opinion, "the work which astronomers of future generations will be most grateful for, and which will most powerfully conduce to the progress of astronomy, will *not* be the chart but the catalogue." Plates showing fourteenth magnitude stars, however, are necessarily over-exposed for the brighter ones, and are hence not available for the most refined determinations. A set of short-exposure plates, reaching to the eleventh magnitude, are accordingly to be taken with a view to cataloguing about one million and a half stars to serve as reference-points for the twenty millions crowded on the chart plates. Such a catalogue (we again quote Dr. Gill) "may be considered complete for the practical purposes of astronomy, because the eleventh magnitude is the faintest which can be measured with accuracy in the larger class of equatorials usually employed in working observatories."

The mass of stellar statistics thus collected will include data as to relative brightness. The "magnitudes" of stars can be derived from photographs either by comparing the size of their images on the same plate, or by measuring the time that elapses before they produce a sensible impression. Estimates founded on the circumstance that the diameters of the photographic discs of stars bear a strict ratio to their lustre have proved accurate (on an average) to one-fifth of a magnitude; and varying length of exposure affords the only fixed standard of brightness at present available for the minuter orders of stars. The photometric range of the eye is somewhat narrowly limited, and large errors attest its incompetence below the eleventh or twelfth magnitude. The sensitive plate, on the other hand, measuring light-intensity as it were by the clock, records its gradations between faint objects more precisely than between bright, because the corresponding intervals of time are larger. Stars of the first, second, and third magnitudes can all be photographed in a small fraction of a second; but stars of the thirteenth magnitude require five, of the fourteenth thirteen, of the sixteenth eighty minutes, before they become perceptible with the apparatus of the MM. Henry. Intermediate positions on the photometric scale can hence, it is obvious, be assigned much more easily and securely towards its lower end.

(TO BE CONTINUED.)

THE COMETS OF 1887.

DR. H. C. WILSON.*

For the MESSENGER.

The authorities referred to in this paper are the *Astronomische Nachrichten* (A. N.), *Astronomical Journal* (A. J.), *Bulletin Astronomique* (B. A.), *Monthly Notices of the Royal Astronomical Society* (M. N.), and SIDEREAL MESSENGER (S. M.). The numbers of volume and page are both given in figures but are separated by periods. Different pages of the same volume are separated by commas, and different volumes by the semicolon. Thus A. N. 117. 293, 307; 118. 109, means *Astronomische Nachrichten*, vol. 117, pp. 293 and 307; vol. 118. p. 109. I have endeavored to collect references to all of the observations published in the above journals, and to give the dates of the first and last observation at each place.

Comet 1886 VII (Finlay *e* 1886, Sept. 26). This comet was observed during the last three months of 1886 and the first two months of 1887. The first elements determined of the orbit of this comet bore such a resemblance to those of the lost comet of De Vico, 1844 I, that the two were thought to be identical. The later computations by Professor Krueger and Professor Boss render the identity very doubtful (see further upon this point *Astr. Nach.* 116. 335, *Astr. Jour.* 7. 43, and *Sid. Mess.* 6. 121). The elements by Professor Krueger depend upon observations from Sept. 29, 1886, to Feb. 23, 1887, and are as follows:

$$T = 1886, \text{Nov. } 22.38708 \text{ Greenwich mean time.}$$

$$\left.\begin{aligned} \pi &= \ \ 7^\circ 34' 14.6'' \\ \Omega &= 52 \ \ 29 \ \ 58.8 \\ i &= \ \ 3 \ \ 01 \ \ 39.2 \end{aligned}\right\} 1886.0.$$

$$\varphi = 45 \ \ 54 \ \ 22.7$$

$$\mu = 532''.6894.$$

$$\text{Period} = 2432.937 \text{ days.}$$

* Carleton College Observatory.

The following observations have been published:

Albany, Sept. 29—Feb. 25, A. J. 7. 21, 52, 84.
Alger, Dec. 11—Jan. 25, B. A. 4. 136.
Berlin, Dec. 17, A. N. 117. 171.
Bethlehem, Pa., Oct. 16—Jan. 26, A. J. 7. 54, 61.
Bordeaux, Nov. 24—Dec. 30, A. N. 117. 99.
Brussels, Nov. 22—Jan. 17, A. N. 117. 145.
Cape, Sept. 26—Dec. 28, M. N. 47. 290; A. N. 116. 309.
Cordoba, Oct. 14—Jan. 27, A. N. 117. 271; A. J. 7. 117.
Dresden, Nov. 27—Feb. 12, A. N. 116. 43, 111, 247.
Genf, Sept. 29—Feb. 10, A. N. 117. 41.
Glasgow, Nov. 12—Feb. 24, A. N. 117. 113.
Gottingen, Jan. 18, A. N. 116. 219.
Greenwich, Jan. 16—25, M. N. 47. 275.
Hamburg, Dec. 18—Jan. 23, A. N. 116. 111, 219.
Kiel, Nov. 22—Feb. 11, A. N. 116. 13, 77, 111, 127, 219.
Kopenhagen, Dec. 19—Mar. 16, A. N. 118. 73.
Kremsmunster, Oct. 23—Jan. 27, A. N. 116. 41; 117. 147.
Lyon, Nov. 12—Dec. 23, B. A. 4. 100.
Milan, Dec. 12—Jan. 28, A. N. 117. 163.
Nice, Sept. 29—Dec. 6, A. N. 115. 239; 116. 151; B. A. 4. 134.
Orwell Park, Nov. 18—Feb. 25, M. N. 48. 55.
Padua, Nov. 19—Dec. 26, A. N. 116. 215.
Palermo, Nov. 17—Dec. 18, A. N. 116. 151, 263.
Plonsk, Nov. 26—Jan. 25, A. N. 116. 261.
Pola, Oct. 23—25, A. N. 116. 193.
Princeton, Dec. 16—Feb. 19, A. J. 7. 110.
Rome, Sept. 29—Feb. 25, A. N. 115. 237, 253, 267, 283, 303; 116. 27, 43, 331.
Sydney, Sept. 30—Oct. 12, M. N. 47. 68.
Taschkent, Oct. 28—Nov. 18, A. N. 116. 247.
Turin, Oct. 22—Dec. 23, A. N. 115. 397; 116. 153; 117. 115.
Washington, Sept. 30—Feb. 16, A. J. 7. 8, 31, 62, 78.
Wien, Sept. 30—Dec. 26, A. N. 116. 347.
Windsor, Oct. 8—Dec. 30, A. N. 117. 109.

Comet 1886 VIII (Barnard *c* 1887, Jan. 23). This was the third comet discovered in 1887, but had already passed its perihelion Nov. 28, 1886. It was discovered by Mr. E. E. Barnard, of Nashville, Tenn., on the morning of Jan. 24, a dim hazy object several degrees southwest of β Cygni, circular, 1′ in diameter, with some central condensation. It moved northward, diminishing slowly in brightness, the last published observation being at Orwell Park, May 20. The latest published elements are by Mr. H. V. Egbert (A. J. 7. 87) and depend upon only three single observations, on the dates Jan. 24, Feb. 18, and March 20.

$$T = 1886, \text{ Nov. } 28.37512, \text{ Greenwich mean time.}$$

$$\left.\begin{array}{l} \omega = 31^\circ 53' 16'' \\ \Omega = 258 \;\; 11 \;\; 58 \\ \iota = 85 \;\; 35 \;\; 18 \end{array}\right\} 1887.0.$$

$$\log q = 0.170274.$$

Observations:

Albany, Jan. 24—Mar. 26, A. J. 7. 56, 83.
Alger, Jan. 27—Feb. 5, B. A. 4. 137.
Bordeaux, Jan. 26—Mar. 4, A. N. 116. 157; 117. 99.
Cambridge, Jan. 24, A. N. 116. 191.
Dresden, April 27, A. N. 117. 41.
Gottingen, Jan. 25, A. N. 116. 157.
Greenwich, Feb. 28, M. N. 47. 275.
Hamburg, Feb. 17—18, A. N. 116. 249.
Konigsberg, Jan. 25, A. N. 116. 159.
Kopenhagen, Feb. 13—16, A. N. 118. 73.
Kremsmunster, Jan. 28—Mar. 24, A. N. 118. 105.
Nashville, Jan. 23—30, A. N. 116. 251; A. J. 7. 63, 79.
Nice, Jan. 26—Apr. 27, B. A. 4. 58, 194; A. N. 117. 41.
Orwell Park, Feb. 13—May 20, M. N. 48. 56.
Padua, Jan. 28—30, A. N. 116. 171.
Palermo, Jan. 26–27, A. N. 116. 157, 159.
Paris, Jan. 27, A. N. 116. 159.
Scarborough, Feb. 3, A. N. 116. 175.
Wien, Jan. 27—Mar. 31, A. N. 116. 159, 191, 367; 117. 41.

Comet 1886 IX (Barnard-Hartwig, *f* 1886, Oct. 4). This comet became invisible to observers in the northern hemisphere early in January, 1887, but was followed in the southern hemisphere until the middle of June. The following set of elements computed by Lieut. Wm. H. Allen, U. S. Navy, (A. J. 7.55) from four normal places, of dates Oct. 8.0, Nov. 3.5, Dec. 2.5 and Dec. 10.0, represent the observations fairly well:

$$T = 1886 \text{ Dec. } 16.50579 \text{ Greenwich mean time.}$$
$$\left.\begin{aligned} \omega &= 86^\circ\ 21'\ 33.1'' \\ \Omega &= 137\ \ 22\ \ 36.8 \\ \iota &= 101\ \ 36\ \ 55.5 \end{aligned}\right\} 1886.0$$
$$\log q = 9.821628$$

Observations:

Albany, Oct. 6—Nov. 1, A. J. 7. 98.
Alger, Nov. 11—Jan. 3, B. A. 3. 586; 4. 136.
Bothkamp, Oct. 29—Dec. 2, A. N. 115. 283; 116. 125.
Brussels, Oct. 22—Dec. 20, A. N. 117. 145.
Cape, April 29—June 16, A. N. 117. 339.
Dresden, Dec. 26—Jan. 8, A. N. 116. 247.
Gotha, Oct. 28—Dec. 29, A. N. 115. 317; 116. 171.
Greenwich, Nov. 2—Dec. 16, M. N. 47. 27, 65, 116; 48. 116.
Hamburg, Oct. 27, 28, A. N. 115. 283.
Harrow, Dec. 19—Jan. 5, M. N. 47. 549.
Kiel, Oct. 27—Dec. 10, A. N. 115. 283, 317; 116. 125.
Kopenhagen, Oct. 6—Dec. 31, A. N. 115. 253; 117. 11.
Kremsmunster, Oct. 9—Dec. 2, A. N. 116. 43; 117. 147.
Liege, Oct. 31, A. N. 115. 317.
Lyon, Oct. 7—10, B. A. 4. 100.
Marseille, Oct. 7—11, B. A. 3. 533.
Milan, Dec. 5—Jan. 13, A. N. 117. 163.
Nice, Oct. 29,—Dec. 23, B. A. 4. 134.
Orwell Park, Oct. 22—Jan. 10, M.N. 48. 57.
Padua, Nov. 28—Dec. 28, A. N. 116. 215.
Palermo, Oct. 9—Dec. 27, A. N. 115. 255, 267; 116. 27, 329.
Pola, Oct. 30—Nov. 2, A. N. 116. 193.
Prag, Oct. 9—Dec. 5, A. N. 115. 255; 116. 155.
Strassburg, Oct. 24, A. N. 115. 285.
Turin, Oct. 30—Dec. 4, A. N. 115. 397; 116. 153; 117. 117.
Washington, Oct. 7—Dec. 10, A. J. 7. 8, 31.
Wien, Oct. 7—28, A. N. 115. 253; 116. 347.

Comet 1887 I (*a* 1887, June 18). This comet appeared suddenly in the southern hemisphere, and was discovered by several persons at different places on the same night Jan. 18, and by others on subsequent nights. It was described by Mr. Finlay as presenting the appearance of a pale, narrow ribbon of light, quite straight and of nearly uniform brightness throughout its length. There was no head or condensation of any kind near the end, the light simply fading away to nothing. According to Dr. Thome of the Cordoba Observatory "the tail steadily grew in apparent brightness and length as the comet increased its distance from the horizon until Jan. 25, when it became evident that it had been fading from the first." Mr. Finlay of the Cape of Good Hope Observatory and Mr. Todd of the Adelaide Observatory both speak of this comet as resembling very closely in appearance the comet of February 1880, which during its short season of visibility occupied the same part of the sky and came into view equally suddenly. Considerable difficulty has been encountered in attempting to compute the orbit of this comet because of the uncertainty of the observed positions, there being no well defined nucleus or even head upon which observers could point the telescope. Entirely different sets of elements may be obtained from the observations made by different observers. The following table gives the elements which have been published. The first set depend upon observations made at Melbourne, Windsor and Cordoba, the second upon those at Cordoba alone, the third upon those at the Cape alone, and the last two upon the observations at the Cape and Adelaide observatories:

T. Gr. mean time.	Ω	ω	ι	log. q.	Computer.	Reference.
1887 Jan. 8.730	132°49′	174°49′	57°52′	8.3628	Chandler.	A. J. 7.92
1887 Jan. 8.825	315 36	234 18	115 35	9.2938	Thome.	A. J. 7.91
1887 Jan. 11.244	359 41	90 00	141 16	8.1644	Finlay.	M. N. 47.303
1887 Jan. 11.230	337 43	63 36	137 00	7.7389	Chandler.	A. J. 7.100
1887 Jan. 11.415	339 52	64 40	138 02	7.6666	Oppenheim.	A.N.117.13

The last three sets of elements bear some resemblance to those of the remarkable group of great comets of 1843, 1880 and 1882, each of which approached very close to the sun. Dr. H. Oppenheim thinks that this may be another member of that comet system (A. N. 117. 16).

Observations:

Adelaide, Jan. 21-27, M. N. 47. 305.
Cape, Jan. 22-28, M. N. 47. 303.
Cordoba, Jan. 20-27, A. J. 7. 91; 117. 259.
Melbourne, Jan. 23-24, A. N. 116. 143.
Windsor, Jan. 28, 30, A. N. 116. 319.
Sextant observations on board ship, Jan. 21-25, M. N. 47. 432.

The comet was observed only ten days after discovery, full moonlight then rendering it invisible. After the moon had passed from that part of the sky, no trace of the comet could be found.

On February 13, Professor Swift of the Warner Observatory at Rochester, New York, found two objects, one of which he thought to be the comet, in R. A. 3*h* 33*m* and Decl. —37°35′, about —38*m* and +4° from the computed place of of the comet. They are designated as Nos. 14 and 15 of Catalogue No. 6 of nebulæ discovered at the Warner Observatory (A. N. 117. 217). As a long period of cloudy weather followed, Professor Swift was unable then to verify his observation, but in November, 1887, Mr. E. E. Barnard while at the Davidson Observatory, California, examined that part of the sky with an eight-inch telescope, and found nothing. He did find, however, two known nebulæ, G. C. 697 and 698, in R. A. 3*h* 18*m*, Decl. —37°36′, which answer exactly Swift's description of his Nos. 14 and 15 (A. N. 118. 173). It seems probable, therefore, that these known nebulæ were the objects which Swift observed, and that the R. A. given in his catalogue No. 6 is 15*m* too great.

Comet 1887 II (Brooks *b* 1887 Jan. 22). Discovered by Mr. W. R. Brooks at Phelps, N. Y., on the evening of January 22, in the constellation of Draco. It was then round, with some central condensation, and easily visible with moderate apertures. It attained its greatest brilliancy about the middle of February, and vanished from view in April. The following elements by Professor Boss were derived from observations made Jan. 24, Feb. 15, and March 12 (A. J. 7. 85):

$$T = 1887 \text{ March } 16.9819 \text{ Greenwich mean time.}$$

$$\left.\begin{array}{l} \omega = 159^\circ\ 09'\ 00'' \\ \Omega = 279\ \ 49\ \ 58 \\ i = 104\ \ 18\ \ 19 \end{array}\right\} 1887.0$$

$$\log q = 0.213070. \quad \Delta\lambda \cos\beta = +\ 9.0''; \quad \Delta\beta = -4.1''.$$

The orbit does not differ materially from a parabola.

Observations:

Albany, Jan. 24—March. 12, A. J. 7. 56, 61, 85.
Alger, Jan. 27—April 14, B. A. 4. 136, 423.
Bethlehem, Pa., Feb. 9-19, A. J. 7. 80.
Berlin, Feb. 11, A. N. 116. 189.
Bordeaux, Jan. 29—March 30, A. N. 116. 157; 117. 99.
Cambridge, Jan. 24-27, A. N. 116. 191.
Dresden, Feb. 15—March 24, A. N. 116. 203, 249, 267, 317, 327.
Genf, Feb. 10—April 20, A. N. 116. 333; 117. 55.
Gottingen, Feb. 15—March 15, A. N. 116. 203, 219, 249, 267; 117. 149.
Greenwich, Feb. 27— . M. N. 47. 275, 392.
Hamburg, Feb. 13-15, A. N. 116. 203.
Kiel, Jan. 27—Feb. 15, A. N. 116. 157, 189, 203.
Kopenhagen, Feb. 13—March 16, A. N. 118. 73.
Kremsmunster, Jan. 24—March 21, A. N. 117. 149; 118. 105.
Milan, Jan. 27, A. N. 116. 173.
Nashville, Jan. 23, A. N. 116. 203; A. J. 7. 63.
Nice, Jan. 27-29, B. A. 4. 135.
Padua, Jan. 27-30, A. N. 116. 171.
Palermo, Jan. 29—Feb. 24, A. N. 116. 219, 265.
Paris, Jan. 27, A. N. 116. 173.
Plonsk, Feb. 11-25, A. N. 117. 305.
Strassburg, Jan. 26—Feb. 11, A. N. 116. 143, 157, 203.
Washington, Jan. 24—March 12, A. J. 7. 62, 78, 86.
Wien, Jan. 28—Feb. 12, A. N. 116. 173, 203, 205.

Comet 1887 III (Barnard *d* 1887 Feb. 16). Discovered by Mr. E. E. Barnard at Nashville on the night of Feb. 16. It was very faint and had a very rapid apparent motion. The last observation was made April 10 at Orwell Park Observatory. Mr. Barnard has computed the following elements of the orbit of this comet from his own observations of Feb. 16, Feb. 28 and March 12:

$$T = 1887 \text{ March } 28.39633 \text{ Greenwich mean time.}$$

$$\left.\begin{aligned} \omega &= 36^\circ 28' 50'' \\ \Omega &= 135\ \ 27\ \ 17 \\ i &= 139\ \ 48\ \ 39 \end{aligned}\right\} 1887.0$$

$$\log q = 0.00295$$

Observations:

Albany, Feb. 19—25, A. J. 7. 84.
Alger, Feb. 24—March 25, B. A. 4. 137, 423.
Berlin, Feb. 28, A. N. 116. 251.
Cambridge, Feb. 17—28, A. J. 7. 79; A. N. 116. 267.
Dresden, Feb. 24—March 24, A. N. 116. 221, 267, 317.
Genf, Feb. 24—March 18, A. N. 116. 251, 315.
Gottingen, Feb. 24, A. N. 116. 221.
Greenwich, Feb. 28, M. N. 47. 275.
Hamburg, Feb. 26, A. N. 116. 221.
Kremsmunster, Feb. 24—25, A. N. 117. 149.
Kopenhagen, March 16, A. N. 118. 73.
Nashville, Feb. 16—22, A. J. 7. 79; A. N. 116. 251.
Nice, Feb. 28—March 1, B. A. 4. 194.
Orwell Park, Feb. 28—April 10, M. N. 48. 61.
Palermo, Feb. 27, A. N. 116. 267
Paris, Feb. 17, A. N. 116. 207
Rome, Feb. 24—25, A. N. 116. 251; 117. 269.
Strassburg, Feb. 23—March 14, A. N. 116. 221, 267.
Wien, Feb. 24—28, A. N. 116. 221, 251.

Comet 1887 IV (Barnard *e* 1887 May 12) was also discovered by Mr. E. E. Barnard. It was described by Professor Boss on May 13 as extremely condensed, with a star-like nucleus of the 11.5 magnitude. It attained its greatest brilliancy, which was only 1.6 times its brightness when discovered, in June, and was lost to sight in August. Mr. S. C. Chandler (A. J. 7. 104) has computed the following elements from seventeen observations, combined into four normal places, extending from May 12 to May 30:

$$T = \text{June } 16.73745 \text{ Greenwich mean time.}$$

$$\left.\begin{aligned} \omega &= 15^\circ\ 11'\ 53.6'' \\ \Omega &= 245\ \ 13\ \ 01.9 \\ \iota &= 17\ \ 35\ \ 18.4 \end{aligned}\right\} 1887.0$$

$$\log q = 0.144408.$$

Observations:

Albany, May 13-23, A. J. 7. 103.
Alger, May 16—Aug. 9, A. N. 117. 57; B. A. 4. 424, 465.
Berlin, May 23—June 26, A. N. 117. 43, 385; 118. 285.
Bordeaux, May 22—Aug. 10, A. N. 117. 151, 307.
Bothkamp, June 15—July 25, A. N. 117. 133, 215.
Cambridge, May 13—July 12, A. J. 7. 111, 119, 152; A. N. 117. 243.
Cape, May 19—June 17, A. N. 117. 339.
Dresden, May 19—July 16, A. N. 117. 43, 59, 133, 215.
Genf, May 10—June 30, A. N. 117. 43; 118. 239.
Gottingen, June 15, A. N. 117. 133.
Gohlis, June 13-25, A. N. 117. 213.
Greenwich, June 12-19, A. N. 117. 215.
Hamburg, June 16-19, A.N. 117. 133.
Harrow, June 12-22, M. N. 47. 550.
Kiel, May 14-21, A. N. 117. 31, 43.
Kremsmunster, May 15—July 12, A. N. 118. 107.
Marseille, May 14-June 28, B. A. 4. 462.
Nashville, May 12—Aug. 11, A. N. 117. 31, 57, 243, 385; A.J. 7. 103.
Nice, May 14— —, B. A. 4. 225, 380; A. N. 117. 43.
Nicolaiew, May 14-21, A. N. 117. 55.
Orwell Park, June 9—July 28, M. N. 48. 61.
Padua, May 14—June 23, A. N. 117. 43, 101; 118. 233.
Palermo, May 15-31, A. N. 117. 31, 59, 101.
Paris, May 14, A. N. 117. 43.
Prag, May 27, A. N. 117. 59.
Rome, May 14—Aug. 7, A. N. 117. 43, 269, 275.
Scarborough, May 20-29, M. N. 47. 498.
Strassburg, May 15, A. N. 117. 31.
Wien, May 15-17, A. N. 117. 43.

Comet 1887 V (Olbers-Brooks *f* 1887 Aug. 24). This comet was discovered by Mr. W. R. Brooks at Phelps N. Y., on the morning of August 25, in the constellation of Cancer. The first set of elements, computed by Mr. H. V. Egbert at Albany, established its identity with the Olbers' comet of 1815, the return of which was expected sometime in 1886 or 1887. Bessel computed an elliptic orbit from 187 observations at the apparition of 1815, obtaining a period of 70.049 years. He anticipated that planetary perturbations would bring it back to perihelion Feb. 9, 1887. A new investigation was undertaken in 1879 by Mr. F. K. Ginzel, in response to the offer of a prize by the Holland "Gesellschaft der Wissensschaften" and his results were published in 1881 by that society. He re-reduced many of the observations and computed the perturbations by all of the planets and derived a period of from 72⅓ to 75⅝ years. He assigned as the most probable date of perihelion passage Dec. 17, 1886 ± 1.6 years (A. J. 100. 75 and 109. 321) and computed a sweeping ephemeris for the last three months of the year. The perihelion passage actually occurred Oct. 8, 1887, giving a period of 72.45 years.

On August 25, Mr. Brooks described the comet as brightish with eccentric condensation. Later a short tail was developed. Its greatest brightness was attained in October. The comet is still in favorable position, although very faint, and may be followed for some time longer.

Mr. Ginzel has derived the following elements, using observations of Aug. 27, Sept. 6, and Sept. 14 to determine the corrections to the semimajor axis and perihelion time (A. J. 118. 389):

$$T = 1887 \text{ Oct. } 8.40998 \text{ Greenwich mean time.}$$

$$\left.\begin{aligned} \omega &= 65^\circ\ 16'\ 06.5'' \\ \Omega &= 84\ \ 29\ \ 40.8 \\ i &= 44\ \ 33\ \ 53.0 \end{aligned}\right\}\ 1887.0$$

$$\begin{aligned} \varphi &= 68\ \ 36\ \ 23.8 \\ \log q &= 0.079040 \\ \log a &= 1.240743 \\ \mu &= 48.85311'' \end{aligned}$$

He intends to pursue farther the investigation of this orbit.

Observations:

Albany, Aug. 26—Nov. 1, A. J. 7. 128, 136, 152.
Alger, Aug. 29—Sept. 22, A. N. 117. 325; B. A. 4. 466.
Besancon, Aug. 29—Sept. 1, A. N. 117. 341.
Bordeaux, Sept. 8—25, A. N. 118. 109.
Bothkamp, Sept. 18—Jan. 18. A. N. 117. 387; 118. 287.
Dresden, Jan. 25, A. N. 118. 271.
Genf, Aug. 29—Nov. 4, A. N. 117. 293, 307; 118. 109.
Hamburg, Sept. 20—24, A. N. 117. 355, 387.
Kiel, Sept. 14—20, A. N. 117. 327, 341, 355.
Konigsberg, Aug. 27—Nov. 11, A. N. 117. 295, 341, 387; 118. 41, 94.
Kremsmunster, Aug. 28—Sept. 17, A. N. 117. 293; 118. 107.
Leipzig, Sept. 15—26, A. N. 118. 249.
Marseille, Aug. 27—Sept. 26, B. A. 4. 462, 464.
Milan, Aug. 30—31, A. N. 117. 307.
Nice, Aug. 29—Sept. 26, B. A. 4. 467.
Orwell Park, Dec. 6—18, A. N. 118. 207.
Padua, Sept. 13—Nov. 17, A. N. 117. 389; 118. 233.
Plonsk, Sept. 6, A. N. 117. 327, 391.
Pulkowa, Sept. 25—Nov. 15, A. N. 118. 109.
Rome, Aug. 27, A. N. 117. 293.
Strassburg, Aug. 27—Sept. 14, A. N. 117. 293, 341.
Turin, Aug. 29—31, A. N. 117. 293, 327.
Wien, Aug. 27—Oct. 21, A. N. 117. 293; 118. 45.

TOTAL SOLAR ECLIPSE, AUG. 19, 1887.*

DR. B. VON ENGLEHARDT, DRESDEN.

For the MESSENGER.

The following abstract is taken from the interesting report of Dr. Khandrikoff, professor of astronomy in the Prussian Imperial University at Kiew:

The total eclipse of this year, the calculation of which twenty-five years ago was the subject of his doctor's thesis, was observed by him at Mount Blaghodat, an isolated peak in the most eastern part of the Ural Mountains. This mountain lies in latitude 58°17′20″ north, and longitude 3*h* 59*m* 10*s* east of Greenwich, and was near the central line of totality of the eclipse. For the observation he used a three and one-half-inch telescope, with a micrometer, a chronometer, and a sextant.

During eleven days before the eclipse the rate of the chronometer was tested, and the surface of the sun repeatedly observed. During the eclipse four points of astronomical interest were very distinctly noted: the first contact, the beginning and end of the totality, and the last contact, as well as two obscurations of small sun spots.

But the chief interest was not in the astronomical, but in the astrophysical observation. As the black disc of the moon passed over the sun the contour of the mountains of the moon could be accurately noted by means of the steady and sharp images in the telescope. Until the disc of the sun was half covered the decrease of light was not manifested, at least not as strongly as reported by many observers of former eclipses. A rapid but not especially remarkable decrease of light began only ten minutes before totality, and, at the same time a yellowish coloring of all objects was distinctly perceived. The white paper lying before the observer appeared yellowish red. Fifteen seconds before totality the narrow crescent of the sun was notched by the mountains of the moon, and the northeastern cusp was strongly blunted. In this place, a short distance from cusp, the outlines of the disc of the moon could be perceived beyond the sun, because it projected itself upon the lower part of the

* This interesting account of the total solar eclipse of Aug. 19, 1887, from Dr. B. von Englehardt of Dresden, has been translated from the German, for the benefit of the readers of THE MESSENGER.

corona. These appearances were not noticed in relation to the other cusp.

It is difficult to represent the sensations at the moment of totality. With the disappearance of the last points of sunlight a wonderful halo flamed up around the entire dark disk of the moon; the shining corona appeared in a silver blaze with differently colored rays or bands of light and the protuberances were painted in hues not found on any painter's palette. These wonderful tongues of fire were of a bluish-red color and possessed the transparency of a delicate flame.

In the first moment of totality four protuberances were visible on the eastern limit of the sun. The most southern had the greatest dimensions and could be seen even with the naked eye. By the progress of the moon three of the protuberances were covered, but the most southerly one remained visible until the end of totality. Their size was colossal, reaching to about one-third the radius of the sun.

The light of the corona was strong only to a distance of one or two minutes of arc from the limit of the moon, and its intensity was not uniform. The directions of the bands of light of the corona varied considerably. Some extended in the direction of the radii of the sun, some made varying angles, and others were perpendicular to the radii. The most important of these had an expansion of at least twice the radius. Also the forms were varied. Two were lenticular and consisted of converging rays. All the rays of the corona had an intense silver blaze, were steady and retained their form and position unchanged during the entire totality.

The four colored pictures finished in oil and which were sent with the Professor's report, show the appearances at four different moments, given in local time. Plate I is taken shortly before the beginning of totality. Plate II shows the phenomenon at the moment of totality. Plate III, at the middle, and Plate IV a short time before the end. The pictures in Krasnojarsk (Siberia) received from the expedition of the Russian Imperial Physico-Chemical Society are identical with these.

About forty seconds before the end of totality an important group of protuberances having a breadth of at least sixty degrees, appeared upon the western edge. They were seen late because they were so very low.

There was no time to count the stars visible to the naked eye in the immediate neighborhood of the sun. Still Venus was seen on the left, and Mercury and Mars upon the right of the sun. Besides, the star α Leonis was visible almost in the rays of the corona, from which it may be concluded that the light of the corona is less than that of the full moon, because α Leonis would be seen with difficulty at the same distance from the bright moon.

During totality it was so dark that neither notes nor chronometer could be read without a lantern.

The decrease of temperature during totality did not exceed one degree.

The Professor is inclined to the opinion that the phenomena observed by him are somewhat opposed to the present theories of the constitution of the sun. It is commonly believed that a close relation exists between the sun spots, faculæ and protuberances. According to Faye the spots are funnel-shaped vortices into which the relatively cold hydrogen of the chromosphere is drawn, and through which, the faculæ are originated. After the hydrogen has reached a certain depth it rises again on account of the heat. Sometimes the glowing hydrogen breaks out violently, like the outburst of a volcano, and becomes visible in the form of a protuberance. In the year 1887, we were near the minimum of the sun-spots (the next minimum occurs in 1889); during the eleven days before the eclipse only a few sun spots were to be seen; and consequently we should expect to see scarcely any protuberances. But on the contrary, the sun was rich in beautiful and large protuberances, which opposes the theory of a relation between the sun-spots and the protuberances. But still more puzzling is the corona and especially the rays or bands of its light which form different angles with the directions of the radii of the sun. Possibly these appearances could be explained in this way; that the surface of the moon, strongly reflecting the sunlight, is so uneven that, like the facets of the diamond, it turns the sunlight in different directions. Through the reflection of the sunlight from the formations very near the limb of the moon, rays can be turned from the direction of the sun's radii, and even be made curvilinear.

From his observations the Professor comes to the following conclusions:

I. Between the sun-spots and the protuberances there is no immediate relation, at least not the relation which Faye assumes in his hypothesis, on the structure of the sun.

II. The corona does not consist of matter but is a light-phenomenon which, perhaps, takes place on the surface of the moon, and is brought to our eye through the mediation of the earth's atmosphere.

FOR STUDENTS AND YOUNG OBSERVERS.

Interesting Phenomena for April.

THE PLANETS.

Mercury will not be in very favorable position for observation in the northern hemisphere during this month, because his declination is more south than that of the sun. He may be seen, perhaps, about an hour before sunrise when the atmosphere is exceptionally clear toward the east. He will be in conjunction with Venus at midday on the 13th, being then 1°10′ south of the latter. The diameter of this planet will decrease during the month from 7.2″ to 5.2″ while its brilliancy will increase from one-half to about two-thirds of that when it was so well seen in the middle of February.

Venus is in nearly the same right ascension as Mercury, but, being so much brighter, will be seen without difficulty, rising a little more than an hour before the sun. Venus will be in aphelion, *i. e.*, at greatest distance from the sun, April 2, in conjunction with the moon, north 2°23′, on the evening of the 8th. Her brilliancy is slowly decreasing, although her phase increases from 0.892 to 0.944 during the month.

Mars comes to opposition on the 10th of this month, so that its disc will be full at that time. Its nearest approach to the earth will be on the 16th, when Mars will be about 56,000,000 miles from the earth and 149,000,000 miles from the sun. It will be remembered that the orbit of Mars is quite excentric and that its distance from the earth at opposition varies from 33,000,000 to 62,000,000 miles. Comparing these numbers it will be seen that the present opposition is one of the least favorable for the study of minute details of surface markings.

Jupiter is coming into position for evening observation, rising at 9 P. M., at the end of the month. His polar diameter is 39.9″ on the first, and 42.4″ on the last day of the month. The number of phenomena of the satellites to be observed this month appears to be rather greater than usual. Observers will do well to watch carefully the appearance of the different satellites while in transit across the disk of the planet. It is found that they differ from each other in the appearance presented during transit. The second satellite always appears bright, *i. e.*, brighter than the face of the planet upon which it is projected, during the whole transit. The third sometimes disappears after entering a certain distance upon the disk and reappears as a dark spot; disappears again and reappears white before leaving the disk; at other times remains white throughout the transit. The first and fourth always disappear, and reappear as dark spots, the first generally turning light steel gray, but sometimes dusky or almost black. The fourth is usually bright for the first ten or fifteen minutes of transit, then lost for about the same time, reappears as a dark spot, becoming jet black; in passing off the disk, the phenomena occur in the reverse order. In the *Monthly Notices of the Royal Astronomical Society*, for November, 1887 (Vol. 48, p. 32), there is an interesting paper upon this subject by Mr. E. J. Spitta, in which, it seems to us, the author has given a very satisfactory explanation of the phenomena of dark transits.

Saturn will be in quadrature on the 18th. Many of our readers doubtless have noticed his retrograde motion during the last few months, by the flattening of the triangle formed by Saturn with the two pairs of bright stars in Gemini and Canis Minor. The motion this month will be in the opposite direction. We have obtained several exquisite views of this planet with the 8¼-inch refractor during the past month. The three rings and the white equatorial belt were nicely shown and glimpses were obtained of the Encke division of the outer ring and of narrow belts and mottlings on the southern hemisphere of the planet.

Uranus on the first of the month is 39*m* or about 10° west of Mars and about two degrees north. At the end of the month Mars will have retograded so far that the two planets will be very near together, Uranus being 4.9*m* west and

23′ south, *i. e.*, in the same field of view of an ordinary finder. They can be seen in the southeast after 7 P. M.

Neptune is in Taurus about 5° south of the Pleiades.

	R. A. H. M.	Decl.	Rises. H. M.	Transits. H. M.	Sets. H. M.
			NEPTUNE.		
April 5............	3 45.3	+18°10′	7 28 A. M.	2 47.3 P. M.	10 06 P. M.
15............	3 46.6	+18 15	6 49 "	2 08.7 "	9 28 "
25............	3 48.0	+18 19	6 12 "	1 31.3 "	8 51 "
			SATURN.		
April 5............	8 07.7	+20 49	11 37 A. M.	7 08.6 P. M.	2 40 A. M.
15............	8 08.5	+20 46	10 59 "	6 30.1 "	2 01 "
25............	8 10.1	+20 42	10 21 "	5 52.4 "	1 23 "
			URANUS.		
April 5............	12 56.8	−5 20	6 15 P. M.	11 57.0 P. M.	5 39 A. M.
15............	12 55.3	−5 10	5 33 "	11 16.1 "	4 59 "
25............	12 53.8	−5 01	4 52 "	10 35.3 "	4 19 "
			MARS.		
April 5............	13 31.1	−6 59	6 55 P. M.	12 31.2 P. M.	6 07 A. M.
15............	13 16.5	−5 53	5 57 "	11 37.3 "	5 17 "
25............	13 02.8	−4 55	5 00 "	10 44.3 "	4 28 "
			JUPITER.		
April 5............	16 17.2	−20 20	10 38 P. M.	3 16.8 A. M.	7 55 A. M.
15............	16 14.7	−20 14	9 56 "	2 34.9 "	7 14 "
25............	16 11.0	−20 04	9 12 "	1 52.0 "	6 32 "
			VENUS.		
April 6............	23 32.7	−4 29	4 46 A. M.	10 31.4 A. M.	4 17 P. M.
16............	0 18.2	+0 17	4 33 "	10 37.2 "	4 42 "
26............	1 03.3	+5 04	4 19 "	10 42.8 "	5 06 "
			MERCURY.		
April 6............	23 28.6	−5 54	4 47 A. M.	10 27.0 A. M.	4 07 P. M.
16............	0 21.0	−0 33	4 39 "	10 39.8 "	4 41 "
26............	1 23.0	+6 34	4 33 "	11 02.4 "	5 32 "

Occultations Visible at Washington.

Date.	Star's name.	Magnitude.	IMMERSION. Wash. Mean Time. H. M.	IMMERSION. Angle f'm N. Point. °	EMERSION. Wash. Mean Time. H. M.	EMERSION. Angle f'm N. Point. °	Duration. H. M.
April 12	μ Ceti	4½	6 59	165	Star 2.5′ S. of moon's limb.		
14	63 Tauri	6	8 46	81	9 43	267	0 57
15	*m* Tauri	5½	5 25	87	6 48	261	1 23
16	χ^4 Orionis	5	8 41	73	9 41	298	1 01
19	δ Cancri	4	8 50	18	Star 5.7′ N. of moon's limb.		
24	80 Virginis	6	16 02	48	16 28	353	0 26
27	χ Ophiuchi	4¼	11 36	201	Star 3.6′ S. of moon's limb.		
29	B.A.C.6336	6	14 44	5	Star 2.6′ N. of moon's limb.		
May 3	45 Aquarii	6½	14 21	348	Star 6.1′ N. of moon's limb.		

Phases of the Moon.

	Central Time. D.	H. M.
Last Quarter..	April 3,	6 41.2 A. M.
New Moon..	11,	3 7.7 "
First Quarter..	19,	5 52.4 "
Full Moon..	26,	12 22.2 "

Great Red Spot on Jupiter—Times when its Zero Meridian Passes the Centre of Jupiter's Disc.

Central Time. D.	H. M.	Central Time. D.	H. M.	Central Time. D.	H. M.
April 2,	6 15.7 A. M.	April 12,	4 30.3 A. M.	April 22,	2 44.6 A. M.
3,	2 06.9 "	13,	12 21.4 "	22,	10 35.6 P. M.
4,	7 53.7 "	14,	6 08.3 "	24,	4 22.5 A. M.
5,	3 45.0 "	15,	1 59.5 "	25,	12 13.6 "
5,	11 36.1 P. M.	16,	7 46.3 "	26,	6 00.5 "
7,	5 23.0 A. M.	17,	3 37.5 "	27,	1 51.6 "
8,	1 14.1 "	17,	11 28.5 P. M.	27,	9 42.7 P. M.
9,	7 01.0 "	19,	5 15.4 A. M.	29,	3 29.6 A. M.
10,	2 52.3 "	20,	1 06.6 "	29,	11 20.6 P. M.
10,	10 43.4 P. M.	21,	6 53.4 "	May 1,	5 07.5 A. M.

Minima of Algol, (β Persei; R. A. 3h 01 m; Decl. +40°31′).

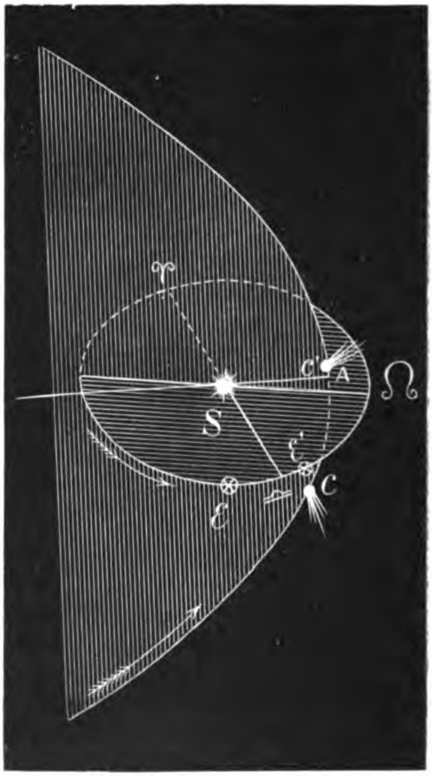
Central Time. D.	H. M.	Central Time. D.	H. M.	Central Time. D.	H. M.
April 1,	10 10 A. M.	April 12,	9 26 P. M.	April 24,	8 41 A. M.
4,	6 59 "	15,	6 15 "	27,	5 30 "
7,	3 48 "	18,	3 04 "	30,	2 19 "
10,	12 37 "	21,	11 53 A. M.		

Phenomena of Jupiter's Satellites.

Central Time. D.	H. M.			Central Time. D.	H. M.		
April 1,	11 54 P. M.	II	Sh. In.	April 18,	10 22 P. M.	III	Tr. In.
2,	1 56 A. M.	II	Tr. In.	18,	11 48 "	III	Tr. Eg.
2,	2 24 "	II	Sh. Eg.	19,	10 15 "	II	Tr. Eg.
2,	4 22 "	II	Tr. Eg.	21,	2 51 A. M.	I	Sh. In.
5,	4 36 "	I	Sh. In.	21,	3 55 "	I	Tr. In.
6,	1 59 "	I	Ec. Dis.	22,	12 14 "	I	Ec. Dis.
6,	5 06 "	I	Oc. Re.	22,	3 05 "	I	Oc. Re.
6,	11 05 P. M.	I	Sh. In.	22,	9 20 P. M.	I	Sh. In.
7,	12 02 A. M.	I	Tr. In.	22,	10 01 "	I	Tr. In.
7,	1 17 "	I	Sh. Eg.	22,	11 33 "	I	Sh. Eg.
7,	2 13 "	I	Tr. Eg.	23,	12 12 A. M.	I	Tr. Eg.
7,	11 33 P. M.	I	Oc. Re.	23,	9 31 P. M.	I	Oc. Re.
8,	1 35 A. M.	III	Ec. Dis.	25,	1 51 A. M.	II	Ec. Dis.
8,	3 11 "	III	Ec. Re.	25,	11 08 P. M.	III	Sh. In.
9,	2 29 "	II	Sh. In.	26,	1 00 A. M.	III	Sh. Eg.
9,	4 19 "	II	Tr. In.	26,	1 46 "	III	Tr. In.
9,	4 59 "	II	Sh. Eg.	26,	3 11 "	III	Tr. Eg.
11,	12 52 "	II	Oc. Re.	26,	10 08 P. M.	II	Tr. In.
13,	3 53 "	I	Ec. Dis.	26,	11 26 "	II	Sh. Eg.
14,	12 58 "	I	Sh. In.	27,	12 33 A. M.	II	Tr. Eg.
14,	1 49 "	I	Tr. In.	29,	2 18 "	I	Ec. Dis.
14,	3 11 "	I	Sh. Eg.	29,	4 50 "	I	Oc. Re.
14,	4 00 "	I	Tr. Eg.	29,	11 13 P. M.	I	Sh. In.
14,	10 21 P. M.	I	Ec. Dis.	29,	11 46 "	I	Tr. In.
15,	1 20 A. M.	I	Oc. Re.	30,	1 26 A. M.	I	Sh. Eg.
15,	10 27 P. M.	I	Tr. Eg.	30,	1 57 "	I	Tr. Eg.
16,	5 04 A. M.	II	Sh. In.	30,	8 37 P. M.	I	Ec. Dis.
17,	11 16 P. M.	II	Ec. Dis.	30,	11 16 "	I	Oc. Re.
18,	3 12 A. M.	II	Oc. Re.				

"*Period of the Rotation of the Sun,* as determined by the Spectroscope" is the title of a very suggestive paper in the February number of the *American Journal of Science,* by Henry Crew of Johns Hopkins University.

Orbit of Comet a 1888. We give below a cut showing the relation of the orbits of the earth and the new comet now in view. The figure was drawn according to Finlay's elements, and by the neat method for making comet models, given by Professor William Harkness in the December number of THE MESSENGER. The letters *e* and *c* represent the positions of the earth and comet respectively at the time of discovery, Feb. 18; those of *e′* and *c′*, the positions of the same bodies April 1, approximately. By referring to Professor Harkness' article, any student or teacher of astronomy might make a model of the orbits of these bodies that would certainly prove of great interest to himself and friends, especially with this picture as a guide.



In so doing notice the position of perihelion, *A*, where the comet was March 18.18 G. M. T.; that ω is 4° 29′ north of the earth's orbit; that the ☊ is 244° 6′ from the (♈) vernal equinox; that *i* the inclination is 43° 57′ and that *q*, its perihelion distance, was 0.6846, the earth's radius being unity.

Stereoscopic Views of the Moon. Not long ago a letter, with a stereoscopic view of the moon, was received from an interested reader of THE MESSENGER in Arkansas. In the letter it was asked how stereoscopic views of the moon were made. Thinking this query and its answer may interest other readers, space is given them here.

On the card was printed "full moon," "taken by Henry Draper," and "C. Brestadt, Niagara Falls, N. Y.;" the last name being, doubtless, that of a local photographer who had mounted or copied these astronomical views obtained from the late Henry Draper of New York. The measure of the polar diameter of the discs representing the full moon was 55.5 millimeters (nearly 2¼ inches), lengthwise of the pictures. The great crater Tycho was in the diameter measured, hence the shifting of that crater in the two views, taken to give stereoscopic effect, would show approximately how the pictures were taken. From the phase in the left hand picture below, and that in the right hand picture above, it is readily seen that the displacement of Tycho in the two pictures is mainly due to libration in latitude. Projecting and roughly measuring the angle that Tycho makes with the limb in each picture, there is an apparent change of place of 6°. But astronomers know that the maximum libration of the moon in latitude can not exceed 6° 40′ 49″. The result given above is near enough to show that good conditions for stereoscopic pictures were chosen, and that the moon must have been in extreme north and south latitude, at opposite points of its orbit, in order to get 6° of libration in latitude. By noticing what is said of photography for stereoscopic views, elsewhere given, it will be seen that this was Dr. Draper's method.

A New Minor Planet (No. 273) was discovered by Palisa, March 8.548, Greenwich mean time, in R. A. 10*h* 30*m* 48*s*; Decl. + 10° 36′; daily motion—48*s* in R. A., and + 12′ in Decl.

EDITORIAL NOTES.

We have willingly set aside much miscellaneous matter to give place in this issue to a part of an excellent article on the subject of *Astronomical Photography*.

Professor Geo. W. Coakley presents the nebular hypothesis, as given by La Place, in clear and concise way, and easily within the grasp of the popular reader. Subsequently we hope to give some of the geometrical proofs used in connection with this useful paper.

The *Messenger* is indebted to Mr. Sadler, Editor of *The Journal of the Liverpool Astronomical Society*, for several late copies of that valuable publication.

The Scientific American (March 17) has the best illustrations of the site and buildings of Lick Observatory that have yet been published.

The New Comet has been seen at northern observatories. The following observation and illustration were kindly furnished by Mr. John R. Hooper of Baltimore:

"At five o'clock on the morning of the 15th of March, the comet had the appearance in the telescope as given in the drawing appended. Dawn commenced when the comet was 5° above the horizon. The nucleus was not stellar, and its magnitude equaled 6.5. I could only trace the tail 30′, expanding in straight lines as shown in cut."

On the 19th Mr. Hooper writes: "The tail of the new comet could be traced more than one degree; that the nucleus had a bright point which in clearer sky would probably have been decidedly stellar. There was also the appearance of an elongated nucleus, but this may have been due to the condition of the atmosphere which was unfavorable for observation."

Elements of Comet a, 1888, computed by Finlay of Cape Town, Africa, were received by telegraph, in cipher, from Harvard College Observatory, Feb. 29, as follows:

$T = 1888$, March 18.18.

$$\left.\begin{array}{l} \omega = 4^\circ\ 29' \\ \Omega = 244\ \ \ 6 \\ i = 43\ \ 57 \end{array}\right\} \text{Mean Eq. 1888.0} \qquad \begin{array}{lr} & C\text{—}O \\ \Delta\lambda \cos.\beta & -.5' \\ \Delta\beta & -.2' \end{array}$$

$q = .6845$

Dr. Wilson of Carleton College Observatory computed an ephemeris from these elements for March, by which the places of the comet until April 2 were known, and given in cut on page 168.

The following ephemeris is from the A. N., No. 2830, and was computed by Dr. B. Matthiessen:

1888.	α	δ	Log r	Log Δ	H.
	h m s	° ″			
April 1	22 7 15	+ 5 24.8			
2	10 30	6 31.1			
3	13 45	7 35.9	9.8821	0.0728	0.83
4	16 59	8 39.1			
5	20 12	9 40.7			
6	23 24	10 40.8			
7	26 36	11 39.3	9.9035	0.0934	0.68
8	29 46	12 36.3			
9	32 55	13 31.7			
10	36 2	14 25.7			
11	39 8	15 18.4	9.9267	0.1134	0.56
12	42 13	16 9.6			
13	45 17	16 59.5			
14	48 20	17 48.2			
15	51 21	18 35.7	9.9507	0.1328	0.46
16	54 21	19 21.9			
17	22 57 19	20 6.9			
18	23 0 16	20 50.7			
19	23 3 11	+21 33.5	9.9749	0.1513	0.38

Observations of Comet a 1888, made by Frank Muller with the 26-inch equatorial of the Leander McCormick Observatory:

1888. Local M. T.	*	No. Comp.	Comet — * Δα	Δδ
h m s			m s	′ ″
March 12, 17 33 35	1	1	+2 11.23	....
13, 17 33 31	2	4	....	+2 28.9
13, 17 40 36	2	5	+0 33.14	....
16, 17 27 05	3	1	+4 25.14	....
16, 17 33 07	3	1	....	+0 30.7

1888. Local M. T.	App. α	App. δ	log pΔ For α	For δ
h m s	h m s			
March 12, 17 33 35	20 59 05.87	....	9.635 n.	....
13, 16 33 31	....	−20°36′15.9″	....	0.803
13, 17 40 36	21 03 22.70	....	9.628 n.	....
16, 17 27 05	21 13 21.73	....	9.618 n.	....
16, 17 33 07	....	−16 11 24.2	....	0.793

Mean places for 1880.0 of the comparison stars:

*	α	Red. to App.	δ	Red. to App.	Authorities.
	h m s	s	° ′ ″	″	
1	20 56 57.68	−3.04	−21 58 41.1	....	Cinn. Zones, 3538.
2	21 2 52.52	−2.96	−20 38 43.8	−1.0 ¼	Cape 1850, 4219 + BB VI, 21.1 + Camb. 1849, 871 + Cinn. Zones 3559.
3	21 8 59.13	−2.54	−16 11 52.9	−2.0	Oe. Arg., 21244.

March 12. Nucleus 0′.1 in diameter; 4.5 magnitude; suspicion of a tail at position angle 90°. Like a blurred star. Observed in twilight. March 13. Nucleus, 0′.1; 5.5 magnitude; tail suspected as on March 12. Observed in twilight. March 16. Nucleus, 0′.2; 5.5 magnitude; tail visible for 2½′ at position angle 270°. Observed about dawn.

The estimates of magnitude were reduced by comparison with the Durchmusterung magnitudes of neighboring stars.

An astronomical friend at East Oakland Cal., speaking of the new comet savs: It was picked up in the field of a comet eyepiece this morning, *March 16th*, at 5 o'clock, then being 4° above the S. E. horizon, in declination S. 16°. Shortly afterwards it was visible with a field-glass and so continued until it faded away with the approaching dawn at 5:30.

Only about 3° of the tail was visible, owing to the light. The tail is very straight, gradually diminishing in brightness as it leaves the nucleus.

Double Stars h 3823 and h 4321. These stars are contained in Flammarion's catalogue of double stars with certain or probable motion. Flammarion considers that there is great probability of orbital motion in *h* 3823 and that the position angle of *h* 4321 is certainly diminishing. Recent observations, however, indicate that there is very little, if any change in *h* 4321 and that the motion in *h* 3823 is rectilinear. The observations of the latter when platted lie approximately in a straight line, and can be satisfied by a proper motion in right ascension of ± 0s.001 and in declination of ± 0″.04. If the present rate and direction of change continues the distance will diminish until the year 1950 ± when the position angle will be 60° and the distance 6″.1.

The following are all the observations known to the writer.

h 3823 5*h* 56*m*;—31° 3′

8.3——8.4

Time.	P.A.	Dist.	Observer.
1836.90	130.5°	4.84″	J. Herschel.
76.79	119.6	3.73	H. A. Howe.
77.13	122.4	3.91	W. Upton.
81.15	123.0	2.88	H. S. Pritchett.
88.15	115.0	3.00	F. P. Leavenworth.
	h 4321	10*h* 24*m*;	—30° 0′
		5.4——9.0	
1835.20	225±	10.00	J. Herschel.
56.23	226.7	6.23	Jacob.
76.24	204.1	12.	O. Stone.
77.09	225.3	11.46	W. Upton.
77.11	226.7	10.69	H. A. Howe.
80.21	224.9	10.82	H. S. Pritchett.
88.12	225.6	11.05	F. P. Leavenworth.

Haverford College. F. P. LEAVENWORTH.

Stellar Parallax by Photography. Professor C. Pritchard, director of the University Observatory, Oxford, who, in 1886, demonstrated the practicabilty of using photography in making accurate determinations of stellar parallax, by applying his method to 61 Cygni (Mo. No. R. A. S. XLVII pp. 27, 322 and 444), has continued his investigations in that line by applying the same method to μ Cassiopeiæ and Polaris (Mo. No. XLVIII, p. 28). On each of fifty-three nights four photographic plates were taken of μ Cassiopeiæ. The resulting parallaxes from two comparison stars are:

From star (A) $\pi = 0''.0501 \pm 0''.0270$.

From star (B) $\pi = 0'':0211 \pm 0''.0235$.

"These parallaxes are extremely small, and, taking into account the large proper motion of μ Cassiopeiæ, are interesting. Bessel, in 1816, investigated the parallax of this star by means of differences of right ascensions on seventy nights, but he arrived at a *negative* value of 0.12″. It is, however, both proper and interesting to remark that this research and its result apply to a time long anterior to the introduction of the heliometer in 1829. In 1356 Professor Otta Struve obtained a parallax of this star by means of micrometrical comparisons, amounting to 0.342″; a quantity well within the compass of Bessel's method in 1816."

The determination of the parallax of *Polaris* from photographs taken through the whole year is not yet completed, bnt a provisional value from selected nights is 0.052″, which according to Mr. Maxwell Hall is close to the mean 0.043″ of all the determinations made by preceding astronomers.

Professor Pritchard proposes hereafter to limit the observations of each star to five nights in each of four periods of the year indicated by the position of the parallactic ellipse, and hopes in this way to determine the parallax of from ten to fifteen stars in the year. He proposes first to apply this method to all the stars between the magnitudes 1½ and 2½ which attain a sufficient altitude at Oxford, and expects from experience that the parallaxes will be determinable by this method when they are not less than the thirtieth of a second of arc.

The Age of the Stars. A very interesting address delivered at the annual public session of the five academies of France, Oct. 25, 1887, by M. Jannsen, the director of the observatory at Meudon, France, is published in the December numbers of *Ciel et Terre* and the January and February numbers of *l'Astronomie*. The principal thought is that the idea of evolution may be applied to the stars as well as to terrestrial things. The stars are not fixed and eternal but are subject to change and time. They have a beginning, a period of activity, a decline and an end. By recent advances in the study of celestial physics, especially with the spectroscope, we are enabled to know something of the actual condition and relative age of some of the stars. We may assume that the age of stars, other things being equal, will depend upon their temperature, and that their temperatures are higher in proportion as their spectra are richer in violet rays. The majority of the stars which are visible to the naked eye are white or bluish, and therefore at a high temperature; but many are yellow or orange like our sun, showing that they have passed their youth, while others are from dark orange to dark red, showing that their sidereal evolution is far advanced. In a subsequent number of THE MESSENGER we will give an extract of some length from this address.

H. C. W.

The Editor of the Journal of the Liverpool Astronomical Society, Herbert Sadler, F. R. A. S., kindly calls our attention to a letter published in the *English Mechanic*, Feb. 13, 1882, in which he gave a drawing of θ Orionis showing, as he thinks, the same small star claimed to be discovered by Mr. Alvan G. Clark in January last, by the aid of the 36-inch equatorial of Lick Observatory. Later his copy of that drawing will be given with other statements of interest furnished by Mr. Sadler.

Mr. Proctor and Professor Holden. Mr. Knobel's letter* is correct in every detail. But I am at a loss to understand why he or you (editor of THE MESSENGER) should regard it as involving a contradiction of anything in my letter. Especially, he is right in saying that I did nothing positively to advance Professor Holden's election. My letter should

* See February MESSENGER, page 89.

show that I *could* not have done anything of the kind. I repeat my statement, however, that "but for me" ("my silence," I should have said, if I had supposed it possible I could be in any degree misunderstood) Professor "Holden's name would have beeh rejected."

Though I had withdrawn my name from the Council, I had many friends in it, men of honor and probity: and I believe the Council to have been mainly constituted in 1884 of men of that stamp. Hence my certainty in regard to the fact mentioned in my letter which Mr. Knobel has not in any way contradicted. RICHARD A. PROCTOR.

The editor of THE MESSENGER thinks the *Observatory* is right in saying that "it is difficult to understand how anything less than an unreserved withdrawal of his (Proctor's former) statements will meet the case."

Catalogue of Nebulæ. Dr. Dreyer has recently completed a most important work, viz: the collection into one general catalogue of all nebulæ of which observations have been published. This catalogue, containing particulars of 7,840 objects, forms Part I of Vol. XLIX of the Mem. R. A. S., and in view of its importance to observers we believe that a certain number of additional copies have been printed by the Society, and may be purchased at 15*s* each. The work seems to have been done with a thoroughness worthy Dr. Dreyer's reputation. Besides the new collection of catalogues, the well known inaccuracy of Herschel's General Catalogue, due to the rapidity with which many of the observations were made, has necessitated a careful revision in many places; and the dozen closely printed pages of notes which are given at the end of the catalogue show that this labor has been somewhat severe.

The least satisfactory part of the catalogue must needs be the estimates of brightness, which can only be taken as approximations. The observer's eye, the weather, and the instrument used are factors in the results. It is to be hoped ere long that some photometer may be adapted to the more accurate determination of the relative brightness of nebulæ. —*Observatory.*

The comet is receding from the earth and the sun.

Continued cloudy weather has prevented observations of the new comet at Carleton College Observatory.

Focal Length and Figure of Mirrors. In an interesting article on making glass specula by hand, in *Nature* (Feb. 16, 1888), Mr. A. A. Common "considers that when the focal length exceeds 40 feet, even with a theoretically perfect mirror, the slightest touch or variation of temperature will be sufficient to destroy good definition with high powers, irrespective of the disturbing effects of the atmosphere, and he comes to the conclusion, that by decreasing the focal length, the rays cross at a less acute angle, and small variations in the reflecting surface have not so detrimental an effect—a statement that is entirely unsupported."

BOOK NOTICE.

A Manual of Descriptive Geometry with numerous Problems. By CLARENCE A. WALDO, A. M., Professor of Mathematics, Rose Polytechnic Institute, Terre Haute, Ind. Messrs. D. C. Heath & Co., Publishers: 1888; pp 77.

The purpose of this little book is to answer the question, how a solid having three dimensions can be truly represented on a surface which has but two dimensions. Readers of mathematics will at once recognize this query as the leading one in Descriptive Geometry. Such also know that it can be answered, in practice, only by a right use of the laws of projection, depending on the principles of mathematics for a scientific basis for its methods. If this be rightly done, it is true that the smallest details of projection may be represented in plane surfaces accurately in form and measurement.

After speaking of the method of solving problems in descriptive geometry, the author considers the projection of a point, line, surface and solid, giving with each a large number of exercises. The next step is the generalization of these simple concepts which calls for more knowledge of the higher mathematics. It is readily seen that this progressive course of study is calculated to show the student some of the uses and the beauties of this delightful branch by making them definite and real to the mind in the constant effort to picture them to the eye neatly and accurately.

This is a neat little book and will find friends where it is known.

THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE,

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

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THE RELATION OF SHORT-PERIOD COMETS TO THE ZONE OF ASTEROIDS.

BY DANIEL KIRKWOOD.

FOR THE MESSENGER.

The comets whose periods are inlcuded between those of Mars and Jupiter have a striking family likeness. The conjecture that the cluster had a common origin in the zone of asteroids seemed therefore not improbable, and was adopted by the writer, though with some hesitation, more than twenty years since.* The question, however, is still undecided; the most prominent theories of the cluster's origin being the following:

(1.) The theory of capture by Jupiter.—The well-known views of La Place in regard to the entrance of comets into the solar system may be found in Note VII., Vol. II., of his *Systeme du Monde*.† Similar views have been advocated by M. Faye, Professor H. A. Newton, and others.

(2.) The theory of explosion.—According to this hypothesis comets have been thrown out by an eruptive force from the major planets, as gaseous matter is often seen to be projected from the sun's surface. This view is sustained with much ability by Mr. R. A. Proctor.

(3.) The asteroidal theory, already referred to.—In this scheme, suggested by the late Stephen Alexander, LL. D.,‡ the short-period comets were originally asteroids so situated in the group that they were liable to great perturbation by Jupiter. The cluster, as hitherto observed, contains twenty-two members. For convenience of reference a conspectus of their elements is given below:

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* Met. Astr. pp. 118, 119.

† They are also briefly stated in Met. Astr. pp. 117, 118.

‡ Gould's Astr. Jour. Nos. 19, 20.

Table of the Elements of the Asteroidal Comets.

No.	Designation.	Mean Distance	Eccen.	Per. Distance	App. Distance	Mean Daily Mot	Inclination.
1	Encke	2.2150	0.8458	0.3423	4.0969	1077″.0	12°54′
2	Blainpan	2.8490	0.6867	0.8926	4.8060	737 .8	9 1
3	1766, II	2.9340	0.8640	0.3990	5.4670	706 .1	8 2
4	Tempel (1873)	3.0051	0.5525	1.3447	4.6656	681 .3	12 45
5	Barnard (1884)	3.0743	0.5840	1.2788	4.8700	657 .8	5 28
6	Clausen (1743)	3.0913	0.7213	0.8615	5.3211	652 .8	1 54
7	Brorsen	3.1015	0.8098	0.5899	5.6129	649 .6	29 23
8	De Vico	3.1028	0.6173	1.1863	5.0194	648 .8	2 55
9	Tempel-Swift	3.1180	0.6560	1.0726	5.1627	644 .6	5 24
10	Lexell	3.1560	0.7861	0.6745	5.6375	632 .8	1 34
11	Pigott	3.1583	0.6784	1.4953	5.3009	621 .1	44 53
12	Winnecke	3.2326	0.7268	0.8832	5.5820	610 .5	14 27
13	Brooks	3.4102	0.7840	0.7366	6.0838	563 .1	12 56
14	Tempel	3.4844	0.4051	2.0733	4.8973	545 .4	10 50
{15	Biela	3.5139	0.7552	0.8602	6.1673	538 .7	12 56
{15′	Biela′	3.5289	0.7551	0.8606	6.1969	535 .2	12 34
16	Tuttle	3.5222	0.6737	1.1493	5.8951	536 .9	19 30
17	Finlay	3.5435	0.7181	0.9989	6.0881	532 .7	3 2
18	D'Arrest	3.5491	0.6263	1.3264	5.7720	530 .8	15 42
19	{Wolf, 1884	3.5716	0.5599	1.5719	5.5717	525 .5	25 15
19′	{Before 1875	4.6100	0.2787	3.3252	5.8948	358 .1	27 37
20	Coggia	3.6241	0.7876	0.7698	6.4784	512 .7	26 44
21	Fay	3.8540	0.5490	1.7381	5.9701	469 .0	11 20
22	Denning	4.2732	0.8303	0.7252	7.8212	400 .6	6 50

Table of the Elements of the Asteroidal Comets.

No.	Period.	Long. of Per.	Long. of Asc. N.	Time of Per. Passage.	Calculator.	Date of Disc.
1	3.307y	158°33′	334°37′	1885, Mar. 7	Backlund.	1786, Jan. 30
2	4.809	67 19	77 14	1819, Nov. 20	Encke.	1819, Nov. 28
3	5.025	251 13	74 11	1766, Apr. 26	Burckhardt.	1766, Apr. 1
4	5.209	306 7	121 2	1884, Nov. 20	Schulhof.	1873, July 28
5	5.394	306 11	5 37	1884, Aug. 16	Egbert.	1884, July 16
6	5.435	93 20	86 54	1743, Jan. 8	Clausen.	1743, Feb. 10
7	5.462	116 15	101 19	1879, Mar. 30	Schulze.	1846, Feb. 26
8	5.469	342 31	63 50	1844, Sept. 2	Brunnow.	1844, Aug. 22
9	5.505	43 10	297 1	1886, May 9	Bossert.	1869, Nov. 27
10	5.607	356 17	131 59	1770, Aug. 13	Leverrier.	1770, June 14
11	5.613	49 32	55 12	1783, Nov. 19	Burckhardt.	1783, Nov. 19
12	5.812	276 4	101 56	1886, Sept. 4	A. Palisa.	1858, Jan. 4
13	6.300	229 46	53 3	1886, June 6	Hind.	1886, May 22
14	6.507	241 22	72 24	1885, Sept. 25	Gautier.	1873, July 3
{15	6.587	109 5	245 50	1852, Sept. 23	D'Arrest.	1826, Feb. 28
{15′	6.629	108 58	245 58	1852, Sept. 23	D'Arrest.	1826, Feb. 28
16	6.610	200 47	175 4	1858, May 4	Schulhof.	1858, May 2
17	6.670	7 34	52 30	1886, Nov. 22	Krueger.	1886, Sep. 26
18	6.686	319 11	146 7	1884, Jan. 13	Villarceau and Leveau.	1851, June 27
{19	6.749	19 3	206 22	1884, Nov. 17	Lehmann-Filhes.	1884, Sep. 17
{19′	9.898	352 37	207 34	1868, Sept. 24	Lehmann-Filhes.	1884, Sep 17
20	6.900	85 42	248 47	1873, Dec. 3	Schulhof.	1873, Nov. 10
21	7.566	50 49	209 35	1881, Jan. 22	Moller.	1843, Nov. 27
22	8.833	18 36	65 52	1881, Sept. 28	Plummer.	1881, Oct. 3

REMARKS ON THE TABLE.

(1.) If the acceleration of Encke's comet has been uniform its period was two-sevenths of Jupiter's about A. D. 600.

(2.) The period of No. 4 is four-ninths that of Jupiter; of No. 12 (Winnecke's), six-elevenths; the periods of Nos. 15

and 16 are five-ninths that of Jupiter, and those of Faye and Denning, approximately two-thirds.

(3.) Several members of the group, viz., Nos. 2, 3, 6, 8, 10, 11 and 15, have mysteriously disappeared. For this fact we may assign either of two causes; dissolution into parts below the limits of visibility, or the transformation of orbits by Jupiter's influence. Biela's comet is an example of the former; Lexell's, of the latter. These being known and sufficient causes, no others need be sought for.

(4.) The perihelia are thus distributed:

In the 180° from 110° to 290°.................. 7, or 33 per cent.
In the 180° from 290° to 110°..................15, or 67 per cent.
This maximum coincides with that of the minor planets. See "The Asteroids," p. 50.

DID THE SHORT-PERIOD COMETS ORIGINATE WITHIN JUPITER'S ORBIT?

In the *Monthly Notices of the Royal Astronomical Society* for November, 1872, and in his subsequent writings, Mr. Proctor has presented arguments of no ordinary weight against the theory of capture. His reasoning need not here be repeated. It may be remarked, however, that the explosion hypothesis is not the only alternative. His mathematical objections do not hold against the theory of an asteroidal origin. Let us, therefore, briefly consider a few of the facts which may be advanced in its favor:

(1.) *All* the members of the cluster have direct motion. It may be admited that on the theory of capture a majority of the motions would be direct. Jupiter's influence, however, could not in all cases reverse the direction of the cometary mass in its approach to the sun; and of the twenty-two discovered, some might be expected to have a retrograde motion.

(2.) No example of the transformation of a parabolic to an elliptic orbit by Jupiter's influence is recorded as a historical fact.

(3.) The asteroid zone is an abundant source of supply, and the dominating influence of Jupiter a true and sufficient cause for the change of orbits. The history of Lexell's comet is a striking illustration. Before its close approach to Jupiter in 1767, it had been moving in an ellipse whose perihelion was so remote that the comet could never be seen from the earth, though, as in the case of other members of the group, its period was included between those of Mars and Jupiter. At that epoch Jupiter's influence threw it into a new orbit, corresponding to a period of five and one-half years. After one revolution of the planet and two of the comet another close approach so modified the elliptic elements that the body has not since been seen. Its future identification, however, as a short-period comet, may not yet be impossible.*

(4.) The comet which passed its perihelion on the 17th of November, 1884, affords another instance of remarkable disturbance. Before 1875 its orbit was an ellipse whose eccentricity was only 0.2787—a less deviation from the circular form than those of twelve known asteroids. Its perihelion distance was 3.325—beyond the limit of visibility by ordinary telescopes. Its aphelion was a short distance beyond Jupiter's orbit; hence its liability to great perturbation. So close was its approach to that planet in May, 1875, that its orbit was transformed into that designated as No. 19 of the foregoing table. Had this body been detected before the transformation of its orbit it would doubtless have been considered an asteroid—more distant indeed than any now known, but in no other respect very clearly distinguished. Its eccentricity was doubled in the perturbation.†

OBJECTIONS.

(1.) It may be objected that this theory is not general and that in the case of other comets we must have recourse either to the theory of La Place or that of Proctor. If, in the cosmogony of La Place, nebulous bodies, "strangers to our system," entered from inter-*stellar* space, may not others, consistently with the same view, have had an inter-*planetary* origin?

(2.) The "asteroidal comets" differ from asteroids in their physical characteristics. The latter are said to change their aspect solely or chiefly with their change of distance from the earth. The former vary greatly in apparent magnitude with their changing distance from the sun, some even devel-

* See Leverrier's discussion in *Mem. Acad. Sci.*, 1847.

† Annuaire, 1886, pp. 249, 250.

oping tails in approaching perihelion. Can these facts be harmonized with the theory that such bodies are but stray asteroids?

This objection is plausible but perhaps not fatal. In the case of some asteroids a variation of apparent magnitude, greater than that due to varying distance from the earth, has undoubtedly been noticed.* It may also be stated that the observed physical changes in the short-period comets occur mostly, if not entirely, when they are in the vicinity of perihelion, or within the zone of asteroids. The phenomena might disappear with decreasing eccentricity.

ASTRONOMICAL PHOTOGRAPHY.† ‡

A star of any given order of lustre emits just two and a half times as much light as a star of the magnitude next below. One of the sixteenth is accordingly a million times fainter than one of the first magnitude, and under identical conditions takes a million times longer to get photographed. This is the proper and only definite criterion of the rank of such feebly luminous objects, visual estimates of which are little better than guess-work.

It is true that color exercises a disturbing influence owing to the predominant sensitiveness of silver salts to the more refrangible rays. Aldebaran, for instance, is reduced by the fiery tinge of its light to the fifth or sixth *chemical* rank; and small red stars are frequently missing from photographs which display crowds of objects equally or less bright to the eye. Such discrepancies, however, have an interest of their own, and they do not impair the general correspondence

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* The Asteroids, p. 53. † Continued from p. 153.

‡ From January *Edinburgh Review*, being a review of the following articles:

1. La Photographie Astronomique a l'Observatoire de Paris et la Carte du Ciel. Par M. le Contre-Amiral E. Mouchez. Paris: 1887.

2. An Investigation in Stellar Photography conducted at the Harvard College Observatory. By Edward C. Pickering. Cambridge, U. S.: 1886.

3. First Annual Report of the Photographic Study of Stellar Spectra conducted at the Harvard College Observatory. By Edward C. Pickering, Director. Cambridge, U. S.: 1887.

4. The Applications of Photography in Astronomy. Lecture delivered at the Royal Insitution, Friday, June 3, 1887. By David Gill, LL. D., F. R. S (The Observatory, July and August, 1887.)

5. Die Photographie im Dienste der Astronomie. Von O. Struve. (Bulletine de l'Academie Imperiale des Sciences de St. Petersbourg, Tome xxx. No. 4: 1886.)

between visual and photographic evaluations of brightness. Nor, even when they differ, is there any valid reason for preferring the former to the latter. Both serve as means to the same ends; and chemical determinations are in so far at least to be preferred that they are authentic over a wider range.

Accurate comparisons of stellar brilliance serve two chief purposes—an individual, so to speak, and a general. Taken separately, they are a direct test of variability; taken together, and on an average, they are a safe guide to distribution.

The great problem of the constitution of the sidereal universe is not to be solved by a stroke of genius. The generations of men are but as hours for its study; each contributes its little quota of gathered facts, and more or less ineffectual thoughts, and goes to its rest only a shade less ignorant than its predecessors. It was Herschel's great merit to have perceived that no reasoning on the subject could stand unless based on a solid substructure of statistics, and he even made the attempt by his "guages," or counts of stars in various directions, to supply the needful data. But the information attainable by the labors of an individual was as nothing compared with what must be collected before profitable discussions could even begin. Now at last the requisite materials are, it would seem, about to be provided, and a long pause in the progress of knowledge may be compensated by a leap forward. When the photographic survey of the heavens is completed, conclusions of reasonable certainty on some fundamental points connected with the galactic structure will be within comparatively easy reach.

The mere counting of the stars of various orders on the plates will show whether they give any signs of *thinning out*. Stars of any assigned brightness should, on the supposition of tolerably even scattering, be nearly four times as numerous as those one magnitude brighter. There should be more of them because they occupy a wider shell of space. Thus, a marked scarcity, local or general, of faint stars would afford evidence of an approach to the limits of the system; it would indicate a determinate boundary to the Milky Way.

It is practically certain that such a boundary must somewhere exist. Were the stars agglomerated in the Galaxy infinite in number they would emit an infinite quantity of light; and (unless on the gratuitous assumption of its extinction in space) our skies should blaze with a uniform and unendurable lustre. But the sum-total of stellar radiations striking the earth is very small. It has been estimated at one-tenth of full moonlight; it is in reality probably much less. The grand aggregate number of stars, however, corresponding to that amount of light comes out, by a recent computation, at no less than *sixty-six milliards*, and the frontier line of the system constituted by them is drawn at the average distance of stars of the seventeenth magnitude.* All this is, of course, largely hypothetical, but it is a certain and a curious fact that we receive much more light from stars invisible than from those visible to the naked eye. All the lucid orbs might, in fact, be withdrawn without sensibly diminishing the general illumination of the sky.†

The concentration of stars towards the Milky Way appears, from the evidence of Schönfeld's zones, to be far less marked in the southern than in the northern hemisphere.‡ Photographic statistics will supply the means of deciding whether any such difference really exists. They will, moreover, test the truth of M. Celoria's interesting theory of a double Galaxy. The sidereal world is, in his view, composed of two rings of stars at widely different distances from us, one inclined at a considerable angle to and including the other, the sun being situated in the plane of neither, and excentrically towards both. We shall see whether the twenty millions about to be charted conform to this plan.

The movements of the stars, as tending to reveal the laws governing the stellar commonwealth, are of even higher interest than their distribution; but we are still very much in the dark about them. The impending photographic survey will be a preparatory measure for the acquiring extended knowledge on the subject. About the year 2000 A. D. the seed planted in our time will have begun to bear fruit. A fresh determination of their places for that epoch will reveal the amount and direction of their changes in the interim. Something of the meaning of those changes can hardly fail to become legible. Stars associated by a general "drift" can

* Hermite, "L'Astronomie," tome v. p. 412. † Ibid. p. 409.
‡ Seeliger, "Sitzungsberichte," Heft ii. p. 228. Munich: 1886.

be marshalled into systems; others in specially rapid motion —the so-called "flying" or "runaway" stars—will show their common peculiarities; an inkling of the purpose of the sun's mysterious journey through space may be gained, and its rate and aim, in any case, ascertained; his companions on the voyage may even be picked out. The motion-harmonies of the Cosmos will begin to sound intelligibly in the ears of humanity.

But present as well as prospective results may be looked for from the contemplated star-enrollment. Its progress must inevitably be attended by interesting disclosures. Now a new asteroid will stamp its light track on a plate, or a remote giant planet will be distinguished by disappearance from or intrusion into a duplicate record; a comet approaching the sun will announce itself from afar; stars will show unsuspected nebulous appendages; others, too faint for visual separation, will spontaneously divide on the chemical retina.

Our readers can now to some extent appreciate the importance of securing a trustworthy picture of the sky for a given epoch. But this was not the sole care of the astronomers assembled at Paris. The miscellaneous application of photography also engaged their attention; and by appointing M. Janssen and Mr. Common as a permanent committee for the purpose of studying and promoting them, they made sure, in this direction also, of rapid progress.

Mr. Common's well-known photograph of the great nebula in Orion, taken in Ealing, January 30, 1883, not only superseded all previously existing delineations of that strange object, but virtually prohibited any such being attempted in future. Changes in its condition, it was made plain, must thenceforward be investigated by a comparison of photographs taken at various dates. No living astronomer has devoted more care to the telescopic study than Professor E. S. Holden, now director of the Lick Observatory. Yet he frankly admits that "every important result reached" by an assiduous scrutiny of four years with the Washington twenty-six-inch equatorial, "and very many not comprised in it, were attained by Mr. Common's photograph, which required an exposure of forty minutes only."*

* Photography the Servant of Astronomy, p. 10.

Since about seven thousand nebulæ are now known, the field of research thus entered upon is sufficiently wide. And its cultivation must be largely disinterested. Time, for the most part, will be needed to ripen its results. Some centuries hence, for example, the examination of a "vitrified" picture of a spiral nebula dating, say, from 1890, may reveal alterations of form decisive on some leading points connected with the genesis of worlds.* Posterity will not, however, alone reap the benefits of such labors. Some first fruits have been already gathered. A photograph by Mr. Common of the central portion of the Andromeda showed that the star which blazed out near the nucleus in August, 1885, had no visible existence a year earlier. It was *not*, then, developed by some sudden catastrophe out of one of the minute stellar points powdering the surface of the nebula, but was "new" in the relative sense in which alone we can safely use the term.

The discovery of the nebulous condition of the Pleiades, again, has been an almost startling illustration of what may be learnt by sheer perseverance in exposing sensitive plates to the sky. Nearly thirty years ago M. Tempel, an exceptionally acute observer, detected a filmy veil thrown round, and floating far back from the bright star Merope; and Mr. Common *saw*, with his three-foot reflector, February 8, 1880, some additional misty patches in the same neighborhood. In general, however, the keen lustre of the grouped stars appeared relieved against perfectly dark space.

Great then was the surprise of the MM. Henry on perceiving a little spiral nebula clinging round the star Maia, on a plate exposed during three hours, November 16, 1885. The light of this remarkable object possesses far more chemical than visual intensity. Were its analysis possible, it would hence doubtless prove to contain an unusually large proportion of ultra-violet rays. It is of such evanescent faintness that its direct detection was highly improbable; but since it has been known to exist, careful looking has brought it into view with several large telescopes. It was first visually observed on February 5, 1886, with the new Pulkowa refractor of thirty inches aperture, and M. Kammermann, by using a fluorescent eyepiece, contrived to get a sight of it with the ten-inch of the Geneva Observatory.

* Mouchez, op. cit. p. 61.

The further prosecution of the inquiry is due to Mr. Roberts of Liverpool. With his twenty-inch reflector he obtained, on October 24, 1886, a picture of the Pleiades that can only be described as astounding. The whole group is shown by it as involved in one vast nebulous formation.* "Streamers and fleecy masses" extend from star to star. Nebulæ in wings and trains, nebulæ in patches, whisps and streaks, seem to fill the system, as clouds choke a mountain valley and blend together the over exposed blotches which represent the action of stellar rays. What processes of nature may be indicated by these unexpected appearances we do not know; but the upshot of recent investigation† leads us to suppose them connected with the presence of copious meteoric supplies, and their infalls upon the associated stars.

The mechanical condition of globular clusters of stars offers a problem of extraordinary interest and complexity. It can, however, be usefully studied only by the aid of photography. Take as an example the marvellous agglomeration in the constellation Hercules. The many thousands of stars composing it run together towards the centre, into one unbroken blaze utterly defying measurement of every kind; while the outlying "grains of bright dust" bewilder the eye so as to incapacitate it for methodical operations.‡ But from the the Paris plate all such separate stars can and will be perfectly well mapped and catalogued. Dr. O. Lohse has since 1884 been working in Potsdam with signal success in the same department; and thus data are being stored up for the future detection of interstitial movements in these complex systems. They must, in general, be extremely minute; and a star in the cluster No. 1440, shown as markedly displaced in eighteen years by a comparison of M. Von Gothard's photographs with Vogel's micrometric measures,§ will most likely prove to be accidentally projected *upon* the cluster, and not to form part of it.

Doubts as to the superiority of the photographic method of measurement for double stars can only arise where the components are considerably unequal. In this case the

* Monthly Notices, vol. xlvii. p. 24.
† Described by Mr. Norman Lockyer, before the Royal Society, Nov. 17. 1887.
‡ Mouchez, op. cit. p. 54. § Astr. Nachrichten, No. 2777.

brighter star, necessarily over-exposed, gives an indistinct and distended image ill suited for precise determinations. The same difficulty impedes photographic operations for ascertaining the parallaxes of large stars. Professor Pritchard has, however, shown conclusively by his successful measures of 61 Cygni that this most exacting problem of stellar astronomy lies for the most part well within the competence of the camera. Its prerogatives in the matter are obvious, and the result of its employment will infallibly be a rapid multiplication of the stars at known distances from our system.

We are far from having reckoned up all the tasks of astronomical photography. They become every year more numerous; their scope widens as we contemplate it, while that of eye observations dwindles proportionately. Even transits, it appears, can now be taken with increased accuracy on the sensitive plate. It is indeed difficult to set bounds to the revolution in progress by which all the practical methods of celestial science are being swiftly and irresistibly transformed.

The tendency of the camera to usurp the functions of the eye is nowhere more apparent than in the study of stellar spectra. When Dr. Huggins laid before the Royal Society, December 6, 1876, a little print of the spectrum of Vega,* only a prophetic imagination could have anticipated that, within ten short years, so vast a development would be given to the subject. After the lapse of three years, the same eminent investigator communicated his discovery of the complete ultra-violet spectrum of hydrogen as depicted, dark by absorption, in the analyzed light of Vega and other white stars. This rhythmical series of vibrations, repeated, in varied terms, in the spectra of some metals,† may yet serve as a clue out of the labyrinth of speculation regarding the molecular constitution of matter. None of its nine invisible members occur in ordinary sunlight; but they appeared in a photograph of the spectrum of a prominence taken by Dr. Schuster during the total eclipse of 1882. Their presence would seem to be conditional upon a high

* The first photograph of a star spectrum showing lines was obtained by Dr. Draper, in 1872.

† Cornu, "Journal de Physique," Mars, 1886.

state of excitement by heat of the hydrogen atoms emitting them; and their strong reversal in the spectra of Sirius, Vega, and their congeners almost compels the belief that the photospheres of such stars are more intensely incandescent than that of our sun.

The work to which Dr. Henry Draper devoted his chief energies during the later years of his life was that of stellar spectroscopic photography; and it is now being prosecuted at Harvard College as a memorial to him, and with funds and instruments provided by his widow. "The attempt will be made to include all portions of the subject, so that the final results shall form a complete discussion of the constitution and condition of the stars as revealed by the spectra, so far as present scientific methods permit."* There can be little doubt that, under Professor Pickering's direction, this "attempt" will be successful. Already superb specimens of photographed spectra have been distributed, obtained by methods so expeditious as to enable stars by the score together to stamp the characters of their analyzed light on the same plate. And in sidereal astronomy, the subject matter of which is all but infinite, the quantity of information collected in a given time is nearly as important as its quality. Hence large expectations from the Harvard researches are justly entertained.

The spectroscope supplies information not only about the physical constitution, but about the movements of the stars, and it is safe to say that its messages on this head will henceforth be read almost exclusively by photographic means. The acquisition of power to determine, by the displacement of known lines in its spectrum, whether a heavenly body is moving towards or from the eye, and at what rate, is one of the most considerable of recent additions to the resources of astronomy. Its use as regards the stars, however, has hitherto been hampered by grave difficulties of observation. Small deviations of delicate lines kept continually thrilling and shivering by air tremors can be but insecurely registered. But on such photographs as Professor Pickering's (once provided with a standard of wave-length) the readings will be sure and easy.

* Draper Memorial, First Report, p. 3.

Here we find the natural meeting-place of the old and the new astronomies. Spectroscopy and photography here directly lend themselves to dynamical inquiries, and so help to found the future science of sidereal mechanics. They combine to measure movements otherwise wholly imperceptible. More complete data as to the mutual relations of the stars are thus afforded, and means provided for determining the rate of translation of the solar system by contrasting stellar rates of approach or recession in opposite quarters of the sky. Stars sensibly exempt from visual displacement because the whole of their motion is 'end on' can be discriminated from stars really almost immovable relative to the sun, because associated with it in a journey towards the same bourne in space. The members of the stellar group to which the sun belongs can in this way be identified, and some insight gained into its structure. And all this in the immediate future. For spectroscopic determinations of movement are complete in themselves. They evade the necessity for exact comparisons after the lapse of tedious years or centuries. They tell us at once *what is.*

Astronomical photography includes tasks of all kinds and suited to every capacity. The Baconian principle of the division of scientific labor will by it be brought into full play. One division of workers will devote themselves to the exposure and development of plates, another to their measurement. It may even happen that the first set of operations will be conducted in a different part of the globe from the second, as the Cape photographs are now in course of measurement at Groningen, and the Cordoba photographs at Boston. The same negatives may be studied by one astronomer in search of new members of the solar system; by another, for the purpose of detecting displacements due to annual parallax or proper motion; by a third, with a view to eliciting facts relative to stellar distribution; by a fourth, for the sake of information latent in them as to stellar variability. In each branch of sidereal astronomy photographic experts will arise skilled in developing the special conditions favorable to success in a special direction. The picturing of nebulæ is a totally different art from stellar chartography; double stars require modes of treatment not applicable to clusters; impressions for photometric purposes would be wholly useless for measuring displacements; the obstacles met in depicting stellar spectra are of another order than those which impede the photographic sounding of space.

Several magnificent instruments will shortly be available for photographic use. A "bent equatorial," twenty-nine and a half inches in aperture, in preparation at Paris, will offer particular advantage for lunar and planetary work from the extremely long focus (fifty-nine feet) which its peculiar form enables it to receive. The Lick object-glass will collect nine times as much light as any actually existing photographic telescope.

"A single exposure," Professor Holden remarks,* "will give us a map of the sky comprising four square degrees on a plate twenty-four by twenty-four inches. A few minutes will impress on this plate a permanent record of the position and brightness of all the stars visible in even the largest telescopes. A comparison of two such plates, taken on different nights, will point out any changes which might easily escape the most minute observations by other methods. The sun's image unmagnified will be six inches in diameter; a large sunspot will be the size of one's finger-nail. Beautiful photographs of the planets can be taken so as to register with perfect accuracy the features of their surfaces. Comets and nebulæ can be studied at leisure from their automatic registers, as one studies a copperplate engraving. The variations of refraction from the horizon to the zenith can be made to record themselves for measurement. There is absolutely no end to the problems lying close at hand, and their number and their importance will develop with time. We are merely at the threshold of this subject."

But even the Lick refractor will be beaten out of the field, as regards luminous capacity, by the five-foot, silver-on-glass reflector which Mr. Common is now personally engaged in constructing. Twice as many rays as the other transmits will be concentrated by it, and its other qualities, unless they belie expectation, will correspond to its power. Unfortunately, however, there is another large factor in the account. A bad climate cripples the use of the most perfect instrument. Its size renders it only the more sensitive to atmospheric troubles. And Ealing is half submerged by the fogs of London, while Mount Hamilton, as an observing site, has no known rival in the world.

We have said enough to show that a new and hopeful era is opening for astronomy. It is greeted on all sides with the enthusiasm which the drawing of large possibilities never fails to evoke. The time-honored problem of "how the

* Photography the Servant of Astronomy, p. 10.

heavens move" presents itself under a novel aspect. Novel implements of research are being zealously adapted to its requirements. The shrinkage of films, the vitrification of negatives, the distension of photographic star-discs, devices for modifying the qualities of salts of silver, are being studied with the same patient ardour that Bessel brought to determinations of "collimation-errors" or "personal equation." There is no longer a "new" and an "old" astronomy. The two are fused into one, to the enormous advantage of both. It seems hardly possible to be over-sanguine as to the results.

ON THE NEBULAR HYPOTHESIS OF LA PLACE.*

BY GEORGE W. COAKLEY.†

The next question discussed by La Place is: How far may the atmosphere of such a rotating mass extend, especially above its equator, where the centrifugal force is greatest, and is most directly opposed to gravity? It is certain that the earth's atmosphere can not extend indefinitely above its equator; for the farther you go from the centre of the earth the less the force of gravity becomes in proportion to the square of the distance; while the higher up the atmosphere reaches, the greater the centrifugal force becomes over the equator, precisely in proportion to the distance from the axis, or, in this case, from the centre. So that we must ultimately reach a distance above the equator, at which gravity is so reduced, and centrifugal force so increased by the distance, that these two opposing forces are equal and neutralize each other. At the next step beyond the centrifugal force exceeds gravity, and the part of the atmosphere above the equator at this greater distance would cease to belong to the Earth, and would be driven away from it. But on the top of the atmosphere, at several degrees away from the equator on either side, the centrifugal force is less than just over the equator, and besides does not directly oppose gravity, so that those portions could still press down toward the Earth's surface. La Place calls the distance at

* Continued from page 137.

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

which the centrifugal force just balances gravity, the *Centrifugal Limit.* Where would this centrifugal limit be over the Earth's equator, with our present rotation, once in about twenty-four hours? It is easily computed, and I find it to be, over the Earth's equator, at about nearly 27,000 miles from the centre, or about 23,000 miles above the surface of the Earth. It is well known that at the equator, and on the surface of the Earth, the centrifugal force is now about the $\frac{1}{289}$ of the force of gravity; and that if the Earth's angular velocity were about seventeen times as great as it is, or its time of rotation were reduced to about one hour and twenty-five minutes, objects at the equator would cease to have weight, or begin to be repelled from the Earth. Certainly, the whole of the atmosphere at the equator would then leave the Earth.

To come back to La Place's equation, and his discussion of it. He supposes now that the atmosphere of his rotating body has reached the *centrifugal limit* over the equator, and enquires what, in that case, is the ratio of the equatorial to the polar radius, or the ratio of R' to R. As he puts n for the angular velocity of his rotating body, at the unit's distance from the axis, and takes the equatorial radius of the nucleus for the unit of distance, hence n^2 is the centrifugal force at the unit's distance, and $n^2 R'$ is the certrifugal force at the surface of the atmosphere over the equator. Again, $\frac{M}{1^2} = M$ is the force of gravity at the unit's distance from the centre, and $\frac{M}{R'^2}$ = the force of gravity at the surface of the atmosphere over the equator. Hence, at the *centrifugal limit*, we have $n^2 R' = \frac{M}{R'^2} \therefore \frac{n^2}{M} R'^3 = 1$. Hence his preceding equation, $\frac{n^2}{M} R'^3 = 2 \frac{R'-R}{R}$ becomes

$$1 = 2\left(\frac{R'}{R} - 1\right) = 2\frac{R'}{R} - 2 \therefore 2\frac{R'}{R} = 3, \therefore \frac{R'}{R} = \frac{3}{2}$$

It follows, therefore, that, at the *centrifugal limit* of the atmosphere of a rotating body, over the equator, the *equatorial radius* is to the *polar* precisely as 3 to 2. Moreover, we have found that when the *centrifugal limit* is reached we must have $\frac{n^2}{M} . R'^3 = 1$. Hence $n^2 R'^2 = \frac{M}{R'}$; or $n R' = \sqrt{\frac{M}{R'}}$. This is the velocity of rotation at the surface of the atmosphere over the equator. If, therefore, M remains the same mass, or very nearly the same, we have the fact that the *equatorial velocity* at the surface of the atmosphere, when the *centrifugal limit* is reached, is either exactly, or very nearly proportional *inversely to the* SQUARE ROOT *of the radius of the limit.* This is precisely what is given also by Kepler's Third Law. Hence the assertion made by some writers that the velocity at this distance must be inversely as the *square of the distance* is entirely disproved by La Place's equations.

La Place next proves that when the atmosphere of a rotating body reaches the *centrifugal limit* over its equator, the equatorial radius, R' is then the greatest possible, and that there can be no greater ratio of the equatorial to the polar radius of the atmosphere of such a body than that of 3 to 2. From this fact he concludes that the very flattened form of the zodiacal light proves that it is not the atmosphere of the sun, but that it must revolve around him as a detached ring, somewhat perhaps like the rings of Saturn. The foregoing principles, strictly demonstrated, are the real foundation of La Place's celebrated nebular hypothesis.

Let us see now something of the use which he makes of these principles, and his mode of reasoning upon them. It should be remembered that, while the principles themselves are mathematically demonstrated in the *Mecanique Celeste*, they are afterwards merely stated without further proof in the *Exposition du Systeme du Monde*; and in the last note to the latter work La Place proposes his hypothesis.

The important parts of that note I shall present in a free but fair translation.

In order to arrive at the cause of the original motions of the planetary system, we have, says La Place, the five following phenomena:

(1) The motions of the planets in the same direction, and nearly in the same plane;

(2) The motions of the satellites in the same direction as those of the planets;

(3) The rotations of these different bodies, and of the Sun in the same directions as their orbital revolutions, and in planes that differ but little from each other;

(4) The nearly circular orbits, orbits of small eccentricity, both of the planets and of the satellites;

(5) On the contrary, the great eccentricity of the orbits of comets, their mutual inclinations at the same time having every possible value, and their directions as if abandoned to chance.

That La Place knew nothing of any nebular speculations of Kant is evident from his statement that Buffon is the only one that he knew who, since the discovery of the true system of the world, has endeavored to trace the origin of the planets and satellites. He then states Buffon's theory, and easily refutes it.

In proposing his own theory, La Place says:

Of whatever nature was the cause of the five phenomena before stated, since it has produced, or directed, the motions of the planets, it must have embraced all these bodies; and on account of the great distances which separate them, this cause could only have been a fluid of immense extent. In order to have communicated to these bodies in the same direction an almost circular motion around the sun this fluid must have surrounded the sun like an atmosphere.

The consideration of the planetary motions leads us, therefore, to *suppose* that, in consequence of an excessive heat, the atmosphere of the sun has in former times extended beyond the orbits of all the planets, and that it has successively contracted up to its present limits.

In the primitive state which we suppose the sun to have had, it resembled those nebulæ which the telescope shows us, composed of a more or less brilliant nucleus, surrounded by a nebulosity which, by condensing towards the surface of the nucleus, transforms it into a star. If, by analogy, he says, we conceive all the stars to have been formed in this manner, we may imagine their anterior state of nebulosity, preceded itself by other states in which the nebulous matter was more and more diffused, the nucleus being less and less luminous. By thus going back as far as possible, we may arrive in thought at a degree of nebulosity so diffused, that we can scarcely conceive of its existence.

For a long time the particular arrangement of certain stars, visible to ordinary sight, has struck the attention of philosophical observers. Mitchell has already remarked how little probability there is that the stars of the Pleiades, for example, have been contracted into the narrow space which encloses them by chance alone; and he has concluded that this group of stars, and similar groups which the heavens present, are the effects of some primitive cause or of some *general law* of nature.

These groups are a necessary result of the condensation of the nebulæ into several nuclei; for it is evident that the nebulous matter, being constantly attracted by these different nuclei, ought to form at length a group of stars like that of the Pleiades. The condensation of nubulæ into two nuclei would form in like manner a pair of close stars revolving about each other, such as the binary stars, whose relative motions have been already recognized.

But how has the solar atmosphere determined the motions of rotation and revolution of the planets and satellites? If these bodies had penetrated deeply within this atmosphere, its resistance would have caused them to fall into the sun. We may, therefore, *conjecture* that the planets have been formed at the successive *centrifugal limits* of the solar atmosphere, by the condensation of the zones of vapor which, in cooling, it has been obliged to abandon in the plane of its equator.

Let us recall, says La Place, the results which we have given in the tenth chapter of the preceding book. [He refers to the "*Exposition du Systeme du Monde.*"]

The atmosphere of the sun, he says, could not extend outward indefinitely. Its limit is the point where the centrifugal force, due to its motion of rotation, balances gravity. Now, in proportion as its cooling causes the atmosphere to contract and to be condensed towards the sun's surface, the motion of rotation *must increase*. For, by virtue of the principle of areas, the sum of the areas described by the radius-vector of each molecule of the sun and of its atmosphere, when projected on the plane of his equator, being always the same, the rotation ought to be more rapid when these molecules are brought nearer the sun's centre. The centrifugal force, due to this increased motion, thus becoming greater, the point at which gravity is equal to it approaches nearer the sun's centre

By *supposing*, therefore, what it is very natural to admit, that the sun's atmosphere, at any epoch, had extended up to this *limit* (where the gravitation and centrifugal forces were equal,) it would be necessary, on further cooling, for the atmosphere to abandon the molecules situated at this *limit*, and at the *successive limits* produced by the increase of the sun's rotation.

These molecules, thus abandoned, have continued to circulate around the sun, in the same direction as before, since their centrifugal force was just balanced by their gravity towards the sun.

But this equality of centrifugal force and gravity not taking place with regard to the atmospheric molecules placed on the parallels to the solar equator, these latter molecules by their gravity will follow the atmosphere in proportion as it is condensed, and they will not cease to belong to it, until by their motion they have reached the equator.

Let us consider now, says La Place, the zones of vapor successively abandoned. These zones ought, most probably, to form, by their condensation, and the mutual attraction of their molecules, various concentric rings of vapor, revolving around the sun. The mutual friction of the molecules of each ring ought to accelerate those moving more slowly, and retard the swifter, until they should all have acquired the same *angular* motion about the sun. Hence the *real velocity* of the molecules *farthest from the sun* will be the *greatest*. The following cause ought to contribute also to this difference of velocity. The molecules of the ring most distant from the sun, and which, by the effect of cooling and condensing, are brought nearer so as to form the outer portion of the ring, have always described areas proportional to the time, since the central force by which they are animated has been constantly directed towards the sun's centre.

Now this constancy of areas requires an increase of velocity in proportion as they approach the centre of motion. It is evident that the same cause ought to diminish the velocity of those molecules which, by the cooling and contracting process, are carried outwards to form the inner part of the ring.

If all the molecules of one of these vaporous rings had continued to condense without separating, they would have formed at last a liquid or a solid ring.

But the regularity which such a formation requires in all parts of the ring, and in their rate of cooling, ought to render this phenomenon extremely rare.

Hence the solar system offers but a single example of it, namely that of the rings of Saturn. Almost always each vaporous ring ought to be broken into several masses which, moving with nearly the same velocity, have continued to revolve around the sun at the same distance from him. These masses ought each one to take on a spheroidal form, with a motion of rotation in the same direction as their motion of revolution around the sun, since their molecules nearest to him had less velocity than those farthest from him. They must, therefore, have formed so many planets in a vaporous condition. But if one of them had been large and powerful enough to successively re-unite by its attraction all the others around its own centre, the vaporous ring will have been thus transformed into a single spheroidal vaporous mass, revolving around the sun, nearly in the plane of his equator, with a nearly circular orbit, and with its motion of rotation generally in the same direction with that of its revolution around the sun. This last case has been the most common; but the solar system offers to us an example of the first case, in the four small planets revolving between Mars and Jupiter, unless we suppose with Olbers that they formed at first a single planet which some strong explosion has divided into several parts animated by different velocities. [There are now 276 of these bodies known to astronomers.]

If now we follow, says La Place, the changes which further cooling ought to produce in the planets consisting of vapor, the formation of which we have just considered, we shall see a nucleus begin at the centre of each of them, and see it grow continually by the condensation of the atmosphere which surrounds it. In this state the planet perfectly resembles the sun in the nebulous condition which we have been considering. Its cooling ought therefore to produce, at the different *centrifugal limits* of its atmosphere, phenomena similar to those which we have described, that is to say rings and satellites revolving around its centre in the direction of its motion of rotation, and the satellites rotating also in the same direction on their axes.

The regular distribution of the mass of Saturn's rings around his centre, and in the plane of his equator, results naturally from this hypothesis, and, without it, becomes inexplicable. These rings appear to me, says La Place, to be the ever existing *proof* of the former extension of Saturn's atmosphere, and of its successive contractions.

Thus, the singular phenomena of the small eccentricities of the orbit of the several planets, and those of their satellites, or their almost circular orbits, the small inclinations of these orbits to the sun's equator, and the identity of the motions of rotation and revolution of all these bodies with that of the sun's rotation, flow from the hypothesis which we propose, and give to it a *great probability*, which may be still further increased by the following considerations:

All the bodies which revolve around a planet, having been formed, according to this hypothesis, by the zones which its atmosphere has successively abandoned, and the planet's motion of rotation having become more and more rapid, the duration of this rotation ought to be less than those of the revolution of these different bodies. This must be true, likewise, for the sun in comparison with the planets. All this, says La Place, is confirmed by observation. The duration of revolution of Saturn's nearest ring is, according to Herschel's observations, 0.438*d*, and that of Saturn's rotation is 0.427*d*. The difference, 0.011*d*, is small, as it ought to be; because the part of Saturn's atmosphere which the loss of heat has condensed upon the planet's surface since the formation of this ring, being small, and coming from a small height, it ought to have produced but a small increase of the planet's rotation.

If the solar system had been formed with perfect regularity, the orbits of the bodies which compose it would have been perfect circles, whose planes, as well as those of the different equators and rings, would have coincided exactly with the sun's equator. But we can conceive that the innumerable varieties, which ought to have prevailed in the temperature and density of the several parts of these great masses, have produced the eccentricities of their orbits, and the deviations of their motions from the plane of the sun's equator.

In our hypothesis, the comets are *strangers* to the planetary system. Considering them, as we have done, as small nebulæ wandering from one solar system to another, and formed by the condensation of nebulous matter so profusely scattered throughout the universe, it is evident that when they arrive at that part of space where the sun's attraction predominates, he compels them to describe elliptical or hyperbolic orbits. But their velocities being equally possible in all directions, they ought to move indifferently in all directions and under all inclinations to the ecliptic, which is comformable to observation. Thus the condensation of nebulous matter, by which we have explained the motions of rotation and revolution of the planets and satellites in the same direction and in planes of small inclination to each other, explains equally why the comets depart from this general law.

In some eight or nine pages more La Place goes on to strengthen the argument for his theory, and especially to show why the satellites could not form similar rings, and satellites of satellites. But the gist of his theory is now before us.

It will be noticed that he does not explain how the variety of temperature and density of the several parts of a large ring produced the eccentricities of the planetary orbits, nor the deviations of the planes of the orbits from that of the sun's equator, nor the deviations of their equators from the planes of their orbits. He returns to the subject again, and suggests the possibility of the collisions of comets with the planets as the cause of these deviations. But, if the rings had considerable breadth and thickness, and were not homogeneous, as is probable, then they might separate in planes slightly different from the solar equator, but parallel to it, and also into parts at slightly different distances from the sun's centre. Then, when by their mutual attraction they were brought to unite, it would be with a more or less oblique collision, sufficient perhaps to account for all the observed deviations.

In accounting for the fact that the satellites rotate in the same time as that of their revolution about their planets, La Place uses reasoning that is equivalent to the more modern theory of tidal retardations of a planet's rotation. This tidal retardation is perhaps the cause that the planet Mars takes so much more time to rotate on his axis than his nearest satellite does to revolve around him. I find the tidal action of the sun on Mars to be at least one-third greater than it is on the Earth, notwithstanding the greater distance of Mars, because of his small mass for counteracting the sun's tidal action.

Soon after the ring, which formed the nearest satellite of Mars, was separated from him, his diameter must have been, including his atmosphere, larger than the present diameter of the earth, or considerably more than double the present diameter of Mars. The effect of this would be to more than double the sun's tidal action on Mars, or make it equal to the moon's present tidal action on the waters of the earth. It was perhaps mostly at that distant epoch that this tidal retardation gradually reduced the time of rotation of Mars, without affecting the revolution of his satellites.

Perhaps the most plausible objection to La Place's hypothesis is that stated in Professor Newcomb's Popular Astronomy. The author of that objection claims that, instead of a few widely separated rings being detached at the centrifugal limits of the sun's equator, there ought to be a continuous succession, without any interval between them, of such rings, forming one broad flat disc, extending from the orbit of Neptune to the sun's present surface. But whoever was the author of this objection, it seems to me, failed to appreciate what La Place had proved as to the necessary ratio of 3 to 2 of the equatorial to the polar radius of the sun's atmosphere, at the moment of reaching the *centrifugal limit*. This greatest ratio is *only reached* at the moment the ring is about to separate. Immediatley afterwards the lower height of the equatorial surface of the atmosphere *diminishes the centrifugal force*, and at the same time *increases gravity*. The equilibrium figure of the atmosphere becomes at once less eccentric, and approaches the sphere more nearly. Moreover, the loss of the *ring's mass*, and of the *great amount of area* which it had contributed towards the constant sum, has *greatly* changed that constant. A new and a smaller constant for the sum of the areas now governs the sun's rotation. If, therefore, it was necessary, upon contraction, to maintain the *larger constant* by an increase of areal rotation, it is evident that the *smaller constant* may not demand sufficient increase of rotation to re-establish the centrifugal limit until after a very long interval of time.

Besides, after the first planet, say Neptune, was fully formed, he began to exercise a powerful tidal action upon the sun, and upon his rate of rotation. Remembering that tidal action upon any body is proportioned, other things being equal, to the *diameter* of the body acted upon, we may easily realize what a gigantic tide Neptune would raise on the sun, when his diameter was little inferior to the diameter of Neptune's orbit.

This tidal retardation of the sun's rotation would go largely towards neutralizing the acceleration demanded by his contraction. Hence the period of the next centrifugal limit would be adjourned to a very distant epoch. The same reasoning will apply, with greater or less force, to the planets that are formed subsequently.

If the views were correct of those who maintain that the centrifugal limits ought to be continuous, and without interval of any kind, then the present shape of the sun ought to show the ratio of his equatorial to his polar diameter as 3 to 2.

But it is well known that observation shows no appreciable difference in the sun's diameters at present. Hence he is far from being in the condition required for the centrifugal limit.

In the paper on "A New Cosmogony," published in *Nature* on the 4th of August last, it is objected to La Place's theory of the formation of the planets from the broken rings, that "two opposite portions of a ring of the dimensions of Neptune's orbit could scarcely come together in less than 150,000,000 years." The writer justly adds: "It must be admitted that this is a startling demand on the time-exchequer even of the cosmos."

How this computation of 150,000,000 years was made I do not know. But I have made the following computation, with very different results: Suppose the planet Neptune to be at a certain point in its orbit, and a particle of matter at the opposite extremity of a diameter of the same orbit, how long would it take for the planet to attract this particle to its surface?

It is comparatively a simple problem of the differential and integral calculus, applied to the law of gravitation and the known mass of the planet. The result which I found is, that it will take less than 6,000 years to bring the particle in a straight line to the planet. If the particle has to describe the semi-circumference of the orbit, instead of the diameter, then the time would be less than 9,000 years. The revolution of both bodies around the sun, in nearly the same orbit, could by no means prolong the event from the neighborhood of 10,000 years to 150,000,000 years.

In conclusion, it may be asked, Is La Place's nebular hypothesis true? To this question I would answer, it may be true, or it may not be true. But it is by far the most beautiful and the most philosophical theory of the *process of creation* for a solar system like that to which we belong, that has ever yet been proposed.

This theory does not, as some suppose, do away with the necessity of an intelligent Creator and Designer of the universe. That cannot be done until we discover how, without such a Creator, the law of gravitation, and other similar laws of nature, may be imposed upon inert matter.

THE AGE OF THE STARS.*

We may assume in a general manner that when a sun is formed, other things being equal, the higher its temperature is raised the more effectively and the longer will it fulfil the functions of a radiating body.

It is true that the constitution of these celestial bodies is not sufficiently known for us to distinguish certainly the conditions which complicate these simple and general data, but we must not stop on account of these difficulties. Let us say that the age of the stars depends upon the temperature of their matter.

But this temperature reveals itself in the character of the spectrum. That wonderful prismatic image which shows us the collection of rays which a star sends us, separated, classified, arranged, and from which we know how to-day to read the chemical composition, motion, and many other precious data, instructs us also in regard to the temperature.

* Extract from an address delivered at the annual public session of the five Academies of France, Oct. 25, 1887, by M. Janssen, director of the Observatory at Meudon, France.

If the body is simply heated without being raised to incandescence, its spectrum informs us of this circumstance by the absence of those rays which give us the sensation of light. But when incandescence is produced, the luminous and photographic rays show themselves. When this becomes still more pronounced the spectrum is enriched on the side of the violet, which is always an indication of high temperature. If the temperature becomes still higher, the violet and the invisible rays which follow then become more abundant. One may conceive, abstractly, of a body which shall be raised to such a temperature that it will emit only those invisible rays situated beyond the violet, which the eye no longer perceives, and which are only revealed by photography, fluorescence, or thermoscopic apparatus. Thus, in the increasing scale of temperature, the body is first not visible, then becomes visible, and again ceases to be, by excess of the same temperature.

The spectrum faithfully shows all these states, and permits us to read, with wonderful fidelity, the most delicate circumstance.

In applying these facts we assume that the temperature of a star, or, at all events, the temperature of the exterior envelopes, will be higher in proportion as its spectrum is richer in violet rays.

There exists in the sky a great number of stars whose spectra are developed toward the violet side. These are generally the ones whose light appears white or bluish. The most remarkable is that magnificent star, Sirius, which, in the amount of light which it sends us, is without equal in the sky. The volume of this star is enormous and incomparably greater than that of our sun. It is enveloped in a vast atmosphere of hydrogen, so far as its spectrum shows. It contains, without doubt, other metals, but the presence of these is difficult to prove, doubtless because of the power itself of radiation of the vapors of those metals. Every thing indicates here, according to our theory, a sun in all the power of its activity, and which will conserve this activity during immense periods of time.

After Sirius, which is the ornament of our sky, and which will continue for a long time, according to the indications of science, we find as a star surrounded by a vast atmosphere of hydrogen, the star Vega of the constellation Lyra. This is a white star which we often notice in the zenithal regions of our sky. We suppose that the mass of this sun is raised to a high temperature, and that it has before it long spaces of activity and radiation.

These two examples of stars in the full development of their solar activity, are perhaps the most remarkable, but they are not the only ones. There are a considerable number of stars in the sky belonging to this class. We may say even that the greater number of stars visible to the naked eye are in this condition. But we discover at the same time another class of stars in which the character of the spectrum indicates a degree of condensation a good deal more advanced. In place of the vast atmosphere of hydrogen the analysis shows a gaseous covering, lower, more dense, formed of those metallic vapors which we recognize precisely in our sun, for our central body belongs to that class of stars whose solar functions seem still powerful, but which, however, have passed what we may call their *youth*, if you will permit me this expression. It is to be remarked that, in general, the color of these stars is found to be in accord with their constitution. They do not have that brilliancy, that whiteness, which characterizes stars of the first class. Some of them are of a yellow or even orange color.

Let us take as examples of those stars which have passed the period of their most active radiation, first our sun, as I have already said above, then Aldebaran or the Eye of the Bull, which is in the path of the sun and which shines in winter above the celebrated constellations of Orion; Arcturus, the beautiful star in Boötes, which is found in the prolongation of the stars of the Great Bear, and whose red rays declare the evolution already far advanced.

But there are again some stars which have come to a more pronounced degree of their sidereal evolution. Here the spectrum shows signs of a fatal cooling. The violet, the color of high temperature, vanishes here almost absolutely; at the same time some dark bands, indices of an atmosphere dense and cold, where chemical affinities have already commenced their work of association, invade the spectrum. It is to be remarked that the colors of these stars correspond in general to those conditions supposed to be the signs of decrepitude; they become deep orange and pass often to dark red.

Such are the first results of a study which is only begun. I have tried to present it in its simplicity, to avoid the difficulties, the objections, which legitimately arise in its application. I am persuaded that Science will triumph over these difficulties as it has triumphed over difficulties much more considerable, and that the general bases of the method will be definitely established.

AN AUTOMATIC TRANSIT INSTRUMENT.

PROF. FRANK H. BIGELOW.*

FOR THE MESSENGER.

The drift of practical astronomy in the observation of the coördinates of right ascension and declination appears to be setting in the direction of eliminating the personal equation of the observer, by the substitution of some sort of an automatic contrivance. The experience of twenty-five years has lead to the conclusion that the errors arising out of the physiological constitution cannot be controlled by the power of the will, and that an uncertain margin of one-seventh of a second shadows like a penumbra the exact truth that is sought. Clearly if a method can be devised that will measure precisely the facts, we shall be relieved of the necessity of falling back upon the mean result of many observations, and thereby save enormous sums of money now expended in the computations of transits, for which reason the cost to be incurred in the first outlay upon instruments will ultimately become an economical appropriation.

Several attempts have been already made by instrument makers to accomplish this object, but as yet apparently with no satisfaction, so that any suggestion looking to this end, even if imperfect, will be acceptable. In the *Astron. Nach.* No. 2828, J. Repsold, Hamburg, communicates the theory of an automatic apparatus depending upon the instant of mechanical contact between a moving knob, attached to the transit which swings through short hour-angle arcs, and a stationary button, the record being made on the chronograph. The objection is mentioned that the conversion of a fixed instrument into a movable one is liable to substitute other errors for that of the personal equation.

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* Racine College, Wisconsin.

It is, however, to photographic processes that we must turn for help in this emergency, and the success already acquired in other directions ought not to lead to disappointment when applied to transits. The main difficulty has been that bromide paper is not sensitive enough to receive the trails and contacts with sufficient rapidity, and hence the first improvement must come in at this point. It is not likely that the instantaneousness of any process can excel that of the human retina as a receiver, but since the eye is only a transmitter, the photograph gains all the advantages of a primary over a secondary effect. Probably all increase in speed above one-tenth of a second can be claimed as an improvement, while it may not be unreasonable to suppose that one three-thousandth of a second will yet be faithfully recorded. At all events the first question is to secure the utmost sensitiveness of impression, and the second is to have the conditions under perfect mechanical control. The attainment of sensitiveness, doubtless depends upon the employment of the gelatine dry process on glass, because none of the paper preparations can compete with it.

I feel some hesitation in making the following theoretical suggestions, hoping that experiments available to others may put them to the test. The dimensions here given may need modification, although the best meridian circles have been kept in mind in the endeavors to fit an apparatus to them. Suppose instead of plate glass for the photograph, we use a thin symmetrical cylinder of two inches radius, the glass being one-fifteenth of an inch thick, prepared on the outer surface by the best dry process, beyond which we can do nothing for sensitiveness. Mount this as a chronograph barrel on a skeleton frame, one end of which is prominent, the other removable by thumb screws, so that it may revolve concentric to an axis. At one extremity this connects with the final wheel of a clock train by an endless screw or cogs, to be disconnected at will, the first half of the axis being squared and smooth for sliding, and the second with a screw cut for advancing the barrel attached to it by clamp, terminating in a slot on the box. At mid length the axis must be broken, the screw end penetrating as a round pinion into the other part. The whole fits into a rectangular dark box and is to be lifted in and out from end rests, the opening being on a long side. One of its lower short face edges has a hinge and counterpoise weight for turning it through a right angle when desired. On the centre of the upper side is a little cell, holding an electric spark that will send light through a slit with adjustable jaws, at right angles to the star trail, on strokes from the standard clock. On the third side in the same helix, ninety degrees from the spark hole, enters the emergent pencil from the telescope, continuously trailing, except when eclipsed by a thread or obstruction, so that the spark acts fifteen seconds in advance of the pencil, on the supposition that the barrel revolves once a minute.

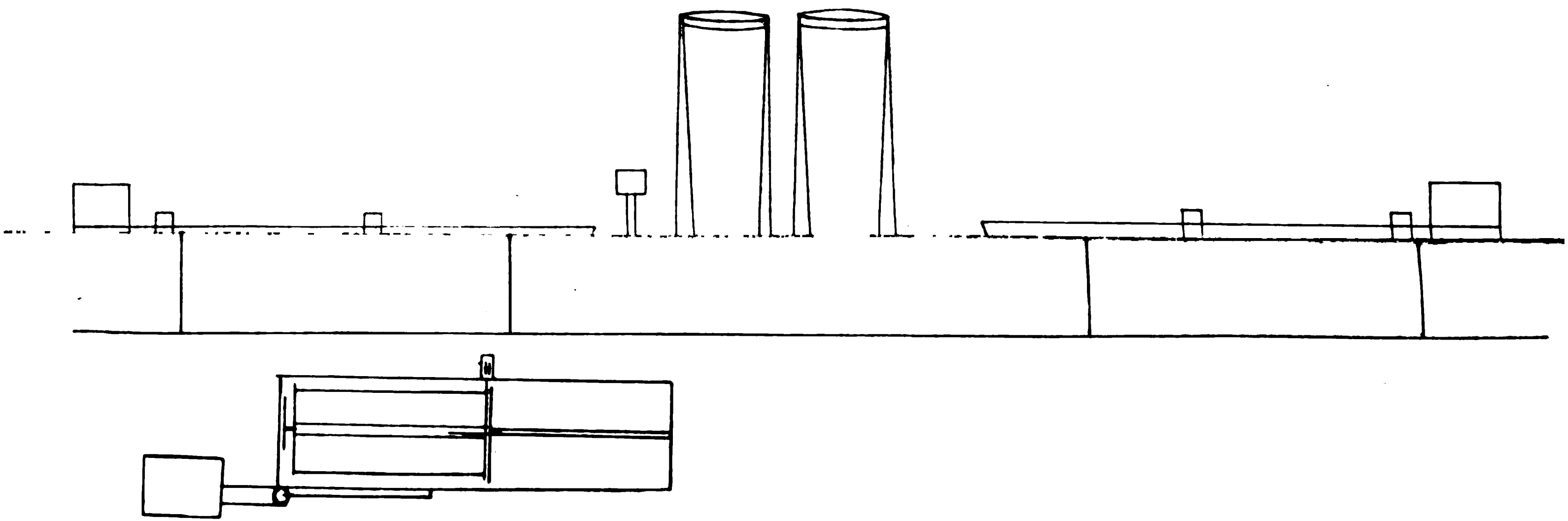
Attention should be called to the facility that this arrangement offers for the enlargement of the negative to any required scale, in order to make a copy on paper for reading and permanent record. After developing, place the cylinder on a circle of equal radius, and on a larger eccentric circle put the paper for copy inside a similar cylinder. In the common axis arrange an incandescent light of sufficient length to illuminate the whole in cross sections, and the diverging radii unless some parallactic blurring from the thickness of the wire modifies the action, will produce an accurate enlarged copy that can be readily translated. The glass cylinder may be washed, and it will then be ready for a repetition of its functions.

The next question concerns the position of the photochronograph, referred to the eye end of the telescope. It is apparent that the lenses must be figured for the actinic rays, and that this implies a loss of visual power for direct seeing. There seems to be no way to compromise the matter if the same tube is to be used, and it is therefore proposed to employ two tubes, one for seeing and one for photographing, both attached to the same cube, now elongated to a parallelopiped, and having the axes of collimation theoretically parallel. The changes in the auxiliary parts of the instrument need be very slight, the telescopes being set about three inches from the middle of the axis towards the pivots, the circles, counterpoises, clamps and handles, the reversing shoulders all being disposed without crowding as in the standard Repsold meridian circle. This telescope is in all respects fitted for chronograph signals, eye and ear transits and measures of declination. The adjustments to the meridian and equator follow the prescribed methods, corrected to include the eccentric position.

The parallel photographic telescope is bent in the cube by a forty-five degree prism or a mirror as thought best, the reticle being located on the end of the pivot, and a counterpoise weight maintaining an equilibrium of the moments of rotation. Screwed upon the pivot is the eye piece almost touching the eye, so that the emergent pencil, if perfectly adjusted to the axis, is stationary in the rotation of the telescope, or else describes a small circle about it; but since the reticle rotates at the same time the transits are subject only to the error of collimation and deviation from the meridian. This enables us to place the photo-chronograph on the upper surface of the pier, between the end of the axis and the counterpoise standards, where it will have a steady yet adjustable position. A hole for the clock work attached to the chronograph is cut in each pier, but it may be found that the vibrations are injurious, and in that case a secondary stand can be set up in the neighborhood. The hinge mentioned above allows the chronograph to be tipped up so as to withdraw the barrel, and also to leave free space to introduce a compensating and collimating eye piece at right angles to the rotation axis. In taking the instrumental errors the same level applies to both telescopes, the same mercury basin viewed in one from a ladder and in the other from the pier head; but two sets of fixed collimators would be required. It is not supposed that difficulties which cannot be met will arise from the additional weight on the cube, as regards flexure. This method is superior to any combination that implies placing the chronograph on the swinging end of the telescope, both for technical reasons and for convenience.

The time telescope system opens the possibility of interesting comparison observations, since the observer is in full possession of the old methods, while the new may go on simultaneously upon the same star. The personal equation can be determined upon such bright stars as the photograph will record, and the correction may then be applied to the whole list. Uncertainties will be avoided in the comparison of stars taken under such widely different circumstances as appear in the current methods employed in the detection of

Illustration of an Automatic Transit Instrument.



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the personal error. It will probably be conceded that the effectiveness of the meridian circle will be in no wise diminished, while all the advantages offered by the use of photography can be controlled to a great degree of sensitiveness.

FOR STUDENTS AND YOUNG OBSERVERS.

Interesting Phenomena for May.

THE PLANETS.

Mercury's path for the month of May is through the constellations of Taurus, Orion and Gemini. He is in superior conjunction with the sun May 10th, at 7 o'clock in the evening, and at the end of the month he is only a few degrees east of the sun. On the 9th he passes to the north side of the ecliptic; on the 14th is in perhelion and on the 24th is in greatest heliocentric latitude north.

Venus is passing through Aries and Taurus; May 8th the planet is in conjunction with the moon, and will be within a degree of Neptune on the last day of the month. Its angular diameter a little less than 5″ and diminishing, as is also the brilliancy of its disc.

Mars, doubtless, has been noticed during the last month by the most casual of observers. His nearest approach to the earth for this year, and full disc towards us were the causes for his unusual ruddy appearance. Mr. Keeler, assistant at Lick Observatory, writes under date of April 10th, that the satellites of Mars are remarkably bright in the great 36-inch lens even without a bar to hide the planet. He thinks they may be followed at Lick Observatory for a large part of the year.

Jupiter is an evening object for the present month, and is retrograding. He will move to the westward, 3° during May, will be in quadrature with the sun 21st, and in conjunction with the moon on the 24th. His polar diameter is 21.6″, but his position in south declination makes his meridian atlitude low in northern latitude, and hence not favorable for observation.

Saturn passes the meridian at about 9 o'clock during this month, but is in more than 20° north declination, so that the planet may be observed in the evening fairly well.

It is in the constellation of Cancer and still makes a triangle with bright stars in Gemini, that has been noticed for months past.

Uranus at the beginning of May is very near to Mars. On the 5th it will be only 30′ directly north of the latter planet. The opera glass will show Uranus well.

Neptune is in Taurus a few degrees south of the Pleiades.

	R. A. h m	Decl.	Rises. h m	Transits. h m	Sets. h m
			NEPTUNE.		
May 5	3 49.4	+18°24′	5 33 A.M.	12 53.2 P.M.	8 13 P.M.
15	3 51.0	+18 29	4 55 "	12 15.4 "	7 36 "
25	3 52.5	+18 34	4 13 "	11 33.8 A.M.	6 54 "
			SATURN.		
May 5	8 12.2	+20 35	9 45 A.M.	5 15.3 P.M.	12 45 A.M.
15	8 15.1	+20 27	9 09 "	4 38.9 "	12 08 "
25	8 18.5	+20 16	8 34 "	4 02.9 "	11 32 "
			MARS.		
May 5	12 52.1	−4 17	4 08 P.M.	9 54.3 P.M.	3 41 A.M.
15	12 46.0	−4 07	3 22 "	9 08.8 "	2 56 "
25	12 44.8	−4 25	2 42 "	8 28.4 "	2 15 "
			URANUS.		
May 5	12 52.4	−4 52	4 10 P.M.	9 54.6 P.M.	3 39 A.M.
15	12 51.2	−4 45	3 29 "	9 14.1 "	2 58 "
25	12 50.4	−4 40	2 49 "	8 34.0 "	2 19 "
			JUPITER.		
May 5	16 06.6	−19 53	8 28 P.M.	1 08.2 A.M.	5 49 A.M.
15	16 01.8	−19 39	7 42 "	12 23.9 "	5 06 "
25	15 56.5	−19 25	6 56 "	11 39.3 "	4 22 "
			VENUS.		
May 6	1 49.1	+9 42	4 07 A.M.	10 49.1 A.M.	5 32 P.M.
16	2 36.0	+13 58	3 56 "	10 56.6 "	5 57 "
26	3 24.5	+17 42	3 49 "	11 05.7 "	6 22 "
			MERCURY.		
May 6	2 37.2	+14 42	4 34 A.M.	11 37.2 A.M.	6 40 P.M.
16	4 03.9	+21 52	4 48 "	12 24.4 P.M.	8 01 "
26	5 29.9	+25.23	5 15 "	1 10.9 "	9 06 "
			THE SUN.		
May 6	2 56.7	+16 49	4 44 A.M.	11 56.4 A.M.	7 09 P.M.
16	3 35.7	+19 19	4 32 "	11 56.2 "	7 21 "
26	4 15.8	+21 18	4 23 "	11 56.9 "	7 31 "

Occultations Visible at Washington.

Date.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean T. h m	IMMERSION. Angle f'm N. Point. °	EMERSION. Wash. Mean T. h m	EMERSION. Angle f'm N. P't. °	Duration. h m
May 16	θ Cancri	5½	10 22	195	Star 1.4′ S. of moon's limb.		
19	B. A. C. 3837	6½	11 14	61	11 52	349	0 37
23	ξ^1 Libræ	6	9 37	47	10 02	8	0 25
24	θ Libræ	4½	9 41	204	Star 7.1′ S. of moon's limb.		
24	49 Libræ	6	12 50	18	Star 5.7′ N. of moon's limb.		
27	o Sagittarii	3½	9 42	104	10 46	272	1 04

Phases of the Moon.

		Central Time. d h m
Last Quarter	May 2,	5 47.1 P. M.
New Moon	10,	7 23.5 "
First Quarter	18,	5 05.2 "
Full Moon	25,	7 40.1 A. M.

Great Red Spot on Jupiter—Times when its Zero Meridian Passes the Centre of Jupiter's Disc.

Central Time. d	h m	Central Time. d	h m	Central Time. d	h m
May 2,	12 58.7 A. M.	May 12,	7 03.7 P. M.	May 23,	11 04.7 P. M.
2,	6 49.7 P. M.	14,	12 50.6 A. M.	24,	6 55.8 "
4,	2 36.6 A. M.	14,	8 41.7 P. M.	26,	12 42.7 A. M.
4,	10 27.7 P. M.	16,	2 28.5 A. M.	26,	8 33.7 P. M.
5,	6 18.8 "	16,	10 19.6 P. M.	28,	2 20.6 A. M.
7,	12 05.7 A. M.	18,	4 06.5 A. M.	28,	10 11.7 P. M.
7,	7 56.8 P. M.	18,	11 57.6 P. M.	30,	3 58.6 A. M.
9,	1 43.6 A. M.	19,	7 48.7 "	30,	11 49.8 P. M.
9,	9 34.7 P. M.	21,	1 35.6 A. M.	31,	7 40.9 "
11,	3 21.5 A. M.	21,	9 26.6 P. M.		
11,	11 12.6 P. M.	23,	3 13.5 A. M.		

Phenomena of Jupiter's Satellites.

Central Time. d	h m			Central Time. d	h m		
May 1,	4 25 A. M.	II	Ec. Dis.	May 18,	4 53 A. M.	II	Tr. In.
3,	3 06 "	III	Sh. In.	19,	10 54 P. M.	II	Ec. Dis.
3,	4 58 "	III	Sh. Eg.	20,	1 25 A. M.	II	Oc. Re.
3,	5 06 "	III	Tr. In.	21,	1 22 "	III	Ec. Dis.
3,	11 31 P. M.	II	Sh. In.	21,	3 03 "	III	Oc. Re.
4,	12 24 A. M.	II	Tr. In.	21,	8 26 P. M.	II	Tr. Eg.
4,	2 01 "	II	Sh. Eg.	21,	8 28 "	II	Sh. Eg.
4,	2 49 "	II	Tr. Eg.	22,	2 16 A. M.	I	Oc. Dis.
5,	8 54 P. M.	II	Oc. Re.	22,	4 28 "	I	Oc. Re.
6,	4 04 A. M.	I	Ec. Dis.	22,	11 23 P. M.	I	Tr. In.
6,	8 27 P. M.	III	Oc. Re.	22,	11 24 "	I	Sh. In.
7,	1 07 A. M.	I	Sh. In.	23,	1 35 A. M.	I	Tr. Eg.
7,	1 30 "	I	Tr. In.	23,	1 37 "	I	Sh. Eg.
7,	3 20 "	I	Sh. Eg.	23,	8 42 "	I	Oc. Dis.
7,	3 41 "	I	Tr. Eg.	23,	10 55 P. M.	I	Ec. Re.
7,	10 30 P. M.	I	Ec. Dis.	24,	8 01 "	I	Tr. Eg.
8,	1 00 A. M.	I	Oc. Re.	24,	8 05 "	I	Sh. Eg.
8,	7 56 P. M.	I	Tr. In.	27,	1 13 A. M.	II	Oc. Dis.
8,	9 49 "	I	Sh. Eg.	27,	3 54 "	II	Ec. Re.
8,	10 07 "	I	Tr. Eg.	27,	4 47 "	III	Oc. Dis.
11,	2 05 A. M.	II	Sh. In.	28,	8 13 P. M.	II	Tr. In.
11,	2 39 "	II	Tr. In.	28,	8 32 "	II	Sh. In.
11,	4 35 "	II	Sh. Eg.	28,	10 40 "	II	Tr. Eg.
11,	5 05 "	II	Tr. Eg.	28,	11 03 "	II	Sh. Eg.
12,	8 18 P. M.	II	Ec. Dis.	29,	4 00 A. M.	I	Oc. Dis.
12,	11 10 "	II	Oc. Re.	30,	1 07 "	I	Tr. In.
13,	9 24 "	III	Ec. Dis.	30,	1 19 "	I	Sh. In.
13,	11 45 "	III	Oc. Re.	30,	3 19 "	I	Tr. Eg.
14,	3 01 A. M.	I	Sh. In.	30,	3 31 "	I	Sh. Eg.
14,	3 14 "	I	Tr. In.	30,	10 26 P. M.	I	Oc. Dis.
15,	12 24 "	I	Ec. Dis.	31,	12 49 A. M.	I	Ec. Re.
15,	2 44 "	I	Oc. Re.	31,	7 33 P. M.	I	Tr. In.
15,	9 30 P. M.	I	Sh. In.	31,	7 47 "	I	Sh. In.
15,	9 40 "	I	Tr. In.	31,	7 47 "	III	Tr. Eg.
15,	11 43 "	I	Sh. Eg.	31,	8 54 "	III	Sh. Eg.
15,	11 51 "	I	Tr. Eg.	31,	9 45 "	I	Tr. Eg.
16,	9 10 "	I	Oc. Re.	31,	9 59 "	I	Sh. Eg.
18,	4 40 A. M.	II	Sh. In.				

New Minor Planet No. (274) was discovered by Palisa April 3.4211 Gr. M. T. R. A. 12*h* 50*m* 39.5*s*. Decl. north 0° 50′ 50″. Daily motion —48*s*; south 5′. It is 13th magnitude.

New Minor Planet No. (275) was found by Palisa, April 15.5120 Gr. M. T. R. A. 12*h* 39*m* 4*s*. Decl. north 3°29′. Daily motion —40s; south 4′. Eleventh magnitude.

New Minor Planet No. (276), also eleventh magnitude was discovered by Palisa April 17.5287. R. A. 14*h* 4*m* 0.8*s*. Decl. 12°34′51″ south. Daily motion —44*s*; south 11′.

Portable Transit Observations. I was much interested in the article published in No. 27 of THE MESSENGER, page 209, "How Time Observations are Taken with a Small Transit at Carleton College Observatory." In using this method it is not necessary to know the value of the azimuth and collimation errors, but their signs must be known.

In the writer's Observatory the transit pier stands in an adobe soil which shrinks and swells with every change from wet to dry weather. The azimuth error has changed on this account from + 2*s* to — 35*s*, and no reliance can be placed on its constancy. There is not sufficient distance for a meridian mark and it is evident that a collimator would be useless on such ground.

By simplifying the method above referred to, the time is taken, and the clock correction examined without knowing either the value or sign of the azimuth errors, but is only available for use with a portable transit which can be quickly used. It is necessary to have a large number of stars to select from. Those in the American Ephemeris and Berliner Jahrbuch will answer.

Method. Find the A factors of all those stars situated between 20° N. Z. D. and 41° S. Z. D., and arrange all the N. Z. D. stars in one column and the S. Z. D. stars in another. Now at the time of observation let us take a star having a certain A factor and, after observing half the wires, reverse the transit and observe the same wires again (which eliminates the collimation error); then take another star on the opposite side of the zenith having nearly the same A value, observe and reverse as before. It is evident that the mean of the two observations will be the true time, and the difference between either star and the mean of the two divided by A will give the error of azimuth, which may be adopted as a provisional value in case the time is found by a single star before using another set. Such sets will be frequently found if both the American and Berliner Ephemerides are used, and should be tabulated for future reference. This method will be found the shortest way for getting true time from unstable transit piers. It should be mentioned that the level error is applied as usual. The following example will illustrate the meaning:

Star.	A.	Decl	
ζ Tauri,	.31	+ 21°04′	Time set.
ι Aurigæ,	.31	+ 49 46	

March 3, 1888.

	ζ Tauri, B. J.		ι Aurigæ, B. J.
	E.		E.
	h m s		h m s
	5 30 52.5		5 36 26.5
	31 26.7		37 15.5
	W.		W.
	5 32 33.8		5 38 52.0
	33 07.8		5 39 41.3
	5 32 00.2		5 38 03.82
Level corr.	—00.42	Level corr.	— 00.80
	5 31 59.78		5 38 03.92
R. A.	5 30 57.01	R. A.	5 37 37.46
	1 02.77 fast.		49.56 fast.
	49.56		
Mean	56.16		(56.16—49.56)÷.31=21.32s azimuth.

This method has been proved by comparing the clock correction thus obtained with that by Mayer's method.

East Oakland, Cal., March 17, 1888. F. G. BLINN.

COME LEARN OF THE STARS.

Student, come hither, leave toiling by lamplight,
Night hath led forth in the heavenly fields
All of her star hosts emblazoned with splendor—
Silver their spears are, and silver their shields.

Yonder, bright Venus descends to the westward
Leading the van of the glittering train,—
Bright but untwinkling goes Venus, the queen-star,
Leading the hosts of the heavenly plain.

High in the zenith Orion is marching,
Keeping his course like a veteran chief,
Wearing his sword like an emblem of office—
Sword that hath never wrought anguish or grief.

Yonder the Pole-star the constant of heaven,
Burneth his beacon for men on the sea;
Yonder goes Cygnus, the swan, flying southward,—
Sign of the Cross and of Christ unto me.

Student, come hither, leave toiling by lamplight,
Night hath led forth and her army is grand;
Almost methinks I can hear the bands playing,
Hear the drums beating and words of command.

Why with this earth-life are we so enchanted?
All that we win here must end in the sod;
Yonder the stars are, and yonder is Heaven,—
Yonder is home and the angels and God.

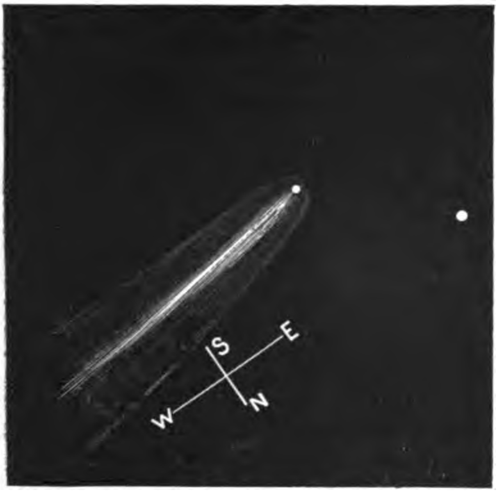
Fayette, Mo. T. BERRY SMITH.

EDITORIAL NOTES.

Historical Note Relative to the Name of the Planet Juewa (139). This planet was discovered October 10, 1874, at Peking, China, by Prof. J. C. Watson while in charge of the American Transit-of-Venus party at that station. At Watson's request the Chinese officials with whom he was in friendly relations, selected a name for the planet from which the present Juewa has been corrupted. There has recently come into my possession an envelope bearing the inscription in Watson's handwriting, "Card received from Prince Kung Nov. 26th, 1874, giving name to new planet discovered Oct. 10th, 1874, at Peking. Name reads *Jue wha sing* or *Juewasing*, "The star of China's fortune." Literally, Jue, felicity or fortune, Wha, flowery or China, Sing, star." The envelope contains a strip of crimson paper with three Chinese characters written upon it which probably represent the name originally given to the planet. GEO. C. COMSTOCK.

Washburn Observatory, April 14, 1888.

The comet discovered by Mr. Sawerthal February 18, 1888, was observed at Carleton College, and two complete positions obtained, which are given below. On the morning of April 14 it was a beautiful object in the telescope, and could be picked up easily by the naked eye, if the observer knew where to look for it. Dr. H. C. Wilson made the accompanying drawing which well shows the appearance in the telescope. The nucleus was bright and sharp and pinkish white in color. The tail was about 2° long, faint in outline, but strongly bright along its axis or central line for its entire length. The star on the right side and near the margin is DM 15°4701, and was chosen for a comparison star, its magnitude being 9.0.



COMET *a* 1888 (APRIL 14).

Observations of Comet a 1888, made by H. C. Wilson with the 8¼ inch equatorial of Carleton College Observatory:

Date. 1888	Local Mean Time. h m s	Comet — * $\Delta\alpha$ m s	Comet — * $\Delta\delta$ ′ ″	No. of Comparisons.	Star
April 11	16 38 38	—1 22.74	—10 41.5	6, 2	1
April 11	16 38 38	—2 28.71	— 8 56.8	6, 2	2
April 13	16 29 47	+3 46.44	— 6 12.3	6, 2	3
April 13	16 29 47	—0 18.21	— 5 46.9	6, 2	4
April 15	16 18 19	—0 14.58	— 0 54.4	6, 2	5
April 15	16 18 19	—2 08.58	+ 6 21.0	6, 2	6

No.	α app. h m s	l. f. p. α	δ app. ° ′ ″	l. f. p. δ
1	22 33 55.78	9.622n	+13 46 46.6	0.733
2	22 33 55.85	9.622n	+13 46 49.3	0.733
3	22 39 38.3	9.612n	+15 26.6	0.728
4	22 39 36.2	9.612n	+15 25.8	0.728
5	22 45 12.1	9.604n	+17 01.2	0.734
6	22 45 10.7	9.604n	+17 00.8	0.734

MEAN PLACES OF COMPARISON STARS.

Star.	α 1880.0 h m s	Red. to app. s	δ 1888.0 ° ′ ″	Red. to app. ″	Authorities.
1	22 35 19.42	—0.89	+13 57 37.2	— 9.2	Greenwich 9 yr. Catalogue.
2	22 36 25.46	—0.90	+13 55 55.2	— 9.2	" " "
3	22 35 52.7	—0.84	+15 33.0	— 9.9	DM 15°4690 (8.5 mag.)
4	22 39 55.2	—0.84	+15 31.7	—10.0	DM 15°3701 (9.0 mag.)
5	22 45 27.5	—0.83	+17 02.3	—10.3	DM 16°4823 (9.3 mag.)
6	22 47 20.1	—0.84	+16 54.6	—10.3	DM 16°4830 (8.4 mag.)

The observations were made with a filar micrometer and have been corrected for refraction. The nucleus was about 8.5 mag., well defined and easy to bisect. The bisections for $\Delta\delta$ were made before and after the transits for $\Delta\alpha$, and the means of the times for $\Delta\alpha$ and $\Delta\delta$ were therefore nearly the same. When the difference between these means was greater than 10s the $\Delta\delta$'s were reduced to the times for the $\Delta\alpha$'s by applying the motion given in Dr. Krueger's ephemeris (A. N. 119.30).

The provisional longitude and latitude of Carleton College Observatory are:

Longitude 6*h* 12*m* 36.0*s* west from Greenwich.
Latitude +44° 27′ 42″.

Orbit of Comet 1888 a. From observations of March 23rd, 30th and April 6th, I have computed the following orbit of comet 1888 *a*.

ELEMENTS.

$$T = 1888, \text{March } 16.99344 \text{ Gr. M. T.}$$
$$\pi\text{-}\Omega = 359°55'\ 6''$$
$$\Omega = 245\ 37\ 35$$
$$i = 42\ 18\ 14$$
$$\log q = 9.84516.$$

MIDDLE PLACE (C—O).

$$\Delta\lambda \cos\beta = +1''$$
$$\Delta\beta = -17''$$

The residuals in the middle place indicate that the orbit of the comet is probably elliptical, as already remarked by Dr. Becker and others. O. C. WENDELL.

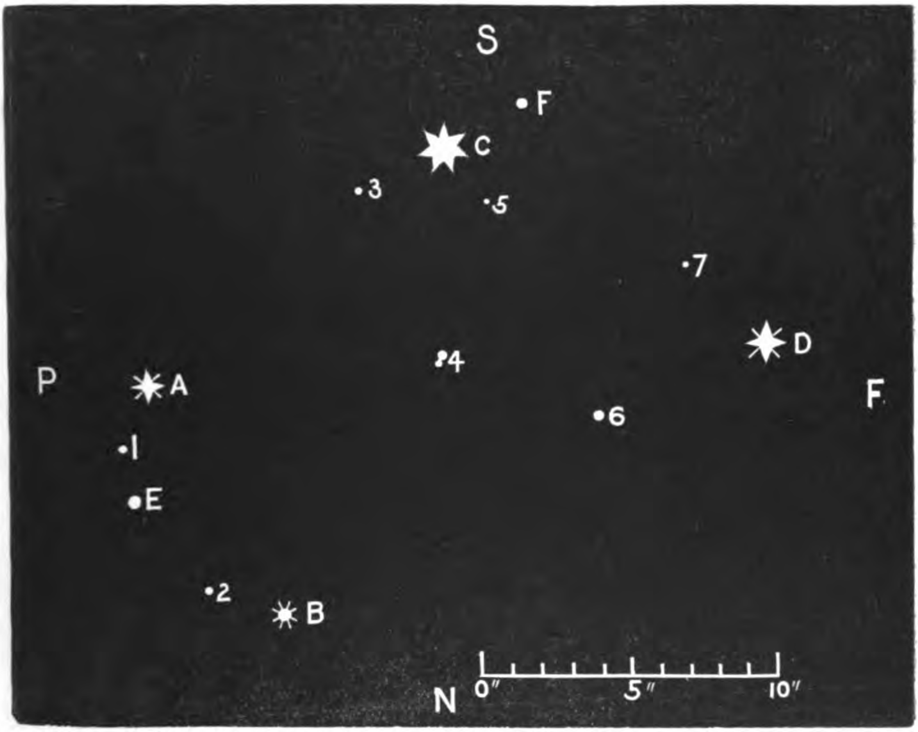
Harvard College Observatory, April 19th, 1889.

Comet a 1888. This comet was observed here this morning and presented a fine appearance in the 9-inch reflector. I made its approximate position 21*h* 40*m* in right ascension, and declination south 5°15′. It was just visible to the naked eye when well located. In the telescope the comet showed a bright nucleus, considerably elongated; the tail was very broad and about one degree in length. The sky was very clear this morning, the first we have had since the comet was far enough north to be visible in this latitude.

WILLIAM R. BROOKS.

Red House Observatory, March 25th, 1888.

θ Orionis. With regard to the nova in the trapezium of θ Orionis, mentioned on page 88 of the February number of THE MESSENGER as being discovered by Mr. Clark with the thirty-six-inch Lick equatorial, Mr Herbert Sadler of London kindly calls our attention to a letter of his which appeared in the *English Mechanic* for January 13, 1882 (letter 19610, p. 448, vol. xxxiv, No. 877.



TRAPEZIUM OF ORION.

Mr. Sadler thinks 6, Mr. Clark's nova in the above drawing (which is a copy of that published at the time above mentioned), was first seen by DeVico with a telescope of seven inches aperture in 1839. It has since been detected by Dr. Huggins with eight-inch aperture, and by Mr. Sadler with a twelve-inch. It is probably variable. Though the star in this drawing does not occupy the same relative place as that shown in Mr. Keeler's drawing in the February MESSENGER, it is so near it that probably Mr. Sadler is right.

Old and New Astronomy.—By kindness of the publishers, Messrs. Longmans, Green & Co., London and New York, we have a copy of the first part of Mr. Proctor's new book entitled *Old and New Astronomy.* This part contains 64 pages imperial octavo, in size of printed page, 5½ by 8½ inches, and consists of the Introduction and a little more than Chapter I of the complete book. The author starts with the place of Astronomy among the sciences, notices the vastness and impressiveness of its field of investigations, its power to elevate the mind and make great thoughts real, the practical uses of the science, and the place and honor rightly given to astronomers in the field of philosophical training. The first chapter treats of ancient and modern methods of observing the heavenly bodies. It is illustrated by upwards of forty good engravings, which make the historical part of the work attractive and easy of comprehension to the popular reader. We have not before seen this portion of the early history of astronomy so well presented as is given in this part. There is no question in our mind but that this, as a beginning is by far the best writing that Mr. Proctor has done in popular astronomy. If it shall be sustained as well as in its beginning, it will be a work of great usefulness.

As we have before said, it is to be published in monthly parts, all finally to be bound, making a book of 800 pages, at a price of twenty-six shillings if paid in advance.

Comet a 1888. The comet recently discovered near Cape Town, in South Africa, was observed on the morning of March 18th at 5:15 A. M. Washington mean time.

The head of the comet is quite bright; the tail about a degree and a half in length, well defined and presents rather a bushy appearance.

I picked the comet up with the comet-seeker at the Naval Observatory, which, through the kind permission of Captain Pythian, the superintendent, I have been using in comet hunting.

After finding it, Prof. Frisby secured only an approximate position, which was due to the absence from or near the field of a star by which a comparison of position could be made.

On the morning of March 19th, however, a comparison between the comet and the star in the field with it, was made. After reducing the observation Prof. Frisby determined the position of the comet as in 21 hours, 19 minutes and 53 seconds in R. A.; 13° 21′ south declination. GEO. A. HILL.

Star Colors. In his interesting chapter on "Star Colors" in "Astronomy for Amateurs," W. S. Franks deprecates the use of any chromatic scale such as was proposed by Admiral Smyth in 1864 as a standard of comparison. It consisted of wafers showing four shades of each color, the deepest of which was called "1" and the palest "4," the objection to this being that the artificial light used at night would materially alter these hues and therefore render them unreliable as a standard of reference. He then points out that any system of reference should be based on the solar spectrum and indicates the place on the spectrum by the central wave number of the colors employed. While all this is of course true it is not very encouraging to amateurs who have only small telescopes and no spectroscopic attachments. The difficulty which many experience, without such aid, is to get a true idea of what the actual colors referred to are.

It is not easy to obtain any artificially prepared standards such as true red, blue or yellow. In order to test the matter, I recently inquired of some large manufacturers of paints, artists' materials, etc., if such existed, and they frankly admitted they knew of none.

I was shown many tints known by the name of one color, as for instance four samples varying from light yellow to full salmon, all known commercially, at least, as chrome yellow. It seems very desirable, therefore, to have artificially prepared standards of some kind based on the solar spectrum, not necessarily to be used at night, but to impress on the minds of those who would like to engage in the work of observing star colors what is meant by true red, blue, etc. When this is done we can no doubt more fully appreciate Mr. Frank's "chart of star colour nomenclature" shown on page 275 of the book referred to. JOHN H. EADIE.

Intersecting Rainbows. In No. 1 of the Publications of Morrison Observatory, a note was inserted on "Intersecting Rainbows" observed here in July 1884. As this phenomenon (on the assumed hypothesis), must always occur under a certain rare combination of conditions, I expressed surprise, in the note, that in regions abounding in small lakes, no observation of it (so far as I know) had been made. I am glad that the publication has served to bring to light at least *one such observation*, made 83 years earlier. And though the subject matter belongs rather to Physics, than to astronomy, yet as astronomers, in every instance, have been connected with the observations, I hope that, in the interest of Science, I may ask for the publication of this note and of the accompaning letter from Herr H. Geelmuyden, assistant astronomer at the observatory at Christiania. It *may be* that there are *other observations*, and the publication may serve to bring them also to light, and even to compel writers on elementary physics to do full justice, at least, to the rainbow. The Norwegian astronomer, Christopher Hansteen, will be remembered, not only as the director and founder of the observatory at Christiania, but also as one of the most vigorous writers on magnetism, in the earlier years of this century.

[COPY OF LETTER.]

CHRISTIANIA OBSERVATORY, 1887, Dec. 20.

Sir: In the Publications of the Morrison Observatory, No I., I see a note on two intersecting rainbows, observed 1884, July 24, at your observatory. Perhaps it may interest you to know of a similar observation made many years ago by the late Professor Hansteen, and described by him in "Magazin for Natur-videnskaberne," Vol. I., Christiania, 1823. The description begins as follows:

"1821, Aug. 10, near the church of Slidre, in the valley of Valders (Norway), at 7 P. M., shortly before sunset, I saw two rainbows intersecting each other near the horizon, and near the east point, at an angle of 20 or 30 degrees, and then withdrawing further from each other at greater altitude. None of the bows were complete,—about the half on the right hand (towards the south) wanting. It was most remarkable that the colors in both followed in the same order as in the primary rainbow, and that both had equal intensity; so that neither I, nor my fellow travellers could decide which was the *genuine* one (*i. e.* that whose center was opposite to the sun), and which the mock one. The sun was already hidden from us by some high mountains towards the northwest."

The explanation given by Hansteen, is exactly similar to that suggested in your case. West and northwest of Slidre is the long and narrow Strandefjord (an extension of the river of the valley), enclosed between mountains, which generally protect it against the wind, and thus give it a smooth reflecting surface. Consequently the lake may have produced the reflection, giving the uppermost of the two rainbows. By calculation, Hansteen then proves the correctness of this hypothesis. I have the honor to be, sir, yours truly, H. GEELMUYDEN, *Assistant Astronomer.*

In conclusion I would express the wish that the scientific journals may take sufficient interest in the matter to elicit all the evidence available. C. W. PRICHETT.

Comet a 1888. On last Thursday morning, April 5th, while examining the head of the Sawerthal comet with the 8½-inch, micrometer eyepiece, power about 120 diameters, (equatorial of this Observatory), I saw in an instantthat the nucleus was composed of two distinct portions, as shown in the sketch herewith sent you. For several mornings it had appeared elongated in a direction corresponding to the line joining the two portions as seen divided on this date; and I have no doubt that I would have seen it *divided* on the earlier occasions had the atmosphere been as remarkably clear and steady as it was on the morning of the 5th, even at the low altitude of the comet.

Comet *a* 1888 (April 5th, 4:50 A. M.) Chabot Equatorial 8½-inch Aperture, Power 120.

By the aid of the micrometer, I estimated the separation equal to about 3″ (arc): that portion *n.*following was very decidedly the brighter. The duplicity was entirely unmistakable, even with illumination *slightly* turned on. I watched it long enough to be certain of the observation, before commencing micrometer measures for the comet's place; and on the succeeding morning recovered the field, identified the stars, and again convinced myself that one of the apparent nuclei was not a star. The bright star shown in the sketch is Arg. +7°: 4842; and Grant No. 5780.

I mentioned the observation to Prof. Holden, and at his suggestion, sent a telegram to Prof. Pickering at Cambridge. The two succeeding mornings' work did not verify the double nucleus to my complete satisfaction, but the air was far from "steady," either time. I await confirmation of this peculiarity with some interest. CHAS. B. HILL.

Chabot Observatory, Oakland, Cal., April 9th, 1888.

Solar Eclipse Aug. 19, 1887. In the account of the eclipse of August 19th, 1887, at pages 162 and 163 of THE SIDEREAL MESSENGER for April, 1888, the solar protuberances then visible are described and their relations discussed. It is stated that "at the first moment of totality four protuberances were visible on the eastern limit of the sun. The most southern had the greatest dimensions and could be seen even with the naked eye. By the progress of the moon three of the protuberances were covered but the most southerly one remained visible until the end of totality." Upon the western edge of the sun a group of protuberances was also observed, but they were "very low."

It is of interest to note the fact in connection with these observations that a brilliant group of faculæ was located precisely upon the sun's eastern edge at the point where the largest protuberance was seen. This group was in full view at Lyons, N. Y., at 5 o'clock P. M., on August 19th, and was followed by a small spot which was seen on the morning of August 20th. Allowing for difference of time the advance portion of this solar disturbance must have been exactly upon the sun's edge and foreshortened so as to be invisible at the very hour when Dr. Khandrikoff was making his observations. This condition of affairs justifies conclusions precisely the reverse of those which he states in regard to the relations between solar protuberances, spots and faculæ.

Lyons, N. Y., April 3rd, 1888. M. A. VEEDER.

Warner Comet Prize Decision. The claim of Mr. William R. Brooks to the discovery of the Olbers' comet, having been contested by Mr. Max Weir of Greenville, Ky., I was obliged to resort to arbitration, and the judges, Profs. E. E. Barnard, George Davidson and James G. Davidson of San Francisco, have awarded the prize to Mr. Brooks. The decision was unanimous as, in view of the evidence, I was quite sure it must be. Mr. Weir claims to have seen it three days previous in the northwest with his naked eye, whereas the Olbers-Brooks' comet has not at any time been visible in that direction, and is and has been only telescopic.

The claim of Mr. Brooks ought never to have been disputed. I saw the comet on the mornings of April 7th, 8th and 9th but failed on the 12th, though I had it in the field. It was too near the milky way to be seen again by any telescope, I think. LEWIS SWIFT.

Warner Observatory, Apr. 20th, 1888.

On the Adjustment of the Sextant. As I have at various times found it necessary to investigate the errors of a sextant, I was interested by the article of Professor Comstock in the April number of this journal.

So far as the adjustment of the index-glass is concerned I fully agree with the statements of Professor Comstock as to the needlessly crude character of the usual method; to me it has always seemed so very unsatisfactory that for some time past I have been giving a method to my students which it may not be out of place to give here.

The telescope-tube of the sextant—which we will call the *cylinder*—is to be set in a (nearly) vertical position on the (nearly) horizontal graduated arc, the eye-tube having first been removed in order that the cylinder may rest on an edge which is in a plane perpendicular to the axis of the cylinder. The index-arm is then to be turned until the cylinder and its image reflected from the index-glass appear to approach coincidence. If the mirror is *not* normal to the plane of the sextant the coincidence can not be secured as the corresponding outlines will not be parallel if we assume that the axis of the cylinder is normal to the plane of its base; to eliminate the error due to a slight inclination of the base, the cylinder should be revolved about its own axis until the position is found in which observed deviation from coincidence is the mean of the extreme deviations during a complete turn of the cylinder. If the coincidence, or parallelism of corresponding outlines is now complete, the index-glass is normal to the sextant.*

To test the accuracy of the adjustment of the index-gass by this method, a strip of plane glass six inches in length was placed under the cylinder and coincidence secured; a slip of paper 0.003 inches in thickness was then placed under the other end of the glass strip, thus causing the cylinder to tilt through an angle of about two minutes of arc; the deviation from coincidence was now readily detected.

To test whether the glass-surface (from which the reflections in these observations must take place) makes the same angle with the plane of the sextant that the silvered surface does, observe whether the two reflections of a white plumb-line three or four feet in length (best seen on a dark back-ground, under an angle of incidence of about 60°) are parallel when the plane of the sextant is approximately horizontal. If the two surfaces are inclined to each other by an angle of only one minute of arc, the deviation from parallelism will

* If the cylinder is placed in a lathe and carefully centered, a slight trimming of the ends of the tube with the cutting tool will evidently form bases which are in planes perpendicular to the axis of the cylinder.

be apparent to the eye. By this method the inclination of the index-glass can be tested for all sextant-readings between 0° and 120°.

Ann Arbor, April 20th, 1888. M. SCHÆBERLE.

BOOK NOTICE.

A Treatise on Plane Surveying by Daniel Carhart, C. E., Professor of Civil Engineering in the Western University of Pennsylvania; Boston: Messrs. Ginn and Company, Publishers, 1888.

This new treatise covers quite fully the field of Plane Surveying. Large space is given to the illustration and description of instruments, including their adjustments and uses. Methods of work are exemplified by a variety of common problems, with solutions for special cases that often present themselves in practical work. It is evident that the writer is both a teacher and a practical surveyor, which give him the two-fold knowledge of the subject most needed in a text-book of this kind.

The plan of the book is as follows:

Chapter I. is devoted to chain surveying, and to give some idea how carefully and fully the subject is treated, we will notice the order of discussion. Section 1, instruments; Gunter's chain, two-pole chain, engineers' chain, tape measure, marking pins, straight poles. Section 2, chaining; how to chain, tallying, error in chaining, sloping ground, field exercises, ranging lines, over a hill, across a valley, through a wood, field exercises; to set a perpendicular to a line, through a point to run a perpendicular to a given line, obstacles to alignment, obstacles to measurement, measurement of heights, examples and field practice. In a similar way the four following sections under this topic treat recording field notes, mapping and plotting, areas, and offsets and tie-lines This chapter covers fifty pages of well selected matter with exercises and enough suitable illustrations. Chapter II. treats of compass and transit surveying to which 145 pages are devoted. A short chapter of twenty pages then follows on the variation of the compass. Chapter IV. is on laying out and dividing land. Chapter V. is devoted to plane table surveying; VI., to the survey of the public lands covering fifty pages; VII., to city surveying; VIII., to mine surveying followed by an appendix and a series of tables that are excellent in form and matter. We are a little surprised not to find in so good a book, some more reference to the elementary part of railroad surveying. In our field work for the last ten years, some of the finest exercises, for young classes, have been selected from this department of plane surveying. In the western part of the United States this branch of work leads all others at the present time.

This book contains 411 pages and 87 of tables and is every way a neat specimen of the printer's art.

THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE,

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

VOL. 7, NO. 6. JUNE, 1888. WHOLE NO. 66.

THE SURFACE OF THE SUN.

THE EDITOR.

In the March number of this journal we stated the problem of the sun's distance and mentioned some of the difficulties met in trying to find its value in any known terrestrial unit of measure. We briefly noticed methods of work, and gave, probably, the best approximate results derived from all work down to the present time. Unofficial information concerning work on the last transit of Venus, now nearly finished, does not materially change the conclusion previously stated. In this connection we desire also to refer the reader to a most excellent article by Professor A. Hall of Washington, enlitled *The Constant of Aberration*, and published in the *Astronomical Journal* (Nos. 169 and 170), more especially for the sake of the following paragraph which suggests a method of finding the distance of the sun not before noticed, and which, in Professor Hall's opinion, is the best that astronomers now have:

The constant of aberration has an interesting connection with the solar parallax. If we designate by k the number of seconds which light requires to pass over the mean distance of the earth from the sun, by φ the angle whose sine is the eccentricity of the earth's orbit, by M the mean anomaly of the earth, and by t the time, we have by definition

$$\frac{k}{\cos\varphi}\cdot\frac{dM}{dt} = \text{constant of aberration} = c.$$

If v be the velocity of light, a the mean distance of the earth from the sun, R the equatorial radius of the earth, and π the solar parallax then

$$v = \frac{a}{k}; \qquad a = \frac{R}{\pi};$$

and eliminating k we have

$$\pi'' = \frac{R}{cv\cos\varphi}\cdot\frac{dM}{dt}\times 206265$$

We have from observation

$\log \frac{dM}{dt} = 8.613493$ Hansen

$\log \cos \varphi = 9.999939$ "

$R = 3963.3$ miles Clarke

$v = 186325$ " Michelson and Newcomb

$c = 20''.4542 \pm 0''.0144$ (derived above).

These numbers give for the solar parallax

$$\pi = 8''.810 \pm 0''.0062$$

There are two theoretical corrections to be applied to the constant of aberration. In the first place the motion of a planet is around the center of gravity of the planet and sun, and not around the center of the sun. This correction is

$$\frac{20''.45 \times m}{\sqrt{a}}$$

m being the mass of the planet, and a its mean distance from the sun (Bessel, *Fund. Astr.*, p. 132). Since for the earth

$$m = \frac{1}{326800}$$

this correction is 0''.00006, and can be neglected.

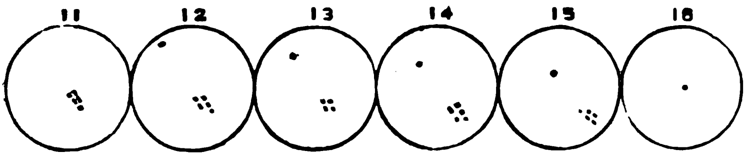
A second correction is required on account of the motion of the solar system in space (Bessel, *Tabb. Reg.*, p. XIX). As yet we have only rough determinations of this motion, since at present accurate observations of the stars do not extend over a sufficient interval of time. Struve's estimate of this motion is 1.6 per annum, the mean distance of the earth from the sun being the unit. This motion would give for the correction to the constant of aberration 0''.0005, as a maximum which could change the position of a star. It is therefore probably too small ever to be recognized by observation. The theory of these corrections has been elaborately discussed by M. Villarceau in the *Conn. des Temps* for 1878, where he has treated also the motion of our sidereal system.

Considering the smallness of these corrections, and the accuracy with which the velocity of light is known, I think the above method of determining the solar parallax is the best that astronomers now have.

After the solar parallax, we called attention to the opinions of some prominent astronomers in relation to the constitution of the sun, with some of the objections that have prevented a general acceptance of those opinions. We now invite attention to a study of the surface of the sun as it appears in the telescope, as it is now understood by the aid of the spectroscope, and by the assistance of of the photographic lens.

The appearance of the sun to the naked eye, properly shielded from its intense light, is that of a flat circular disc, uniformly bright, if not clouded at the time by very large sun spots. In the telescope with only moderate power, the solar surface commonly shows small spots, faculæ and a granular structure whose general appearance is well known to all observers, but the full and satisfactory explanation of which none claim even now certainly to know.

The discovery of sun-spots was made in 1610 by Fabricius and Galileo, and at this time began progressive study of the surface and the constitution of the sun. By careful observation of the sun-spots it was first and soon learned that the sun has a rotary motion round a fixed axis. To show how the spots would appear to move on the solar surface, the following drawing is given which is taken from the observing book of one of the subscribers to the MESSENGER and belongs to six days of the month of November, 1884.



From information like this Galileo claimed that the time of the sun's rotation was about twenty-eight days, and that the solar axis was inclined to the ecliptic by a small angle. We know that the mean time of the sun's rotation is twenty seven days and nine hours, and his inclination 7° 15′. But the most important queries that were asked by all early observers were concerning the nature of the sun-spots. The difficulties attending detailed observation then to secure enough data for any hypothesis gave rise to a number of different theories to account for the cause and meaning of those spots "in the eye of the world." Jean Tarde thought them transits of planets across the solar disc. Simon Marius believed in the *slag* theory. Derham accounted for them by volcanic eruptions; while Lalande and Cassini said the spots were rocky elevations uncovered by the casual ebbing of the luminous ocean we call the solar surface. So from the time of the invention of the telescope for 164 years, progress in knowledge pertaining to the sun was limited to an approximate period of his rotation, inclination to the ecliptic, and spot zones north and south of his equator.

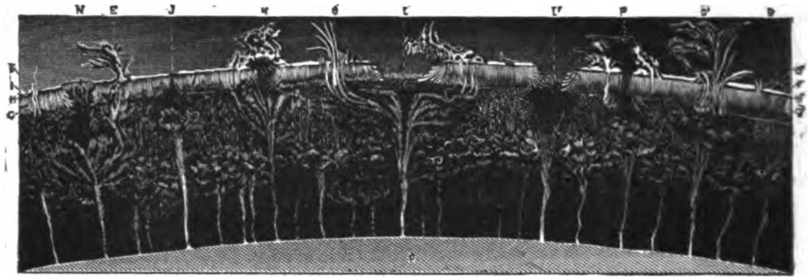
In 1769 Alexander Wilson said that spots were openings in the bright surface of the sun through which the dark and real globe could be seen. His proof was the foreshortening of the penumbra as the spot approached the limb, and the notch made when exactly on the limb. Herschel carried the last theory further, making the central globe cool, solid and habitable and the shell of luminous cloud; without the source of light and heat for the solar system. The theory was ingenious and won a host of friends among the scholars until the spectroscope made belief in its splendid imagery no longer possible.

Next in order come the views of Secchi, Faye, Young and Langley. In Secchi's view the spot is formed of a central region—apparently a dark mass—called the nucleus or umbra, or both, surrounded by a part less dark, the penumbra, which is a thin veiling of filaments or currents precipitating themselves towards the center and sometimes crossing it like a bridge. The existence of the spot has three periods, its formation, its rest and its extinction. In the first, the visible solar surface, or photosphere is distorted by great agitation. Its irregular movements defy description, and their velocities are enormous. They have no parallel at all in terrestrial phenomena. This solar activity is produced by tremendous forces at work beneath the photosphere, and the spots, and eruption of great whirling masses of incandescent metallic vapors, are the effects. In the period of rest these eruptive masses fall back again into the surface of the photosphere and form a more or less circular umbra or spot, and the central up-rush loses in volume and velocity. Finally the eruptive action is exhausted and the absorbing powers of the vapors seem to be dissipated, the photosphere closes over the umbra and the spot is extinguished. At first the spot was a rent in the photosphere, then later it assumed the funnel shape in more definite outline, and was crowned with beautiful faculæ and jets of hydrogen and metallic vapors, the former being often abundant, high and bright, while the latter are low and brilliant. This briefly is Secchi's explanation.

M. Faye's study of solar spots agrees in the main with the foregoing, and emphasizes in addition some particulars worthy of notice. He agrees with Carrington that there exists a simple relation between the latitude of the spots and their angular velocity, but that the parallax of depth, estimated at $\frac{1}{200}$ of the radius of the sun, must be considered, and also, certain oscillations of small extent and long period in order to obtain the exact relation sought. He holds that contiguous bands of the photosphere are rotating with different velocities as the results of gyratory motions about vertical axis extending to great depth; that velocities in the direction of rotation independent of mean angular motion are less towards the poles of the sun; that the nucleus is depressed in respect to the photosphere; that the whirlpools of the sun, like those of the earth, vary in size from the pore to the great spot, and that the penumbra of a spot is due to that portion of the photosphere which forms around their conical surface at a lower level on account of the lessening of temperature produced by the whirlpool. M. Faye has most trouble in explaining the periodicity of the spots.

Professor Young adopts M. Faye's views for the most part, but adds significant details of theory with characteristic insight and scholarly grasp. He believes that the solar globe, except possibly a thin outer shell, is in a gaseous condition with temperature so high, and under pressure so great that chemical interaction is impossible; that the gases are viscous and behave more like tar or honey than air; that from the under surface of the photosphere there is an immense precipitation of "solar rain" descending into the gaseous core; that from the constricting pressure of the cloud shell and descending products of condensation, the internal gases are forced upwards through the intervals between the clouds with great velocity; that the lower portions of the chromosphere are rich in all the gases and vapors which enter into the sun's composition; that Faye's theory he can not reconcile with the want of systematic rotation of the sun's spots, or their peculiar forms, and that the accelerated motion of the sun's equator is the most important of the unexplained facts in solar physics which probably, when understood, will furnish the solution of most other perplexing questions pertaining to the constituttion of the sun that still face the astronomer of to-day for answer.

The best way now at hand to bring the substance of the forgoing views to the eye is by means of an illustration of the interior structure of the solar envelope given by E. L. Trouvelot of France not long ago, in a complete and instructive article on this theme, which the author had the kindness to place on our table. The following cut is a reduced copy of a fine lithograph plate accompanying the article referred to:



SUPPOSED INTERIOR STRUCTURE OF THE SOLAR ENVELOPE.

The paper was written in French, and it has been translated in part that Professor Trouvelot's own description might be given to our readers as another statement of conditions, the substance of which may have been read in American authors, but the details of illustration have not been before so fully attempted.

"The envelope which limits the brilliant surface of the sun, named the photosphere, H, H′, forms a sort of immense spherical shell of which the thickness is relatively small. This envelope in which are produced openings which are known to us under the name of solar spots, is composed of an innumerable quantity of vertical filaments due to the condensation of metallic vapors projected from the interior and held in suspension at nearly the same height as the centre of the vapors of comparatively little luminosity, which separate the filaments and hold them at a distance, G, G′. Each of these elementary filaments of which this envelope is formed contains in itself all the substances which compose it. It is the same as the vapors that separate them, which are formed of the same substance as the filaments which form these in their condensation. In reasoning of the filamentary structure of this spherical envelope of the sun, it would be well to distinguish it from the photosphere by giving it the name "nématosphere," a name much more appropriate than that of the photosphere which pertains only to the surface of those granulations which compose this envelope, and over which light is germinated.

"In the interior of this filamentary envelope, and at a certain depth, is a nucleus whose nature is undetermined, and which may be either solid, liquid, or gaseous, D. But whatever may be the nature of this nucleus, it is certain that it is the subject of violent crises, which are, we may say, permanent, and which extend over the entire surface as is indicated by the faint gray spots which we see everywhere upon the sun, by the minute spots accompanied by faculæ as well as by the hydrogenic protuberances which we perceive all over these latitudes; only these crises are much more violent than anywhere else over the region comprised within 35° each side of the equator.

"The crises of the solar nucleus are manifested by formidable eruptions of hydrogen gas, by metallic vapors, and by incandescent dust which, projected to a considerable height, are seen to accumulate in clouds of fire in the lower part of the nématosphere. The hydrogen mingled with helium, being more light and mobile than the metallic vapors, forms the summit of the eruptive column, and, entering between the filaments which it disperses, and of which it transforms a part into vapors which it carries with it, making a passage for itself, rises above the photosphere partly as an invisible gas which reaches a considerable height, and partly under the form of hydrogenic protuberances, E', with some traces of metallic vapors at their base; or else, if the explosive force is not so great, it expands simply over the surface, where it forms and maintains the chromosphere F, F'. Whenever these eruptive jets are less nourished and of lower temperature, as sometimes happens at the time of minimum spots, the protuberances which result sometimes subside at the beginning of condensation and take then the filamentary structure peculiar to the nématosphere.

"The vapors, more dense and of considerably more emissive power then hydrogen raise the temperature of the elementary filaments which are rapidly decomposed and reunited in one or more compact masses which lifted to greater or less heights above the photosphere, appear under the form of groups of brilliant faculæ, K, and the metallic protuberances pertain to the eruptive type, G, G′, which reproduce to our eyes the form and extent of those eruptive columns lying under that which gave them birth. Thus we see that the general form of these facular groups is always more or less circular, as that of the eruptive columns of terrestrial volcanoes obeying the action of their vents. The phenomena which we have just described are peculiar to the zone of spots, but in the higher latitudes of the sun, the eruptions of the nucleus are much less violent nor do they ever attain such grand heights. There is no hydrogen or helium which appears even in the filiform envelope and projecting between the filaments, rise above it in hydrogenic protuberances. In these regions the metallic eruptions only rarely reach even to the surface where they form only small and rare faculæ and very few protuberances of the eruptive type.

"In looking at the effect which the violent eruptions of the spot-regions produce upon the material which composes the filiform envelope, which rise and are transformed into brilliant faculæ and invisible gases, it is possible to think that the temperature of these vapors is so high that all the chemical elements of which they are composed are in a state of dissolution (or dissociation). Reaching the upper part of the nématosphere the metallic vapors, endued with considerable emissive power and exposed as they are to the radiation of space, cool with great rapidity, and their temperature, as Wilson thinks, lowers very soon to the point of condensation. At this moment it produces a phenomenon almost analagous to that described by our eminent compatriot M. Faye, only in place of forming small clouds as the savant thinks, the metallic vapors take the filamentary structure which we have known upon the sun, and they condense at the same time into liquids and incandescent dust, while their elements, thus far dissociated, combine among themselves according to the laws of affinity. This condensation of the metallic vapors upon the one side and chemical combinations upon the other, germinate, where the phenomena are produced, that is, at the summit of each of the filaments, that enormous heat and intense light which the sun constantly radiates into space. This innumerable multitude of centres of condensation and chemical combinations, which have the summit of a filament for a theatre, form together a brilliant coating exceedingly thin and, we may say, superficial, which alone merit truly the name of *photosphere*, for it is upon this that is born that intense light which the sun radiates H, H′. As these liquids and solid particles, condensing and throwing off an enormous quantity of heat, are much too heavy for the centre where they find themselves placed, they fall in rain toward the nucleus, where the heat causes them speedily to return to the vapor state, and at the same time are replaced in each of the filaments by the condensation of new vapors formed without cessation by the eruptions of the nucleus, condensed without cessation by the cold of space. Thus the filaments of nématosphere interchange and, in consequence, the light of the sun.

"Or, since it is certain after our observations, that the metallic vapors condense in filaments at the surface of the sun, it is true that their condensation is made in the manner noted above, each granulation which in the sum total, is nothing more than the summit of a filament, finds itself encompassed and isolated from its neighbors by a small gaseous envelope composed of the same substances as those which form the filaments, of which, condensed in their turn, they are destined soon to form a part. As these small vaporous envelopes which encompass the granulations owe their orgin to the heat disengaged in the act of the condensation of the metallic vapors into filaments, as well as to that which arises from the chemical combinations which result, their temperature will necessarily be lower, and their light less intense, than that of the granulations; so that they will appear to us as more or less dark and will form around these last a sort of indefinite network resembling that which we see on the solar surface. Further, as these vaporous envelopes which enclose these granulations are at a temperature lower than the last and that, for the rest, they are composed precisely of the same elements, they will absorb the luminous rays emitted by the granulations and will give in consequence an appearance of obscure rays exactly resembling that which we see upon the sun. As the vaporous envelope of the granulation extends not only around but also above them, if we consider them altogether, they will form a thin film continually absorbing which, seen upon the solar edge extends a little beyond the photosphere and during total eclipses of the sun, reverse the rays of Fraunhofer, where the sun is seen to disappear and again to reappear, I, I.′

"The eruptive columns of hydrogen gas and of helium, when they have small force and volume, enter easily among the elementary filaments of the envelope, which they disperse more or less, and form those pale and light gray and diffuse spots everywhere and always visible on the surface of the sun, B. When these have more force and volume, these gaseous, eruptive columns are introduced in one point only between the elementary filaments which they disperse easily and drive from one part to another, forming soon a small black spot without a penumbra, without faculæ, without interior shadows (or clouds or veils), J. With the gas always flowing the spot continues to enlarge, and little by little it is surrounded by a penumbra due to the light removal of the lower part of the filaments forming the border.

"The incandescent metallic vapors which constitute the less elevated part of these same eruptive columns, endued as they are, with considerable more emissive power than hydrogen, heat rapidly the elementary filaments when they approach them, as often happens over the spot zones, decompose them, and return them to the gaseous state, and mingling with them form these brilliant masses which, lifted above the nématosphere, appear to us under the form of brilliant faculæ, K These openings made in the nématosphere by the decomposition and transformation of the filaments into faculæ, and lifting them above the surface, constitute the solar spots, L, L′, of which the penumbra is formed by the lifting of the lower extremity of the filaments, which form and border the edge of these openings, A, A′.

The solar spots disappear in various ways. In the first class they retire (or disappear) gradually, the neighboring filaments, loosening, encroach gradually over the opening in proportion as the gaseous eruption diminishes and finally end by a heaping together. In the second class the phenomenon is much more complex, they disappear sometimes by an afflux of extensive faculæ which advance and cover the opening, sometimes they are luminous points which sink over them and in retaking the filamentary form, enlarge rapidly finish by the heaping together; sometimes at the last they disappear by condensation over the opening of invisible vapors in shadowy vapors which become flocculent, then finally filamentary and transform them little by little into veiled spots, N, which are soon effaced entirely by the accumulation of the filaments. Ordinarily the causes which we have mentioned do not act singly to disperse the spots but all at once.

"The faculæ are almost always formed above the invisible openings of the nèmatosphere, and if they were not held in that state by the interior heat which reaches them constantly through the openings which they cover, they would condense very quickly into filaments as often happens. But nevertheless they frequently disappear little by little, being transformed into invisible vapor and leaving in their places the spots which they cover. The last case is scarcely an exception to the rule, for the greater part of the time, the openings of the nèmatosphere remain more or less obstructed by the faculæ and often pass away unobserved, K, or else they are only indicated by the small lateral spots which are seen at the base of the faculæ whenever they are near the solar edge but which disappear when these are at a little distance.

"At present, observation is dumb upon the causes of the eruption of the solar nucleus, and we have learned nothing either of their periodicity nor of that of the spots, the faculæ, and the protuberances which result. As their periodicity may be real or only apparent, we may conjecture that during the minimum periods, the eruptions are more rare and less violent and are principally hydrogenic; while during the maximum periods they are more frequent and more energetic hydrogenic and metallic at the same time. There would result the predominance of the solar spots, faculæ protuberances and metallic spectacles during the latter periods and their rarity during the former.

"If, as we have supposed, it is true that the heat and solar light are due to the interior activity of the sun which produces these eruptions of metallic vapors, and which condense and germinate this heat and light, we may think that, unless the sun gathers and assimilates constantly the material of space, the day will arrive, however distant we may imagine it, when this interior activity diminishing the photosphere will not extend over the entire surface as it does to-day, but only over a point of the surface, and finally, after alternate action and repose will cease entirely."

This detailed statemeut of the study of visible solar phenomena is given to aid students or interested readers in comprehending some of the questions in solar physics that the astronomer is trying at the present time to solve. The aid given by the spectroscope and the photograph lens in this study we have hinted at only incidentally. These and the interesting researches on solar temperature by Professor Langley must be a reserved for another time.

(TO BE CONTINUED.)

A FURTHER NOTE ON STAR DISTRIBUTION.

BY W. H. S. MONCK.

For the MESSENGER.

The numerical error in my former note on star distribution renders a fresh discussion of some of the questions raised in it desirable. The principal of these is the extent of the thinning of the stars, which takes place as we pass outwards from the solar system into space.

The theoretical multiplier for one-tenth of a magnitude is not 1.0965 but 1.148, and in trying the reverse process it is not $\frac{1}{1.0965}$ but $\frac{1}{1.148}$. In summing the series therefore for the total number of stars above a given magnitude the expression is not 10.363*a* but 6.757*a* (where *a* represents the number of stars confined in the next tenth of a magnitude). From this follows a curious law which holds good to less than one per cent viz.: the number of stars brighter than any given magnitude is equal to the number of stars comprised in the next half-magnitude. The numbers for the next five-tenths of a magnitude will be respectively *a*, 1.148*a*, 1.318*a*, 1.514*a* and 1.738*a*, giving a total for the five subdivisions of 6.718*a* against 6.757*a* as the total number of brighter stars.

This law enables me to show briefly that the thinning out of the stars does not commence until we reach magnitude 2.5. The total number of stars brighter than 2.0 according to the *Harvard Photometry* is 27, and, according to the *Uranometria Nova*, 25. The number of stars between 2.0 and 2.5, according to the former authority, is 30, and, according to the latter, 28. Instead of a deficiency of fainter stars, therefore, there is at this stage a slight excess. But at the next step the deficiency becomes apparent. There are 57 stars rated higher than 2.5 in the Harvard Catalogue and 53 in the Oxford one, but the number of stars from 2.5 to 3.0 is only 41 in the former and 21 in the latter. And this deficiency seems to be maintained down to the point where the catalogues can no longer be relied on as complete.

If, however, we inquire whether the deficiency is maintained below this point, the answer is more doubtful. The magnitudes of Argelander agree so well with those of Pickering and Pritchard as to indicate that the scale of 2.512 for each magnitude has been practically adopted by Argelander. I am happy to learn that Professor Pickering is at present engaged in researches wich will clear up this question. Schönfeld pointed out long ago in a letter to *the Observatory* that Argelander's magnitudes were not reliable beyond 9.2 or, at the utmost, 9.3. I shall only use them as far as magnitude 9, assuming provisionally that Argelander's magnitudes down to this point are comparable with those of Pickering and Pritchard. Adopting Leebyer's results (as given in the *Observatory*), I find the following particulars for the Bonn Durschmusterung and Schönfeld's southern extension of it respectively.

	No. of stars Argelander.	No of stars Schonfeld.	Total.
Brighter than 9.5	4,120	1,265	5,385
6.5 to 7.0	3,887	1,276	5,163
7.0 to 7.5	6,054	1,828	7,882
7.5 to 8.0	11,168	3,506	14 674
8.0 to 8.5	22,898	7,601	30,499
8.5 to 9.0	52,852	18,633	71,485

Here it is evident at a glance that while the thinning out of the stars is still in progress down to the 8th magnitude, it is not only arrested but reversed between the 8th and 9th magnitudes, the interval 8.5 to 9.0 containing nearly five times as many stars as the interval 7.5 to 8.0, while the theoretical number is slightly less than 4. There is another feature in the table which I cannot reconcile with the results of Pickering and Pritchard, viz.: that the total number of stars brighter than magnitude 6.5 is almost exactly equal to the number of those lying between 6.5 and 7.0 in accordance with the hypothesis of uniformity. The figures would have been materially different if we had gone on to the next succeeding stage as we would then have 10,548 stars brighter than 7.0 against 7,882 lying between 7.0 and 7.5. At the final stage the excess is in the opposite direction. We have only 63,603 stars brighter than 8.5 against 71,485 between 8.5 and 9.0 Great reliance cannot be placed on these results pending Professor Pickering's investigation, but I think it may be at all events laid down that the thinning out of the stars has only been shown to exist between the limits of 2.5 and 8.0 magnitudes and that there are some traces of a reversal at both ends of the scale.

The limit, or at least uncertainty, as to the thinning out of the stars renders it more difficult to discover its causes. One cause which I suggested is, that we are situated in the Galaxy, the shape of which, therefore, would rather resemble a segment of a cylinder or a flat round cake than a hollow ring. The stars all around us are, on this theory galactic, but there is a plane in which the Galaxy extends much farther than it extends in a direction perpendicular to this plane. Drawing a number of spheres around us with the sun as centre, the surfaces of the inner spheres would be wholly occupied by the Galaxy; but as the spheres became larger and and larger, the Galaxy would occupy a smaller and smaller portion of the surfaces, and each succeeding surface would, as a consequence, contain fewer and fewer stars compared with its extent. The fact that the Galaxy appears nearly as a great circle on the celestial sphere gives some countenance to this theory. But I think the objections to it preponderate. The thinning out of the stars ought to be greater than it is unless the sun is situated in a particularly poor portion of the Galaxy. It ought not to be confined within the limits 2.5 and 8.0; and I may add that researches on parallax do not seem to show that the stars which lie out of the direction of the Galaxy are among our nearest neighbors as they ought on this theory to be.

But the other theory of loss of light in transmission is not more successful in explaining the limits between which the thinning out has been observed, and there appear to be special objections to supposing that the ether absorbs light. If it exercises a selective absorption all the more distant stars should either present a peculiar color or at all events exhibit peculiar lines in their spectra. On the other hand that bodies capable of intercepting light, especially meteors, exist in space is at all events highly probable; but it may be doubted whether they are numerous enough to intercept an appreciable quantity of light at the distance with which we are now dealing. The whole question thus stands in need of further investigation.

ON THE DISSIPATION OF COMETS.

BY W. H. S. MONCK, DUBLIN.

FOR THE MESSENGER.

That the visits of comets to the neighborhood of the sun are usually attended with a good deal of waste will not, I think, be doubted, nor will it probably be disputed that Biela's comet, at least, has now been finally dissipated in its character of comet. I venture to suggest that the causes of dissipation chiefly exist in or near the ecliptic (or rather, perhaps, the plane of Jupiter's orbit), and that this is the true reason why many comets of short period have not returned. For this purpose I have arranged the comets of short period which ought to have returned since their first discovery in order of their inclinations, and I find the result is as follows:

1. Lexell's comet of 1770; inclination 1°34′. Orbit repeatedly and carefully computed. Period under 6 years; never returned.

2. Clausen's comet of 1743; inclination 1°53′; period about 5½ years. One very doubtful identification; otherwise it never returned.

3. Comet of 1678; inclination, 2°52′; period, according to Le Verrier, similar to the foregoing. One doubtful identification; otherwise it has never returned.

4. De Vico's comet of 1844; inclination 2°54′; period similar to foregoing. Doubtfully identified with No. 3. Never returned since 1844.

5. Tempel's comet of 1869; inclination 5°24′. This is the first in the table that has certainly returned.

6. Tempel's comet of 1867; inclination when discovered 6°24′, but now increased to over 10°, so that it does not now stand sixth in the list. This comet has also returned.

7. Burkhardt's comet of 1766; inclination 8°1′; period in close agreement with the foregoing six. Has not returned (unless identical with No. 6).

8. Blainpain's comet of 1819; inclination 9°1′; period similar to foregoing. Has not returned.

9. Faye's comet; inclination 11°22′; period a little longer than foregoing. Has returned.

10. Biela's comet; inclination 12°33′. Returned several times but seems to be now dissipated.

11. Tempel's comet of 1873; inclination 12°46′. Has returned.

12. Encke's comet; inclination 12°54′. Has frequently returned.

13. Winnecke's comet; inclination 14°27′. Has returned.

14. D'Arrest's comet; inclination 15°42′. Has returned.

15. Tempel's comet of 1866. Inclination 17°12′ (retrograde). The previous visits of this comet seem to be sufficiently established by the corresponding meteor shower, though it is doubtful whether the comet itself was previously observed. The comet of A. D. 1366, perhaps most resembles it.

16. Halley's comet; inclination 17°45′ (retrograde). Has returned regularly since the Christian era.

Of comets with indications exceeding 20° and periods of less than 100 years, those of Tuttle, Brorsen, Pons-Brooks, and Olbers have returned, while Pigott's of 1783 and De-Vico's of 1846 have not; but the period of the latter is doubtful.

The earlier observations appear in no case to have been sufficiently accurate to show that the orbit was elliptic, but it is worth noting that no periodical comet with an inclination of less than 10° has been identified with a comet observed before the time of Newton, as Halley's comet has been with certainty, and Tempel's comet of 1866 and Brorsen's comet have been with some degree of probability.

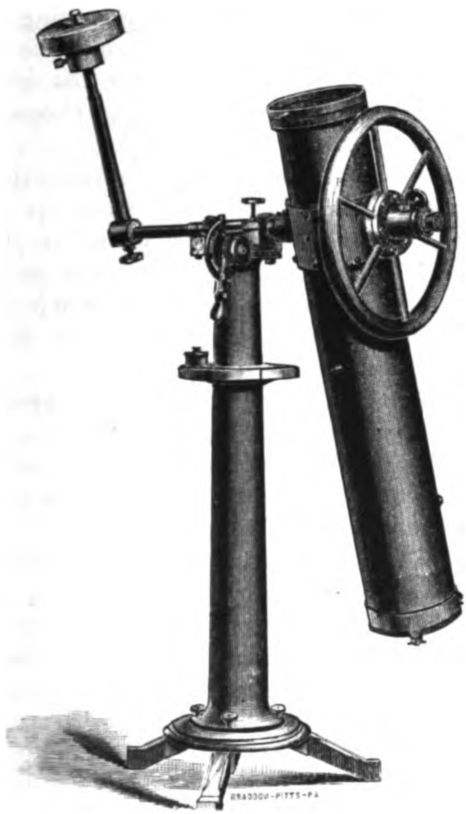
The fact that less than half the comets with inclinations of under 10°, for which elliptic orbits have been computed, have returned while all the elliptie comets with inclination between 10° and 20° have returned (though one seems to have been recently dissipated), is, at all events, remarkable. It points, I think, to dissipation, not perturbation as the cause of non-return.

A NEW FORM OF COMET-SEEKER.

BY GEORGE A. HILL.

FOR THE MESSENGER.

Mr. Brashear of Allegheny City, Pa., has recently made for Professor H. P. Tuttle of the Naval Observatory, from designs of the latter, a new form of comet-seeker which embraces so many salient points that I have been persuaded to write a description of it for the MESSENGER.



A NEW FORM OF COMET-SEEKER.

Mr. Brashear read a paper before the American Association, held in New York, describing the comet-seeker, but as that paper may not come to the attention of all the readers of this magazine, I will describe the plan of the instrument.

Through the kindness of Professor Tuttle I have been, for a short time, using this instrument in my regular comet hunting, and the more I use it the more convinced I become of its great improvement over other forms of comet-seekers.

The wood-cut gives a fair representation of the telescope and its mountings. It is a reflector of 6½ inches aperture, and 40 inches focal length. The telescope tube has a broad collar around its upper end, on one side of which a hub is cast, and which is bored to fit on the end of the declination axis. Directly opposite to this hub the eye-piece holder is mounted, so that when the telescope is swung through any number of degrees of declination, the only movement given the eye-piece is one of rotation; hence the observer is not obliged to change the position of the eye through the entire sweep in declination.

The telescope tube is mounted on a horizontal axis, which is free to move in declination. Encircling the eye-piece will be seen a hand wheel, about 14 inches in diameter, the spokes of which radiate from the eye-piece mounting. The rim of the wheel is made of wood, and of such a size as to be firmly grasped by the hand. By this means the observer is able to move the instrument in declination.

The horizontal axis just mentioned is mounted in a bearing plate, which can be moved rapidly, or, if a slow motion is desired, a tangent screw attached thereto can be used. This tangent screw is capable of being thrown in and out of gear, at the pleasure of the observer.

Attached to the tangent screw is a ratchet wheel and handle, within easy reach of the observer, and which can be so regulated by stops, arranged for it, that "sweeps" of any desired breadth may be taken, thus relieving the observer of the necessity of watching his field. The arrangement just explained can also be used for making horizontal sweeps, or it can be detatched and those sweeps made without it. Should any object be noticed near the edge of the field in the direction in which the telescope is being moved, the ratchet may be instantly released, and by the use of the milled wheel on the tangent screw, the telescope can be moved in the opposite direetion.

Just below the eye-piece will be seen a rotating shelf, on which are kept the eye-pieces, and as they are made to slide into the eye-piece holder, no time is lost in making a change in the power used.

The eye-pieces are of the Airy form, the lowest power giving a field of about a degree and a half.

The heavy disc of metal fastened to an arm, on the left hand side of the telescope, acts as a counterpoise, by which means the instrument will remain fixed in any position the observer may wish to place it.

The telescope tube is fastened to an iron tripod stand, and this in turn is fastened to a small carriage supplied with wheels. By this arrangement the instrument can be drawn to different portions of the yard, or, if the observer has a flat roof from which he observes, it can be drawn to different portions thereof.

Through the kindness of the Superintendent of the United States Naval Observatory the new comet-seeker has been mounted on the roof of that building.

A little house has been built in which the instrument is placed when not in use. Around the west and south sides of the veranda surrounding the small dome a track has been built over which the comet-seeker is drawn, so that all portions of the sky can be viewed.

The ease and comfort with which comet-seeking can be carried on with an instrument made after this new model must be self evident.

In my opinion all observers who use the refractor for comet-seeking would, after using this style of reflector, discard the former at once.

I do not make any claim of the superiority of the reflector over that of the refractor; that I will leave to some one who is more competent to judge than I am. But I do claim that the mounting of this new form of comet-seeker is the nearest approach to perfect ease for the observer, to rapidity of action, and handiness with which all parts of the heavens can be surveyed, of any form of mounting known to me.

The ease with which the observer can sweep on the meridian or near the horizon is the same. In sweeping he has occasion only once in about fifteen minutes to move his chair, and if that be mounted on castors his change of position can be regulated by his feet.

ASTRONOMY IN LATE PERIODICALS.

Monthly Notices for March has among its prominent articles the following: The orbit of the binary star λ Ophiuchi, by Professor S. Glasenapp. This star has been observed for sixty-two years, and the elements of the orbit deduced are:

$T = 1787.9$	$\lambda = 152^\circ.5$ Eq. 1900
$U = 373.5$ years	$i = 38^\circ.1$
$n = 0.9638$	$\epsilon = 0.4424$
$\Omega = 105^\circ.5$ Eq. 1900	$a = 1''.53$

These elements will represent the observations for the period above named.

J. E. Gore has computed the orbit for 70 Ophiuchi, using all the available measures from 1819 to 1887, being about 247 in number. The elements are:

$P = 87.84$ years	$\Omega = 120^\circ 5'$ (1880)
$T = 1807.5$	$\lambda = 171^\circ 45'$
$\epsilon = 0.4912$	$a = 4''.50$
$\gamma = 58^\circ 28'$	$\mu = -4^\circ.098$

In connection with this paper the formulæ are given for the computation of an ephemeris.

W. S. Franks publishes the introduction to a catalogue of the mean colors of 758 stars, and an appendix containing the colors of 26 stars. His earlier catalogue of 3,890 stars was made by the aid of a five-inch refractor, and contained naked-eye stars to declination —25°.

A. Marth's ephemeris for physical observations of moon for nine lunations from April 12 to the end of 1888 is an instructive and a very useful paper.

Nature for April 19 and 26 contains portions of an address, delivered by J. Norman Lockyer before the Royal Society, April 12, 1888, entitled "Suggestions on the Classification of the Various Species of Heavenly Bodies." The first point discussed related to the probable origin of the groups, especially the nebulæ. Mr. Lockyer starts with the idea that the orgin of the nebulæ is meteoric; that light and the glow of gases come from collisions of meteors; that Herschel's planetary nebula has no star for its center; that Sir John Herschel's theory of "hollow shells" and Arago's hollow spherical envelopes illuminated by a brilliant central body do not accord with Rosse's observations, which showed all to be perforated by the aid of his colossal telescope, except (as he believed) those nebulæ of the annular form.

The meteoric hypothesis is briefly this: A swarm is supposed to be the center of activity, and its center of gravity is the focus of attraction for a considerable space surrounding, more or less filled with meteorites. The collisions, few or frequent, that naturally arise in such relations, are the source of greater or less light for the mass. "The collision surface will be practically the only thing visible, and will present to us the exact and hitherto unexplained appearance of a planetary nebula—a body of the same intensity of luminosity at its edge and center—thus putting on an almost phosphorescent appearance." The theory is then applied to the globular nebula showing condensations, until finally a nebulous star is reached; also to the spiral nebula and the cometic nebula.

The second branch of the theme is the classification of the stars, based on observation by the spectroscope in which is presented the results of the labors of Fraunhofer, Rutherford and Secchi, bringing out classifications in relation to temperature which are interesting and novel in some respects. This address contains much useful astronomy.

The Astronomical Journal, No. 171, presents a full and carefully written article by Professor George C. Comstock, entitled "An Examination of Some Errors Possibly Affecting Measures of Distance made with the Prism-Apparatus of M. Loewy;" Elliptic Elements of Comet *a* 1888, by Professor Lewis Boss, as follows:

$$T = 1888, \text{ March } 16.9987$$
$$\left.\begin{aligned} \omega &= 359^\circ 54' 58''.4 \\ \Omega &= 245\ 22\ 46\ .6 \\ i &= 42\ 15\ 23\ .1 \end{aligned}\right\} 1880.0$$
$$\log. \epsilon = 9.997790$$
$$\log. q = 9.844329$$

Professor Boss says the above eccentricity corresponds to a period of 1,615 years, and that he suspects that the true period will be decidedly greater than 2,000 years.

The elliptic elements of this comet computed by Rev. George M. Searle of New York are nearly identical with those given above. The near agreement of different computers is partly explained by the fact that the position of the orbit is remarkably favorable for the manifestation of ellipticity if it should exist.

Observatory for May gives accounts of the meetings of the Royal Astronomical Society, Liverpool Astronomical Society, and the Royal Meteorological Society. The paper by the editors, Messrs. Turner and Common, on the photographic chart of the heavens, though brief, deals with the most important phases of this great work projected by the international conference at Paris. The three following resolutions show the aim and scope of the work:

1. "The progress made in astronomical photography demands that astronomers of the present day should unite in undertaking a description of the heavens by photographic means."

2. "The work should be carried out at selected stations, and with instruments which should be identical in their essential parts."

3. "The principal objects are (*a*) to prepare a good photographic chart of the heavens for the present epoch, and to obtain data which will enable us to determine, with the greatest possible accuracy, the positions and the brightness of all the stars down to a given magnitude (magnitude being understood to be defined in a photographic sense), (*b*) to provide for the means of utilizing, both at the present day and in the future, the results of the data obtained by photographic means."

In connection with this plan of work Dr. Gill's proposition to establish a central bureau with officers and computers at an annual cost of $50,000 for a period of fifty years is criticised in strong terms on the ground of cost, and the limited uses of the extended star catalogue proposed.

Knowledge for May gives large space to astronomical themes. The first is "The Star Story of the Flood." It begins with a description of the ancient skies at the date 3,400 years B. C., and the writer finds, with a star map of that date before his eyes, familiar passages of the ancient poets are explained; and, assuming this as the probable date of the Great Pyramid of Egypt, there are many points in and about it that signify purposes which it served for ancient astronomy and astrology. The first part of the article closes with a comparison of the ancient and the modern constellations, claiming that the former much more nearly represented the objects bearing their names than the later ones do.

"The Canals and Rivers of Mars" is a discussion of Schiaparelli's views concerning details on the surface of Mars which he has repeatedly observed, and which he calls great parallel canals. As Mars is now nearest to earth for the present year, observers with large telescopes have opportunity to study these markings for themselves. The writer in *Knowledge* holds that the parallel tracings seen are not canals, but probably rivers so modified by atmospheric and other possible conditions as to give them the appearance of the dark streaks plainly mapped by Schiaparelli.

Another paper, entitled "Weighing the Earth," gives the details of working out the result by simple methods. A further method by means of leaden weights, first suggested by Professors Richer and Meyer of Berlin, is proposed as worthy of consideration and trial, for a direct comparison between the weight of a large leaden ball and that of the earth.

Journal of Liverpool Astronomical Society for May continues the illustrated notes of the planets by Mr. Denning, with Mars as the theme. He refers to the markings of that planet's surface, known as the parallel canals of Schiaparelli, and says that the present opposition will afford opportunity for their study by the aid of large telescopes. The apparent diameter of Mars at opposition in 1887 was 29″.2; in 1888, 18″.4. More favorable opposition will occur in 1890 and 1892 than for this year. When it is remembered that Schiaparelli saw, in the clear skies of Milan, these canal markings when the disc of Mars was only 13″ in diameter, the giant telescopes of the present time ought to be able to test his observations with good degree of certainty. His statement of power necessary to do this is that "every telescope able to distinguish a dark line 0″.2 in breadth on a dark background, and to separate the one from the other of two such lines when the interval between axis and axis is 0″.5, could be employed for these observations, and to study the duplications if these should be reproduced. In the Milan instrument, the aperture of which does not exceed eight French inches, the greater number of the canals and their pairs were observed with comparative ease whenever the air was still, and only a few cases required a special effort on the part of the observer." M. Perrotin of Nice, with a Henry equatorial of fifteen inches, has seen these markings, with powers 450 and 560, and noticed that some of them were double. He estimates that the phenomena may be produced by clouds or mists circulating in the atmosphere of Mars.

Other interesting papers of this number are: "Comet-seeking," by W. Doberck; "Secondary Light of Venus," by W. T. Lynn; "Water on the Moon," by W. Durham; "Evidence of Subsidence of Lunar Maria," by S. E. Pearl; and the study of the walled plain, "Messala," on the moon, by T. G. Elger.

SUPPOSED OBSERVATIONS OF COMET 1887, I.

PROFESSOR LEWIS SWIFT.

For the MESSENGER.

This is the comet which, on Jan. 8, 1887, so suddenly made its apparition in the southern heavens. It was apparently headless, seeming to consist altogether of train. The first announcement of discovery which reached the northern hemisphere, was made by Mr. Thome of the Cordova Observatory, and, for a while it seemed that he was clearly entitled to the Warner comet prize of $100, but his claim is now contested by Mr. W. H. Haley and others of Australia. On the evening of Feb. 13, setting my telescope as indicated by Mr. Chandler's ephemeris, in about the same R. A. and some degrees farther south, I picked up an object, new to me, which, as it had a cometary aspect and was so near the computed place, I was almost sure was the South American comet. It was perfectly round and without tail. After a moment's observation, I detected, about 4′ north, an exceedingly faint, pretty small, round nebula.

Cloudy weather prevented a subsequent observation and a full year elapsed before an opportunity came to re-examine the place. I have been able to make only three attempts at re-observation, and, each time, the seeing was not exquisite enough to reveal the faint one, but, on two or three occasions, sufficiently good, I felt certain to have shown the bright body had it been there.

In consequence of the erection of a large number of electric street lights south of the observatory, and of the low altitude of the objects, I fear I shall be ever unable to re-find the fainter one which would serve as my guide to the place of the other. Under the best conditions of seeing, in any latitude, a telescope of about fifteen inches aperture would be required to see it.

In calling attention to this matter my object is to prevent the readers of THE SIDEREAL MESSENGER from forming an erroneous opinion from the statements regarding it by Dr. H. C. Wilson, on page 157 of that magazine for April. He gives as the sentiment of Professor Barnard's letter in the *Astronomische Nachrichten*, that he (Professor Barnard), though he had sought in vain for my objects, yet he had found in the same declination, but differing fifteen minutes in right ascension, two nebulæ, one about 4′ north of the other, which, in his opinion, might be the two seen by myself. The doctor seems either not to have seen, or to have forgotten, my letter of reply published also in that journal. Mr. Barnard's nebulæ I have for years been familiar with, and I re-examined them last February for comparison. They are not identical with those under debate, nor do they bear any marked resemblance to them.

Owing to the uncertainty of the observations of the comet in the southern hemisphere, probably not great reliance can be placed on any ephemeris, and though, doubtless, Chandler's may have been as nearly accurate as any, yet the difference from the computed position of the comet at that date did not hinder me, under the circumstances, from strongly suspecting it to be that body. The agreement was quite close in right ascension, but the declination differed about three degrees.

It is not at all surprising that Professor Barnard, with a six and one-half inch telescope (not eight inch as Dr. Wilson says), failed to detect the faint nebula so near the bright one. I still strongly suspect that the object I saw was a comet, and though, of course, it may not have been Comet 1887, I, yet I incline to think that it was.

FOR STUDENTS AND YOUNG OBSERVERS.

Interesting Phenomena for June and July.

THE PLANETS.

Mercury will be at greatest elongation east of the sun June 12 at 2 P. M., and will be in favorable position for observation in the early evening during the greater part of the month of June, setting from an hour to an hour and three-quarters later than the sun. He is coming between the earth and sun, and will reach inferior conjunction July 8, being then about five degrees south of the sun. At the same time Venus and the moon will be in the same region of the sky, within five degrees of the sun. The diameter of Mercury's disc on June 12 will be 8.2″, and at the end of the month will have increased to 12″. During the latter part of July Mercury may again be observed in the morning, west of the sun, although its position will not be so favorable as in June. Very little is known with regard to the surface markings of this planet, or its period of rotation, and it is one to which amateurs devote very little attention, chiefly because of the difficulty of obtaining good images. The smallness of the disc, and the fact that it is usually observed near the horizon, where the waves of heated vapor cause a flaring and distortion of the image so that the phases can scarcely be made out, are serious drawbacks to anything like accurate observations. Mr. W. F. Denning, however, in the February number of the *Journal of the Liverpool Astronomical Society*, has called attention to the fact that the observations need not be made at a low altitude, and that, by selecting suitable times, very satisfactory views of this planet may be obtained. He says, "As a naked-eye object Mercury must necessarily be looked for near the horizon, but there is no such need in regard to telescopic observation, which ought to be only attempted when the planet has surmounted the dense lower vapors and attained sufficient elevation to give the instrument a fair chance of producing a steady image. The presence of sunshine need not seriously impair the definition, or make the disc too faint for detail, but care must be taken to shield the telescope from the sun's rays, or annoying currents will be generated in the interior of the tube, and these will ruin the view. I have occasionally seen Mercury about two or three hours after his rising, with outlines of extreme sharpness and quite comparable with the excellent views of Venus at the time of sunrise and sunset. Those who possess equatorials should pick up the planet in the afternoon and follow him until after sunset, when the heated vapors will interfere. Others who work with ordinary alt-azimuth stands will find it best to examine the planet at his western elongations during the last half of the year, when he may be found soon after rising by the naked eye, or with an opera glass, and followed in the telescope for several hours if necessary."

Venus is in a very unfavorable position for observation, approaching superior conjunction with the sun. The apparent diameter of her disc will be less than that of Mercury during the greater part of the month, and she is so nearly in line with the sun that it will be very difficult to find her with ordinary telescopes. Venus will be at the ascending node of her orbit June 20; in conjunction with Mercury, on the opposite side of the sun, apparently and really, July 8, at 11 P. M., central time; in conjunction with the moon, north 1°57′, at the same time; at superior conjunction with the sun, north 47′ from the sun's center, July 11, at 1 P. M.; in perihelion, July 23; in conjunction with Saturn, July 27, 7 A. M.

Mars will be in good position for observation during June, although he is receding from the earth and his disc is therefore growing smaller, diminishing from 13.2″ June 1 to 10.6″ July 1. Mars may still be seen in the southwest in the early evening during July, but his low altitude will prevent good seeing. Reference is made elsewhere to a paper by Mr. W. F. Denning, in the *Journal of the Liverpool Astronomical Society*, in which he speaks of the most curious features of Mars' surface, the so-called "canals," which were observed by Schiaparelli at Milan in 1881 to run in parallel pairs. This duplication of the canals has been observed since by Mr. Perrotin at Nice. A note, by Mr. R. A. Proctor, on this subject was read at the April meeting of the Royal Astronomical Society. In the discussion which followed the reading of the note Mr. Knobel said: "I quite agree with Mr.

Proctor that there is a great difficulty in accepting the chart of Mars as depicted by Schiaparelli. The parallelism of the canals is so amazing that one cannot but seek for some explanation as was suggested some time back by Mr. Green, those lines being the boundaries of faint tones and shadows on the planet, or, as Mr. Proctor has suggested, there being some light spaces between certain dark marks which Schiaparelli has interpreted into lines like canals. Certainly I have over and over again recently, as well as at every opposition, failed to see anything approaching parallelism in the configuration of the planet. I have not seen the slightest signs of it and it does not appear that, with the exception of the observations made at Nice, any one has seen anything like these parallel canals spoken of by Schiaparelli."

Jupiter is now in its best position for observation this year, crossing the meridian between 10 and 11 P. M. There is no difficulty in recognizing this brilliant planet among the bright stars of Scorpio in the southeast in the early evening. He has been retrograding for some time, but his motion is very slow. July 22 he will become stationary, and after that will advance toward the east. The objects on Jupiter's surface which specially attract observers are the old red spot, the brilliant white spots on the north borders of the great equatorial belts, and the belts and spots closely south of the red spot. It is known that different spots have different periods of rotation, and observers may do useful work in noting the time when different markings come to the central meridian of the planet, and their position north or south of the equator. Mr. Denning has given an interesting discussion of the features of this planet in the March and April numbers of the *Journal of the Liverpool Astronomical Society*.

Saturn will be pretty low in the northwest for good observation, but may be seen in the first hours of the evening during June. During July he will be near the sun, coming to conjunction August 1. Saturn will be occulted by the moon, to observers between the parallels of latitude north 36° and south 24°, July 10, 1 P. M. central time. The occultation will occur in full sunlight, when the planet is only one hour and a quarter east of the sun, but it may possibly be observed by taking proper precautions to shut the sunlight out from the telescope.

Uranus will be in conjunction with Mars June 6 at 11 P. M., north 47′. The two planets will then be in the same field of view of an ordinary finder. One will thus be able to compare directly the greenish hue of the one with the ruddy color of the other. Uranus will be stationary June 19, and in conjunction with the sun July 4.

Neptune comes into view again in the morning, west of the sun. It is in Taurus a few degrees south of the Pleiades.

A Partial Eclipse of the Sun will take place July 8, but will be visible only in the South Indian and Antarctic oceans.

A Total Eclipse of the Moon, July 22, will be visible generally throughout North and South America and portions of Europe, Africa and the Pacific Ocean.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of conjunction in right ascension,
July 22*d*, 17*h* 44*m* 29.5*s*.

	h m s		s
Sun's right ascension	8 11 48.02	Hourly motion	9.92
Moon's right ascension	20 11 48.02	" "	147.84
Sun's declination	20° 00′ 12.7″ N.	" "	0′ 31.0″ S.
Moon's declination	20° 01′ 44.7″ S.	" "	4′ 24.0″ N.
Sun's equa. hor. parallax	8.7	Sun's true semidiameter	15′ 44.9
Moon's equa. hor. parallax	58 43.0	Moon's true semidiameter	15 59.2

TIMES OF THE PHASES.

	Washington mean time. d h m	Central time. h m
Moon enters penumbra	July 22, 9 47.3	8 55.5
Moon enters shadow	10 46.5	9 04.7
Total Eclipse begins	11 45.4	10 53.6
Middle of the eclipse	12 36.6	11 44.8
Total eclipse ends	13 27.8	12 36.0
Moon leaves shadow	14 26.6	13 34.8
Moon leaves penumbra	15 25.7	14 33.9

Magnitude of the eclipse = 1.825 (moon's diameter = 1).

Probable Occultation of Stars by the Principal Planets. In L'Astronomie for May Mr. B. Lihou gives a list of probable occultations of stars by the planets Venus, Jupiter and Saturn during the year 1888. Such occultations have been very rarely observed because they have never been predicted. They would be of use in the study of the physical constitution of the planets, and especially would an observation of an occultation of a star by the rings of

Saturn throw light upon the nature of those strange appendages. It happens, however, that only one of the probable occultations noted by Mr. Lihou will be visible in the United States, viz., that of a 7.7 magnitude star by Jupiter, August 7, 9:22 P. M. central time; maximum duration 358 minutes.

THE CONSTELLATIONS.

At 9 P. M. in the middle of June, Cancer, with the cluster Præsepe and the planet Saturn, is setting in the west. Leo, with the bright star Regulus and the well-known group of the Sickle, is a little less than half way up from the west horizon to the zenith. The second star from Regulus in the Sickle, γ Leonis, is a fine double. The components are about 4″ apart, and their magnitudes, 2d and 4th. It is a binary, having a period of about 400 years. Above Leo is the constellation of Berenice's Hair, an area dotted with faint stars just visible to the naked eye. Not far south and a little west of the zenith one will recognize Arcturus, the principal star of Boötes the Herdsman. This asterism extends almost to the zenith and contains quite a number of bright doubles. About half way from Arcturus to the horizon, west of south, the ruddy planet Mars keeps company with the brilliant Spica in the constellation of Virgo. The star nearest to Mars to the north is θ Virginis, and almost directly west of this star, 15*m* or 4°, the planet Uranus may be found. The next star visible to the eye, toward the west from θ and Mars, is γ Virginis, one of the finest of double stars, a binary with a period of about 180 years. The components are of the 4th magnitude, very nearly equal, 4″ apart, the one silvery white, the other pale yellow. There are many nebulæ in this constellation, but few of them are individually interesting. Southwest from Mars and Spica there is a trapezium of stars, known as Corvus the Raven. To the east of the meridian the first constellation to strike the eye is Scorpio, with the scarlet Antares and irregular configuration of bright stars. It has added to its own charms now the giant planet Jupiter. Antares, besides its fiery red color, has also a close companion of a greenish hue, which is a somewhat difficult object to detect with small telescopes. The bright star, β, nearest to Jupiter is also a double, rather wide, magnitudes 2 and 5.5, colors yellowish white and lilac. The nearest star east of β is also a wide double, magnitudes 4 and 7, and the fainter star of this pair is again double, 2″, magnitudes 7 and 8. Half way between Antares and β is a large nebula like a comet. Directly east of Antares about 2° is a large, rather dim, resolvable cluster of stars followed by a vacant, starless space, one of Herschel's "holes in the sky." The two bright stars of Libra are a little north and west of Scorpio.

North of Scorpio parallel to the Milky Way is the ill-defined constellation of Ophiuchus the Serpent-bearer. To the right of the last one may trace an irregular line of stars, marking the head and neck of the Serpent, North of this we see the Northern Crown ,a circular group of faint stars, and to the left of this Hercules, an asterism difficult to trace because it contains no conspicuous stars and has no definite outline. It is chiefly interesting because it contains that point in the heavens toward which the solar system is supposed to be now moving, and because of the splendid globular cluster which is to be found one-third of the way from the star η to the star ζ of the constellation. These last are the first stars, of the third magnitude, to the east and a little north of the Northern Crown. A line from the zenith to the east horizon will pass near two very bright stars; the uppermost of these is Vega of the Lyre, the lower Altair of the Eagle. One will notice two fainter stars which form an isosceles triangle with Vega. The northernmost of these is ε Lyræ, a double-double, *i. e.*, to the naked eye it appears single, with a low magnifying power double and with a higher power each component is again double. A little way toward the horizon from Vega is another pair of stars of nearly the same brightness and nearly the same distance apart as those nearest Vega. Between these, about half way and almost directly in line, the famous Ring Nebula may be found. Looking towards the north one will see Ursa Major to the west, Ursa Minor and Draco above, Cepheus and Cygnus to the east and Cassiopeia below the pole.

Phases of the Moon.

Phases of the Moon.		Central Time. d h m
Last Quarter	June	1, 6 53.3 A. M.
New Moon		9, 10 34.0 "
First Quarter		17, 12 49.7 "
Full Moon		23, 3 7.5 P. M.
Last Quarter		30, 9 52.6 "

	R. A. h m	Decl.	Rises. h m	Transits. h m	Sets. h m
NEPTUNE.					
June 5............	3 54.2	+18°39′	3 31 A. M.	10 52.2 A. M.	6 13 P. M.
15............	3 55.7	+18 43	2 53 "	10 14.3 "	5 36 "
25............	3 57.1	+18 47	2 14 "	9 36.4 "	4 58 "
SATURN.					
June 5............	8 22.8	+20 02	7 56 A. M.	3 24.0 P. M.	10 52 P. M.
15............	8 27.2	+19 48	7 22 "	2 49.0 "	10 16 "
25............	8 31.8	+19 32	6 49 "	2 14.3 "	9 40 "
URANUS.					
June 5............	12 49.7	−4 36	2 05 P. M.	7 50.0 P. M.	1 35 A. M.
15............	12 49.3	−4 35	1 25 "	7 10.4 "	12 56 "
25............	12 49.3	−4 35	12 46 "	6 31.1 "	12 16 "
MARS.					
June 5............	12 48.7	−5 13	2 06 P. M.	7 49.3 P. M.	1 32 A. M.
15............	12 56.4	−6 22	1 40 "	7 17.8 "	12 56 "
25............	13 7.7	−7 47	1 17 "	6 49.7 "	12 22 "
JUPITER.					
June 5............	15 50.8	−19 10	6 06 P. M.	10 50.5 P. M.	3 34 A. M.
15............	15 46.2	−18 57	5 22 "	10 6.6 "	2 52 "
25............	15 42.4	−18 47	4 38 "	9 23.5 "	2 09 "
VENUS.					
June 5............	4 15.0	+20 40	3 47 A. M.	11 17.9 A. M.	6 48 P. M.
15............	5 7.2	+22 22	3 50 "	11 30.7 "	7 12 "
25............	6 0.4	+23 39	3 59 "	11 44.6 "	7 30 "
MERCURY.					
June 5............	6 38.3	+25 03	5 46 A. M.	1 40.0 P. M.	9 33 P. M.
15............	7 22.5	+22 32	6 04 "	1 44.7 "	9 24 "
25............	7 37.3	+19 33	5 54 "	1 19.9 "	8 45 "
THE SUN.					
June 5............	4 55.7	+22 39	4 21 A. M.	12 01.6 P. M.	7 42 P. M.
15............	5 37.1	+23 21	4 15 "	11 59.6 "	7 44 "
25............	6 19.7	+23 23	4 13 "	11 57.5 "	7 42 "

Occultations Visible at Washington.

Date.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean T. h m	IMMERSION. Angle f'm N. Point. °	EMERSION. Wash. Mean T. h m	EMERSION. Angle f'm N. P't. °	Duration. h m
June 18	80 Virginis	6	9 48	136	10 56	278	1 07
21	χ Ophiuchi	4½	8 31	182	8 56	221	0 25
26	γ Capricorni	3½	12 05	63	13 26	268	1 18
26	δ Capricorni	2½	16 40	71	17 56	241	1 17
27	B. A. C. 7835	6½	11 12	346	Star 6.5′ N. of moon's limb.		

Great Red Spot on Jupiter—Times when its Zero Meridian passes the Centre of Jupiter's Disc.

	Central Time. d h m		Central Time. d h m		Central Time. d h m
June	2, 1 27.8 A. M.	June	11, 11 42.6 P. M.	June	21, 9 57.9 P. M.
	2, 9 18.9 P. M.		12, 7 33.8 "		22, 5 49.1 "
	4, 3 6.0 A. M.		14, 1 20.8 A. M.		23, 11 36.1 "
	4, 10 47.2 P. M.		14, 9 11.9 P. M.		24, 7 27.4 "
	5, 6 48.2 "		16, 2 58.9 A. M.		26, 1 14.4 A. M.
	7, 12 35.2 A. M.		16, 10 50.2 P. M.		26, 9 5.7 P. M.
	7, 8 26.3 P. M.		17, 6 41.4 "		28, 2 52.7 A. M.
	9, 2 13.2 A. M.		19, 12 28.4 A. M.		28, 10 44.1 P. M.
	9, 9 4.5 P. M.		19, 8 19.6 P. M.		29, 6 35.4 "
	11, 3 51.3 A. M.		21, 2 6.6 A. M.	July	1, 12 22.4 P. M.

Phenomena of Jupiter's Satellites.

Central Time. d	h m			
June 1,	7 18	P. M.	I	Ec. Re.
3,	3 29	A. M.	II	Oc. Dis.
4,	10 27	P. M.	II	Tr. In.
5,	12 07	A. M.	II	Sh. In.
5,	12 55	"	II	Tr. Eg.
5,	1 37	"	II	Sh. Eg.
6,	2 51	"	I	Tr. In.
6,	3 13	"	I	Sh. In.
6,	7 48	P. M.	II	Ec. Re.
7,	12 10	A. M.	I	Oc. Dis.
7,	2 43	"	I	Ec. Re.
7,	9 17	P. M.	I	Tr. In.
7,	9 29	"	III	Tr. In.
7,	9 42	"	I	Sh. In.
7,	10 58	"	III	Sh. In.
7,	11 07	"	III	Tr. Eg.
7,	11 29	"	I	Tr. Eg.
7,	11 53	"	I	Sh. Eg.
8,	12 53	A. M.	III	Sh. Eg.
8,	6 36	P. M.	I	Oc. Dis.
8,	9 12	"	I	Ec. Re.
9,	5 56	"	I	Tr. Eg.
9,	6 23	"	I	Sh. Eg.
12,	12 44	A. M.	II	Tr. In.
12,	1 42	"	II	Sh. In.
12,	3 10	"	II	Tr. Eg.
13,	6 53	P. M.	II	Oc. Dis.
13,	10 25	"	II	Ec. Re.
14,	1 56	A. M.	I	Oc. Dis.
14,	11 5	P. M.	I	Tr. In.
14,	11 38	"	I	Sh. In.
15,	12 49	A. M.	III	Tr. In.
15,	1 17	"	I	Tr. Eg.
15,	1 50	"	I	Sh. Eg.
June 15,	8 21	P. M.	I	Oc. Dis.
15,	11 06	"	I	Ec. Re.
16,	6 05	"	I	Sh. In.
16,	7 42	"	I	Tr. Eg.
16,	8 17	"	I	Sh. Eg.
18,	7 00	"	III	Ec. Re.
20,	9 11	"	II	Oc. Dis.
21,	1 01	A. M.	II	Ec. Re.
22,	12 51	"	I	Tr. In.
22,	1 31	"	I	Sh. In.
22,	6 36	P. M.	II	Tr. Eg.
22,	8 03	"	II	Sh. Eg.
22,	10 07	"	I	Oc. Dis.
23,	1 00	A. M.	I	Ec. Re.
23,	7 17	P. M.	I	Tr. In.
23,	8 00	"	I	Sh. In.
23,	9 29	"	I	Tr. Eg.
23,	10 12	"	I	Sh. Eg.
24,	7 29	"	I	Ec. Re.
25,	6 04	"	III	Oc. Dis.
25,	7 51	"	III	Oc. Re.
25,	9 14	"	III	Ec. Dis.
25,	10 59	"	III	Ec. Re.
27,	11 31	"	II	Oc. Dis.
29,	6 26	"	II	Tr. In.
29,	8 08	"	II	Sh. In.
29,	9 54	"	II	Tr. Eg.
29,	10 37	"	II	Sh. Eg.
29,	11 54	"	I	Oc. Dis.
30,	9 03	"	I	Tr. In.
30,	9 55	"	I	Sh. In.
30,	11 15	"	I	Tr. Eg.
July 1,	12 07	A. M.	I	Sh. Eg.

Comet *a* 1888 (Sawerthal) was observed at Carleton College Observatory by Dr. H. C. Wilson on the morning of May 19. It was easily visible in the finder of the 8¼-inch Clark equatorial. The tail could be traced for more than a degree and the central bright line is still visible for its entire length. The following ephemeris is from A. N., No. 2838 for the months of June and July:

1888		α 1888.0 h m s	δ 2888.0 ° ″	Log *r*	Log Δ	L.
June	1	0 27 11	+ 40 1.6			
	2	28 45	40 20.7			
	3	30 18	40 39.6	0.2052	0.2826	0.067
	4	31 49	40 58.3			
	5	33 18	41 16.7			
	6	34 46	41 34.9			
	7	36 12	41 52.8	0.2205	0.2899	0.060
	8	37 36	42 10.5			

1888	α 1888.0	δ 1888.0	Log r	Log Δ	L.
	h m s	° ″			
June 9	0 38 59	+42 28.0			
10	40 20	42 45.2			
11	41 39	43 2.2	0.2352	0.2965	0.055
12	42 56	43 19.0			
13	44 12	43 35.7			
14	45 26	43 52.1			
15	46 38	44 8.3	0.2493	0.3025	0.050
16	47 48	44 24.3			
17	48 57	44 40.2			
18	50 4	44 55.9			
19	51 9	45 11.4	0.2629	0.3080	0.046
20	52 12	45 26.7			
21	53 14	45 41.8			
22	54 14	45 56.7			
23	55 11	46 11.5	0.2760	0.3129	0.042
24	56 7	46 26.1			
25	57 1	46 40.5			
26	57 52	46 54.8			
27	58 42	47 8.9	0.2887	0.3173	0.039
28	0 59 30	47 22.8			
29	1 0 16	47 36.6			
30	1 0	47 50.2			
July 1	1 1 42	48 3.7	0.3009	0.3212	0.036
2	2 22	48 17.0			
3	3 0	48 30.2			
4	3 36	48 43.2			
5	4 9	48 56.0	0.3127	0.3247	0.033
6	4 40	49 8.7			
7	5 9	49 21.2			
8	5 36	49 33.5			
9	6 1	49 45.7	0.3241	0.3278	0.031
10	6 24	49 57.7			
11	6 44	50 9.6			
12	7 2	50 21.3			
13	7 18	50 32.8	0.3352	0.3306	0.029
14	7 31	50 44.2			
15	7 42	50 55.4			
16	7 50	51 6.4			
17	7 56	51 17.2	0.3459	0.3331	0.028
18	8 0	51 27.9			
19	8 2	51 38.4			
20	8 1	51 48.7			
21	7 57	51 58.8	0.3563	0.3353	0.026
22	7 51	52 8.7			
23	7 43	52 18.5			
24	7 32	52 28.0			
25	7 19	52 37.4	0.3664	0.3372	0.025
26	7 3	52 46.5			
27	6 45	52 55.4			
28	6 24	53 4.2			
29	6 0	53 12.6	0.3762	0.3380	0.023
30	5 34	53 20.9			
31	1 5 6	53 28.9			

CLOCK-WORK OF THE TELESCOPE.*

A great variety of these are used by different makers, all more or less effective. Except for extraordinary purposes, the ordinary frictional governor is probably the best, as it is certainly the most common, form.

The principal points to be looked to in the clock are:

1st. Sufficiency of power—*i. e.* not only sufficiency of power to drive instruments under ordinary circumstances, but sufficient also to leave a large margin for possible and probable hitches or differences in force required owing to want of balance or any of those numerous causes which tend to vary the friction of any instrument.

To give an idea of what may be called sufficient, measure the height the clock-weight falls in an hour, and multiply this in feet by the number of pounds weight; the product will be the number of foot-pounds of energy available in each hour.

A 4″ telescope should not have less than 75, and a 6″ less than 200, foot-pounds of energy per hour.

These rough figures will give an idea of what is required, but of course much depends on the character of instrument, and its weight, and the fineness of finish of bearings, etc.

2nd. The train between clock-governor and clock-screw should be as simple as possible, with as few wheels as possible, as short shafts as possible; and, lastly, the gearing up between clock and screw should be as far as possible made with spur instead of bevel gearings. It is not the slightest consequence how complicated the train be anywhere else except between governor and screw but every avoidable wheel introduced there increases the chance of error.

3rd. The governor or regulator should be heavy, and have as much momentum as possible, to enable clock to get over small obstacles without preceptible jerk.

Various forms of improved governors have been introduced from time to time, but none are better than the simple frictional governor for short periods, and this is what is generally required.

If the telescope be required for photographic use, in which

* From "Astronomy for Amateurs," the article entitled "The Telescope" by Sir Howard Grubb, and continued from page 112 of the MESSENGER.

case the star must be kept constant in position for two hours without $\frac{1}{10}$ of a second displacement, the only resource is that of a uniform clock controlled electrically from a pendulum clock; but this arrangement is too complicated to attempt to describe without diagrams. It should be remembered that all these points are more or less important according to the delicacy of the work proposed to be undertaken. If the instrument be intended only for gazing at planets, stars, and comets, these points are of comparatively little consequence; but an instrument quite equal to this work would be useless if it were required to use very high powers for dividing difficult double stars, etc.; and again, an instrument might be sufficiently stable and rigid for this last purpose and not be sufficiently so if delicate micrometrical work were to be attempted.*

A new Minor Planet, No. (277), was discovered by Charlois, of Nice, May 3.5170, R. A. 13*h* 42*m* 17.4*s*; Decl. —11° 13′ 43″. Daily motion —44*s* and +.4′. Magnitude 13.

A new Minor Planet, No. (278 ?), was discovered by Borrelly, May 12.4336, R. A. 16*h* 31*m* 46*s*. Decl. —21° 47′ 06″. Motion in R. A. —56*s*; in Decl. +.03′. Magnitude, 11. This is perhaps Xantippe, No. (156).

A new Minor Planet, No. (279?), was discovered by Palisa, of Veinna, May 16.5483; R. A. 16*h* 21*m* 8*s*. Decl. —21° 35′ 12″. Daily motion in R. A. —56*s*; in Decl. +.01′; Magnitude 12.

Minor Planet No. (269) has received the name *Justitia*; No. (273), *Atropos*, and No. (274), *Philagoria*.

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* Much stress has been laid on the driving clock as an indispensable adjunct to the equatorial, though, from the amateur's point of view, it is still an expensive luxury; and, if the telescope is not to be especially devoted to micrometrical or photographic work, the ordinary tangent-screw, worked by hand, will suffice for most purposes. A sidereal timekeeper is almost a *sine qua non* in the effective use of the equatorial mounting; but an old-fashioned eight-day clock, beating seconds, with a slight alteration in its wheel-work and dial, makes a capital substitute at a merely nominal cost.—W. S. F.

ANAHITA.

Discovered by Dr. Peters, and presented to Anita Rosalie, daughter of Professor Simon Newcomb.

FOR THE MESSENGER.

Deep hidden in the depths of space,
Fain would I see her charming face,
As she moves on with subtle grace—
Anahita!

O brave Columbus of the skies,
Her beauty met thy searching eyes,
And filled our hearts with glad surprise—
Anahita!

She heedeth not the moon, I ween,
The little spot where she is queen
She rules with such an air serene—
Anahita!

O wondrous star of silver light,
Fit for the crown of angel bright,
Could I but hail thee in the night,—
Anahita!

Earth, thou hast many scenes sublime,
Yet I would leave this changeful clime;
To say farewell, I bide my time,—
Anahita!

Say not the new world is too small;
The green trees there may grow as tall,
Their verdant leaves may never fall—
Anahita!

The oceans here are are all too large,
But there I'll float a fairy barge
Upon the blue sea's sunny marge—
Anahita!

A sweeter music than we know,
From many a singing brook may flow;
While poet's hearts with fervor glow—
Anahita!

And what sequestered vales are there!
To break the silence of whose air,
Only the birds and lovers dare—
Anahita!

How beautiful the azure dome
Seen from those fields! O, let us roam
Where every flower finds its home—
Anahita!

There we shall see the roses blown
To perfect fullness; sweeter grown
The pansy faces we have known—
Anahita!

O happy little world above,
As free from guile as is the dove,
But full of faith and hope and love—
Anahita!

Too small is she for any wrong
But large enough for mirth and song,
And all that doth to joy belong—
Anahita!

Clinton, N. Y —LUCY STANTIAL BORST.

EDITORIAL NOTES.

Vacation months follow this. There will be no issue of the MESSENGER for July, but a number will be published for August. Consecutive numbers will always be found at the top of the first cover page.

The Orbits of Aerolites by Professor Newton. The following two propositions were set forth by Professor Newton in his paper read April 19 to the National Academy of Sciences:

1. The meteorites which we have in our collections, and which have been seen to fall, were originally (as a class, and with a very small number of exceptions) moving about the

sun in orbits that had inclinations to the ecliptic less than 90°; that is, their motions in the solar system were direct and not retrograde.

2. The reason why we have only this class of stones in our collections is not a reason wholly, or even mainly, dependent on the habits of men; nor on the time when men are out of doors; nor on the places where men live; nor on any other principle of selection acting at or after the arrival of the stones at the ground. Either the stones which are moving across the earth's orbit in the solar system move in general in direct orbits, or else, for some reason, the stones which have retrograde orbits do not in general come through the air to the ground in solid form.

Denver University Observatory. A recent letter from Professor H. A. Howe, of Denver University, Colorado, discloses the interesting fact that the observatory at that place is to have a new equatorial refracting telescope the aperture of whose object glass will be twenty inches. This is good news for the University and for Professor Howe who well deserves the recognition it implies. For so young a man it is a noteworthy stride in his favorite science, to have a telescope that ranks fifth in size and power in the United States; for those at Lick Observatory, Washington, University of Virginia, and Princeton, only now are larger. Another significant fact in this new enterprise is the altitude of the site, which has been chosen on the new "Campus" of the University about seven miles from the city of Denver, and is 5,000 feet above sea level. If memory serves us rightly this site is higher than that of any other large telescope in the United States, the Lick site being next, at an altitude of 4,200 feet. The name of the generous donor of this large instrument is Mr. H. B. Chamberlin of Denver, Colorado, whom the MESSENGER is pleased to introduce to all its readers as a patron of science they should know and gratefully remember.

Double Nucleus and Comet a 1888. I desire to supplement my former letter about the double nucleus of Comet Sawerthal with additional particulars. Duplicity was confirmed by observation on the same morning (April 5 '88) by E. E.

Barnard with twelve-inch equatorial while visiting at Lick Observatory. Mr. Barnard's sketch made subsequently from memory corresponds with mine already sent you (p. 221, April MESSENGER) I have since examined the comet previous to micrometrical measures each clear morning. I suspected two nuclei April 11 A., M. and saw them distinctly April 13. On last mentioned date, the central shaft of light (in tail) read 4°.7, and line joining nuclei 14°.6, to *north* of zero on position circle. CHAS. B. HILL.

Smith Observatory. Astronomers will be interested to notice, if not already known, that William R. Brooks, so well known everywhere for remarkable comet discoveries, has removed from Phelps, N. Y., to Geneva ,eight miles distant His change of place is due to the interest of another patron of Astronomy by the name of William Smith a resident of Geneva, who has provided Mr. Brooks with a fine residence and an Observatory delightfully situated and fully equipped for astronomical work. Address him hereafter at "Smith Observatory," Geneva, instead of "Red House Observatory," Phelps, N. Y., as heretofore. His observatory and instruments will be more fully described in a later issue.

Photographing the Sky. The first fasciculus of the "Bulletin of the Permanent International Committee for the Photographic Execution of a Chart of the Sky" has just come to hand. It contains much interesting matter. The principal papers are: Regulations of the Bureau of the Permament Committee; Method of mounting the sensitive plates and determining their orientation, by Mr. D. Gill; Note on the application of photography to micometric measures of stars, by Mr. T. N. Thiele. On the influence of the duration of exposure on the exactitude of stellar photography, by Mr. J. Scheiner. Then follows correspondence concerning the preparatory researches, by Messrs. Abney, Eder, Bakhuysen, Christie, Dunér, Gill, Jannsen, Pickering, Struve, Trépied, Vogel and others.

The president of the bureau, Admiral Mouchez, announces that the Bulletin will appear whenever the bureau has any memoir to publish, or any important report to bring to the knowledge of the savants and observatories who are carrying out the decisions of the astrophotographic congress of last April.

The following list of the observatories which had up to March 1, 1888, ordered the instruments necessary to take part in the work, is appended:

Germany—Potsdam.
England—Oxford.
Australia—Melbourne, Sydney.
Brazil—Rio de Janeiro.
Chili—Santiago.
Spain—San Fernando.
France—Paris, Bordeaux, Toulouse, Alger.
Mexico—Tacubaya.
Argentine Republic—La Plata. H. C. W.

The Editor of Knowledge in the April number pays his respects to us, under Gossip, to the extent of considerable space. We notice only one sentence, in which he says: "The editor of THE SIDEREAL MESSENGER actually asks me—an Englishman—how I could feel certain that the Council of the (Royal) Astronomical Society would reject a man (meaning Professor Holden) with contempt who has been convicted of unworthy conduct." That was not the question asked, as the editor of *Knowledge* ought to know, and should have stated fairly. The question to him was, how he could certainly know, before the election of the Council took place, that Professor Holden would be rejected with contempt. The editor of the MESSENGER has never said nor claimed to know, that Professor Holden was "guilty of falsehood, chicanery and malice," as *Knowledge* distinctly charges.

The foreknowledge of the editor of *Knowledge* is a little too previous, and also rather bold for even an American to receive, who does not believe that that English gentleman carries the Council of the Royal Astronomical Society in his vest pocket. In its May issue the *Observatory* (English) has again spoken well in this matter.

Mr. Ambrose Swasey, of the firm of Warner and Swasey, Cleveland, Ohio, spent a day at Carleton College Observatory recently, on his return trip from California. He has employed a considerable portion of the winter months at Mt. Hamilton in setting up and trying the great Lick telescope, the mounting for which was constructed by the above named firm. Mr. Swasey gave us valuable suggestions in regard to the practical manipulation of photographic apparatus in connection with the telescope. His experience with the great thirty-six-inch photographic lens, though limited in time, was certainly instructive.

Messrs. Fauth & Co., makers of astronomical instruments, Washington, D. C., have kindly sent us blue-print drawings of a mounting for an equatorial telescope with several interesting improvements invented by Mr. Saegmüller who is connected with this well known firm.

Astronomy in Rochester, N. Y., is a popular study. From a late issue of the *Union and Advertiser* these interesting items were taken: William M. Rebasz is the possessor of an excellent six-inch refracting telescope by the Clarks. William Streeter has a small equatorial telescope mounted in an observatory of novel design. Rev. N. M. Maain has an equatorial telescope and an observatory, and has written much for the MESSENGER. H. C. Mann owns three telescopes, one refractor and two reflectors, the largest of the mirrors being twelve inches in diameter. Isaac Goldenschuhe has a six-inch reflector of excellent defining power. Professor Otis H. Robinson of the University of Rochester has a small Clark refractor of superior quality. The larger Clark refractor of the Warner Observatory is, however, the chief attraction. Its cost was $11,000; its aperture sixteen inches and its focal length twenty-two feet. Dr. Lewis Swift, more than any other, is undoubtedly the cause of this rapid advancement in the study of astronomy. Dr. Swift made Rochester his home in 1872.

Shattuck School of Faribault, Minn., has recently secured an 8½-inch, equatorially mounted reflecting telescope, made by J. A. Brashear, Allegheny City, Pa. Similar instruments have also been ordered from the same maker for a station in British Columbia, and by Dr. J. G. W. Steedman of St. Louis, Mo. The driving clocks for these instruments are said to work excellently and almost noiselessly.

Mars' Satellites. It may be interesting to some of our readers to know how the tiny satellites of Mars look in the great Lick equatorial, as they have been observed night after night by Assistant Keeler, during the month of May. In conversation with a friend he recently said these minute bodies looked in the great refractor as bright as the companion to Polaris does in a three-inch telescope. Mr. Barnard's estimate of their brightness in April was that they were equal to Jupiter's satellites when viewed with a glass of 1½-inches aperture. They are evidently easy objects to observe in the world's greatest refracting telescope.

Correction. On page 222 of the May MESSENGER, for the name of James G. Davidson, Professor Swift should have written James S. Lawson.

Intersecting Rainbows. The following interesting letter from John G. Hagen, S. J., College of the Sacred Heart, Prairie du Chien, Wis., under date of May 23, contains important observations for Hansteen's theory of intersecting rainbows:

The interesting note of Professor C. W. Prichett in your No. 65 on intersecting rainbows calls to my mind two observations of the same phenomenon, which, in compliance with the desire expressed in the article above mentioned, I gladly communicate to the MESSENGER, as follows:

In the year 1876, about spring time, two intersecting rainbows were observed at sunset by several of my friends, one of whom was professor of physics. The station of observation was Ditton Hall, near Widness, in Lancashire. Although I had not seen the phenomenon myself, there was no doubt as to the correctness of the statement.

The second observation I quote from my observing book: "Prairie du Chien, Wisconsin, May 13, 1886. Two rainbows intersecting above the southern horizon at 6*h* 25*m* P. M., the one being almost vertical, the other apparently corresponding to the altitude of the sun. The vertical branch disappeared a few minutes later."

In relating these facts in the class room, I used to mention that in the first case the Mersey between the observer and the rainbow, and in the second case the Mississippi between the sun and the observer, both rivers lying only some thousand feet from the place of observation, probably produced the secondary rainbows, by reflection of the sun's rays, although Hansteen's explanation published in 1823 was unknown to me until I saw Herr Geelmuyden's letter in your last number.

The Tangent Index. Professor John Haywood, Otterbein University, Ohio, has been for some time at work on an instrument called the Tangent Index, which is designed to explain the chief motions of the earth, and to furnish some help to those who are studying the elements of astronomy and wish to be occupied only with the most important of those relations. We have before stated the principles of the instrument, and now take pleasure in calling attention to a very neat little pamphlet the subjeet of which is the earth and its chief motions and the Tangent Index.

Wolsingham Observatory. Under date May 16, T. E. Espin announces, in Circular, No. 20, the observation of an 8.1 magnitude star on the nights of May 8 and 9, R. A. 20^h 41^m 7^s; Decl. $+44°24'$ (1855). The color of the new star is red; its spectrum is not continuous and it is not found in DM.

Map of Solar Spectrum. At the April meeting of the National Academy of Sciences, Professor Rowland of Johns Hopkins University presented two brief papers giving further studies on certain spectra. With new and improved instruments made at the university it is claimed that he has succeeded in making a much more perfect map of the solar spectrum than his former one. Definition of the lines is better, and some single lines have been divided. He also claims the discovery that carbon is much more widely distributed in the sun than has previously been known.

The Polemic Problem. If any person is interested in the bibliography of the Polemic problem, send to S. C. Gould, Editor of *Notes and Queries*, Manchester, N. H., and get his pamphlet of 32 pages wholly devoted to this theme. It gives a pretty correct idea, probably, of the immense labor expended in finding the value of π by the aid of Cyclometry, Quadrature and Rectification.

Ciel et Terre of Brussels (French), has in its May number, a full account of the Lick Observatory, with two page cuts, copies of those which appeared in the *Scientific American*. The subject matter of the article is credited to the SIDEREAL MESSENGER.

The Literary Magazine, April 14, has a very glowing account of the work of Dr. T. Sterry Hunt and that of Richard A. Proctor, at their respective places of residence near each other, on the banks of Orange Lake, at Oaklawn, Florida, It calls the former the "Darwin of Geology" and the latter the "Darwin of Astronomy."

Progress of Astronomy during 1887. At the April meeting of the Astronomical Society of France, M. C. Flammarion, president of the society, gave the address on the progress of astronomy for 1887. The survey of the present field of astronomical work was general with special reference to new features and new instruments.

Observations of Comet a 1888, by H. C. Wilson at Carleton College Observatory:

	Local mean time.	$\Delta\alpha$	$\Delta\delta$	No. of Comp.	Star.
	h m s	m s	′ ″		
May 18	14 38 00	+ 6 10.27	− 0 06.5	4, 4	1

α app.	l. f. p. α	δ app.	l. f. p. δ
h m s		° ′ ″	
0 03 11.67	9.710n	+35 11 12.5	0.667

ASSUMED PLACE OF COMPARISON STAR.

α 1888.0	Red. to app.	δ 1888.0	Red. to app.	Authority.
h m s	s	° ′ ″	″	
23 57 01.70	−0.30	+35 11 29.7	−10.7	Second Armagh Catalogue 3288.

A comparison of this observation with the ephemeris by Professor Boss in *Astronomical Journal*, No. 171, gives $(c-o)$ $\Delta\alpha = +3.1s$, $\Delta\delta = +25''$.

Pacific Earthquakes. Professor Holden of Lick Observatory, has recently prepared a list of recorded earthquakes in California, Lower California, and Washington Territory, as computed from published works and from private information. Especially the sources of information have been:

1. Printed lists of earthquake shocks in the scientific journals, such as the lists of Mallet, Perrey, Rockwood, Fuchs, Trask, and others.

2. Accounts of earthquakes in printed books, magazines, and newspapers.

3. Lists of shocks put at Professor Holden's disposition by various gentlemen; specially a list by Thomas Tennant of San Francisco, a list by Professor H. G. Hanks, and a very extensive collection furnished by H. H. Bancroft from manuscript records.

This valuable pamphlet of 78 pages of closely printed matter is the beginning of scientific work in this direction at the Lick observatory and the University of California. Instruments for accurate registration of earthquake shocks and tremors are now in use at other points, and systematic study of the regions west of the Sierras will follow.

Dearborn Observatory. In a recent letter from Professor Hough, we learn that all the astronomical instruments belonging to Dearborn Observatory have been removed to Evanston, the new site of the observatory. Plans for the new building have been adopted, and its erection was to begin about the first of May, but the 18½-inch equatorial will not be mounted before January, 1889. The meridian circle has been placed in a temporary building located 250 feet from the shore of Lake Michigan. Professor Hough says the lake seems to have no effect on nadir observations, at least, a moderate storm does not disturb the images perceptibly. In case of a gale, he thinks it is possible that tremors would be felt. The site of the new observatory is to be 250 feet from the lake shore.

Professor Hough is now arranging for the time service for Chicago from his new location.

The Large Dome for Carleton College Observatory. The 30-foot dome, built by Messrs. Warner & Swasey, of Cleveland, Ohio, is now being put in place at the new observatory of Carleton College, under the direction of Messrs. Lucas and Carr, employes of the above named firm. The troublesome problem of protecting the observatory building while the dome is being set in place has been mastered in a novel manner by Mr. D. H. Lord, builder of the observatory. The temporary flat roof which has been in the place of the dome for the last year, has been mounted on vertical supports, underneath which are placed a set of jack-screws by which the roof is raised and lowered morning and evening easily in a few minutes of time. So the work is progressing rapidly and safely, and probably will be completed before the middle of the present month. A cut and discription of this new building will probably be ready for the next number of the MESSENGER.

BOOK NOTICES.

The New Astronomy, Illustrated. SAMUEL PIERPONT LANGLEY. Ph. D., LL.D. Ticknor and Company, 211 Tremont Street, Boston. Royal Octavo, 260 pp. $5.00.

This beautiful popular work on Astronomy merits the highest praise for the artistic work of the publishers, and the value of its subject matter in the text and illustrations. The chapters are the Spots on the Sun, the Sun's Surroundings, the Sun's Energy, the Planets and the Moon, Meteors, Comets, and the Stars, together with an Index. The engravings are elegant in finish and are many of them derived from drawings made at Allegheny City.

It is one more argument to show that the masters of astronomy, in their own departments, are not only willing but most capable of instructing and delighting the public in these subjects, thereby rendering the work of compilers superfluous to the world as well as to the profession. There will be no risk in asserting that all students of the sun, moon and stars will find help in this volume in clarifying their ideas by means of these illustrations; for in fact the imagination is best instructed by seeing. We mention in particular the drawings of sun-spots. It should be also said that all students of Astronomy regret, as deeply as Professor Langley, the fact that we possess in the United States no great and well-equipped physico-astronomical observatory. That the Directors at Cambridge, Princeton and Allegheny have already secured results which make us proud as Americans, by dint of their personal ability, is no reason why this state of things should continue. We hope that the appeal contained in Professor Langley's volume will culminate in the foundation of such an Observatory worthy of our rank in Astronomical Science.

F. H. B.

Elements of the Differential and Integral Calculus, by SIMON NEWCOMB, Professor Mathematics in the Johns Hopkins University. New York: Messrs. Henry Holt & Co., publishers. 1887, pp. 307.

The author has written this book for the use of the undergraduate student in a course of arts or science, and he has chosen about the usual matter found in most good text books in this delightful branch of study now found in many

American colleges and special schools of science. He brings early to notice the troublesome question how the first principles of this science should be presented to the mind of the beginner. He claims that this should be done by laying down the logical basis on which the whole superstructure rests; that it is now well understood that the method of limits is the only rigorous basis for the infinitesimal calculus, and that infinitesimals can be used logically only when based on this method because they flow from it, if the theory has any true significance at all.

This statement of the case is a pretty strong one. It is fully as positive as any given by the friends of the theory of limits that we remember to have seen. If all that is claimed is true, and that only true, then the statement is not too strong; but if not wholly true with regard to the origin, theory, and use of the infinitesimal quantity, then the claim is more than unfortunate for the calculus. It seems to us that the theory of limits offers some difficulties in explaining the infinitesimal. In defining *limit* the author uses this language nearly:

"The limit of variable x is l, which we conceive x to *approach* in such a way that the difference, $l-x$, becomes less than any quantity we can name, but which we do not conconceive x to *reach*. An *infinitesimal* quantity is one considered in the act of becoming less than any quantity which we can name, that is, in the act of approaching zero as a limit."

Now, by the definition of limit, x cannot equal l, for x can only *approach l* as a *limit*. Also the *infinitesimal* cannot equal o, but can only *approach* it, because o is the *limit*. In explaining the elemental operations, the increment of x (Δx) is used, as an intermediate step, and then to obtain the infinitesimal, the statement is constantly made, "pass *to* the the limit" and then Δx becomes dx. This passing *to* the limit is impossible if the language of the definition be good. But the real question is, does Δx, in becoming dx, actually become o? If it does, then dx is not an infinitesimal, if o is the limit, and if o does not have more meanings than one. Whether o has more meanings than one or not, this is certainly true, that dx is o in relation to Δx, which is thought of as a small finite quantity. There are other inconveniences in the method of limits to say the least, in explaining the calculus which we constantly meet in the class room whenever we attempt a philosophical account of the origin of the infinitesimal quantity.

We like this book in many things. On every difficult point on which the student or teacher is likely to want knowledge he will find fresh help under the appropriate head. The applications of the differential calculus are full, varied, and well chosen.

The second part of the book is devoted to the integral calculus. Chapter first gives the elementery forms; the following chapter, those integrals immediately reducible to the elementary forms, and then integration by rational transformation; integration of irrational algebraic differentials; integration of transcendent functions, of definite integrals, and successive integration. The applications are rectificacation of quadrature and the cubature of volumes. The book is nicely printed, and there is as much calculus within the limits of 307 pages as the student will find anywhere probably.

Some Higher Plane Curves, by JOHN BORDEN, Chicago.

Under the above title, the author proposes to consider some of the higher equations by means of their deviations and the curves they generate, when the ordinate is taken to be the first power and the coefficients are real. By root he means the value of x when the second member of the equation is 0. It is thus seen to be a value of x in a special case.

The equation, $x^3+Ax^2+Bx+C=y$, if constructed for the successive real values of x would show each of two quite different figures. Now by use of a straight line it is evident that but one intersection with either locus can be made, if drawn according to certain suppositions imposed; by others three intersections are possible showing three real roots. Then by use of the diffierential coefficients between x and y which bring out the turning points and the law of the locus interesting results are made easily apparent.

The cubic, biquadratic and the fifth degree equation are discussed respectively and methods of obtaining real roots for each furnished.

This pamphlet of 75 pages will interest students of pure mathamatics.

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CONDUCTED BY WM. W. PAYNE,

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

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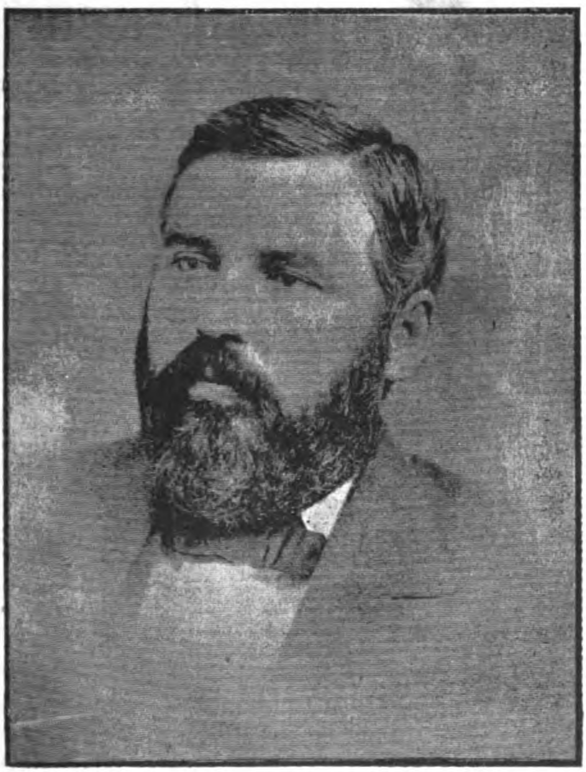

BIOGRAPHICAL MEMOIR OF JAMES CRAIG WATSON.*

PROFESSOR GEORGE C. COMSTOCK.†

At some unknown time, prior to the war of Revolution, the ancestors of James Craig Watson emigrated from Ireland to the colony of Pennsylvania. We know little of the fortunes

* Read before the National Academy, April, 1888.

† Director of Washburn Observatory, Madison, Wisconsin.

of this family before the early years of the present century, but they must, at that time, have been at a low ebb, for, in 1811, we find James Watson, the grandfather of the future astronomer, abandoning the land of his birth and pushing westward seven hundred miles to build for himself a new home in the almost unbroken forests of Upper Canada. The journey was made on foot. William, the father of James Craig Watson, then an infant of tender years, was placed upon an ox-sled which, slipping easily over the fallen leaves, bore the scanty household goods of the family.

They reached their destination in safety, and the work of clearing and cultivating was begun, but the times were unpropitious. Before the year had passed war was declared between the United States and Great Britain, and, Canada becoming the scene of hostilities, James Watson was compelled to abandon his farm for a time and to fly to the East for safety. Upon the return of peace he again took up his former residence, prospered in his labors, and was, at the time of his death, a man of wealth and consequence in the community which had grown up about him But this man's life was not devoted wholly to clearing up his homestead and increasing his acres; he possessed a taste for books and for learning, for the gratification of which he collected an excellent library whose appreciation and use he taught to his children.

Amid these surroundings William Watson grew to manhood, acquiring his father's tastes and learning, but not his energy and practical ability. At the age of twenty-six he married Rebecca Bacon, a native of Nova Scotia. Four children were the fruit of this union, of whom the oldest, James Craig Watson, was born near the villiage of Fingal, county of Elgin, Canada West, on January 28, 1838. The boy inherited a genial disposition and the taste for study which we have noted in his father and grandfather, but the restless and tireless activity which was displayed throughout his whole life, was clearly derived from his mother.

The first twelve years of his life were spent upon the farm in Canada, his father pursuing by turns the occupations of farmer, carpenter and schoolmaster, and instructing his children, three sons and a daughter, in that measure of book lore which he himself had acquired. But affairs went ill with William Watson, and, in 1850, he found himself compelled to abandon his home and seek elsewhere a livelihood for himself and family. He turned westward, not knowing where his foot should find a resting place, but resolved to leave Canada. Arriving in Detroit, Mich., the family found its choice of a home limited to the villages along the single line of railway that then extended west a scanty hundred miles from Detroit. A chance remark made by a stranger, that the State University was situated at Ann Arbor on this line of railway, only forty miles distant, determined the choice. A vague idea that perhaps her children might derive some educational advantages from it seems to have been in the mind of Rebecca Watson, and the decision was made by her.

The family reached Ann Arbor penniless and more destitute than that ancestor who, forty years before, had emigrated to the frontier of Canada. The father found work in a small factory, and James, now a bright boy of twelve years, was employed in various menial offices at the same place. The following years were years of bitter poverty and want, and they left their imprint deep upon the after life of James Watson; but they were also years of development. He quickly learned the work of the factory and noted the incompetence and faithlessness of the man in charge of the steam engine, which he reported to his employer. "I know, Jimmy, the man ain't worth his salt, but he is the only one I can get for the job." "I can run the engine, sir," was the reply. "Oh, no, Jimmy, you don't know how to manage an engine." "But I do;" and the dispute was settled by going to the engine room, where Jimmy satisfied his employer that he did understand the engine. The incompetent man was forthwith discharged and the boy of thirteen became engineer of the factory.

Here he had some chance for study, and a Latin or Greek text-book was kept in a convenient corner and brought out for use whenever a few minutes could be spared from work. In the following winter the factroy was closed and Watson was reduced to the necessity of peddling apples and books at the railway station, an occupation which was exceedingly distasteful to him. As spring approached he disappeared, and for a fortnight nothing was heard from him, until his former employer, who had become much interested in the boy, found him in Detroit, where he had made a bargain with the master of a vessel to go sailing with him in the lake trade, and was to have started on the following day. He was induced to return home, and soon after it was resolved that he should attend school, but at the end of the first half day the relations of teacher and pupil were interchanged; the boy withdrew from school, and the master came to him for instruction in algebra and geometry.

During the next two years Watson's employment was of a desultory character. There were vague hopes that he might at some time enter the University, and he therefore pursued by himself the study of Latin and Greek; but he also worked successively at nearly all the trades that were practiced in the village, becoming a competent workman at most of them, and acquired special skill as a machinist. It was noticeable that during this period he avoided association with boys of his own age and sought the companionship of men, with whom he would discuss topics of current interest, entertaining them with jests and with exhibitions of expert penmanship or of skill in arithmetical operations.

At the age of fifteen Watson entered the University of Michigan as a student, and soon attracted attention for the excellence of his scholarship in every direction. For the classical languages he displayed unusual capacity, and his now venerable instructor, Dr. Frieze, bears witness that "his facility in translation was greater than that of most professors of Latin and Greek;" and the writer of this sketch well remembers the enthusiasm with which he was wont in his later years to refer to his study of the ancient tongues.

The man who, during Watson's university career, exercised the greatest influence over his development was, probably, Francis Brünnow, who had been recently called to the chair of astronomy and the directorship of the new observatory. Brünnow introduced into a Western college the methods of a German university, and lectured in broken English to despairing and dwindling classes until Watson remained his only pupil. He became interested in astronomy early in his college course, and in his junior year began work in the observatory. The theoretical and practical sides of the science seemed to have equal charms for him, and his attention was divided between the *Mecanique Celeste* and the construction a refracting telescope. His mechanical talent and the training of the machine shop triumphed over the difficulties of the latter and produced an excellent instrument of four inches aperture, the grinding and polishing of the glass and the constructing of the mounting being all done by his own hands. Nor was his work of a purely empirical character. There exists now, in Watson's hand writing, a long manuscript translation from *Prechtl's Dioptrik* upon the theory and construction of achromatic objectives, and bearing at its close the signature and date, James C. Watson, January 8, 1857. He was then nineteen years of age.

Watson graduated in 1857 and almost immediately thereafter commenced work in the observatory as a salaried assistant. His earliest contribution to a scientific periodical which I have been able to find appears in Vol. V. of Gould's *Astronomical Journal* and bears the date of April 20, 1857. His great activity at this time is shown by the index to this same volume, which contains under his name the titles of no less than fifteen papers, all published before he had completed his twentieth year.

In 1859 Brünnow resigned his chair in the University of Michigan to assume the directorship of the Dudley Observatory, and Watson was elected Professor of Astronomy and took charge of the observatory, but without the title of director. In 1860 Brünnow returned to Ann Arbor and was re-elected to his former position, Watson being transferred to the chair of physics, which he held until 1863, when, Brünnow again resigning, he was chosen to be Professor of Astronomy and Director of the Observatory. The records of the board of regents of the university show that this appointment was made upon the recommendations of B. A. Gould, Elias Loomis, William Chauvenet, Benjamin Peirce, Joseph Winlock, J. M. Gilliss, and others. In the manly communication to the governing board of the university, in which Watson presents his application for appointment to the directorship and sets forth his qualifications for the position, he states that, in addition to the discharge of the duties which his instructorship in the university entailed upon him, he had prepared and published thirty-two original papers upon astronomical subjects. An examination of his contributions to the periodicals shows that this activity was mainly expended in work upon comets and the minor planets. There are numerous communications containing observations and computations of orbits and ephemerides, and an occasional paper of a theoretical character upon the determination of orbits. To this period of his life belongs his "Treatise on Comets," a work of a popular character, to whose preparation he was incited by the interest aroused by the great comet of 1858.

In May, 1860, he married Annette Waite, of Dexter, Michigan, who, during the remaining twenty years of his life, maintained a constant interest and partial co-operation in his scientific work. No children were born to them.

Early in the '60's Watson became interested in the reduction of the Washington Zones, which had been undertaken by Dr. Gould, and for several years a considerable part of his time was given to computation upon this work. As a computer he possessed extraordinary skill and rapidity, attested at a later period by the computation of elliptic elements of a planet's orbit at a single sitting. The possession of this skill perhaps acted injuriously upon the character of his scientific work, as it led him to give much of his time, as a paid computer, to work which others of inferior talent could have done equally well, though less rapidly.

Immediately after his appointment to the directorship of the observatory Watson begun the preparation of a series of charts of stars lying near the ecliptic, and his reports upon the work of the observatory during the following ten years represent this as being his principal employment, and dwell upon its laborious character. But scant traces of this work can now be found in the records of the Ann Arbor Observatory. The charts which he prepared have become the property of the National Academy of Sciences and are deposited at the Washburn Observatory of the University of Wisconsin. Of these charts, nineteen in number, only two are finished. They are in their general plan similar to Peters's well known charts, but are far from being equally complete. The discovery of the minor planets, with which Watson's name is associated, was a direct consequence of this work; indeed the expectation of such discoveries was probably the incentive to it. His first planet, Eurynome (79), was found in 1863, only three weeks after his election to the directorship of the observatory. Four years elasped before another was found, but during the ensuing years they came in rapid succession. In all, twenty-two of these bodies were discovered by him, the year 1868 alone contributing six to the list, at that time an unprecedented feat. The Lalande prize, decreed to him July 11th, 1870, by the *Academie des Sciences*, was the reward of his earlier labors in this field.

The composition of his treatise upon *Theoretical Astronomy* belongs to the earlier years of his directorship and stands in close relation with his work as a computer and observer of the minor planets. The completion of this treatise, which appeared when he was but thirty years of age, left Watson's hands free for other work, and in 1869 he became associated with Benjamin Peirce in work upon the improvement of the lunar tables. For five years he was engaged in a comparison of the theories of Hansen and Peirce with observation, and spent much time in the endeavor to simplify Hansen's tables, with results which, though satisfactory to himself, were never published and are now lost.

The eclipse expeditions to Iowa in 1869 and to Sicily in 1870 interrupted the continuity of his work, and in 1874, when he accepted charge of the transit of Venus party to China, it was dropped, never to be resumed. The charge of this expedition was Watson's most important scientific commission. In a letter written to Benjamin Peirce, in 1873, he had, in opposition to LeVerrier's well-known views, expressed the opinion that the transit of Venus should be observed by astronomers as extensively as possible, and that every device known to science should be brought to bear upon these observations for the determination of the solar parallax. It is interesting now to note that in this letter he expresses the opinion that observations of contacts and measurements with the heliometer will be found to give a much more trustworthy determination of the parallax than can be obtained by the photographic method, but he joins to this the statement that the photographic method ought to be thoroughly tested.

Watson undertook the conduct of the expedition to China deeply impressed with the responsibility which it imposed upon him, and the last six months of 1874 were among the most laborious and oppressive of his life. It was, therefore, with a sense of profound relief that he saw this period of arduous labor crowned with the success of his party in the observation of the transit at Peking. It is interesting to note that on October 10, 1874, at Peking, he discovered the minor planet Juewa (139). The return from China was made leisurely *via* India, Egypt, and Europe, several weeks being spent in Egypt, at the invitation of the Khedive, in instruction and co-operation with the engineer officers of the Egyptian army in the first steps toward a geodetic survey of that country. This work, performed by Watson without pecuniary compensation, won for him the cordial thanks of the Khedive and the decoration of Knight Commander of the Imperial Order of the Medjidich of Turkey and Egypt.

Close following upon Watson's return to America came his appointment as one of the judges at the International Centennial Exposition of 1876, in connection with which he prepared an elaborate report upon the horological instruments there exhibited.

The year 1878 brought a new subject, which engaged much of Watson's attention during the few remaining years of his life. He had corresponded with LeVerrier about the supposed planet Vulcan, and believed firmly in its existence, and, at LeVerrier's request, had co-operated with him in securing observations of the sun's disk at the times of expected transits of the planet. The eclipse of 1878 offered a favorable opportunity of search for this body, of which he eagerly availed himself, and mounted his telescope upon the crest of the Rocky Mountains at Separation, in Wyoming Territory. We need not here recount the details of the observations which led to the announcement of the discovery of two new bodies supposed to be intra-mercurial planets, since Watson has himself given an account of these in the *American Journal of Science* and in the *Astronomische Nachrichten*. Suffice it to say that he returned home firm in the conviction that he had discovered the unknown Vulcan and, perhaps, another planet as well. Uncertainty as to the latter object soon gave away to confidence that both the bodies seen by him must be major planets moving within the orbit of Mercury. The scientific world was skeptical, but he would convince it that its lack of faith was unwarranted.

The directorship of the new observatory founded at Madison, Wisconsin, by the liberality of ex-Governor Washburn had before this been offered him, but he had hesitated, unwilling to leave the surroundings in which the greater part of his life had been passed. But the scale was now turned, and the promised superior equipment of the new observatory carried him to a new home, confident of speedily demonstrating the reality of his discoveries.

He removed to Madison and entered upon the directorship of the Washburn Observatory in the spring of 1879. The observatory was then far from complete; its large equatorial was mounted, but was its only instrument, and Watson's energies were spent, even to the last hours of his life, in designing and superintending the construction of new buildings and new apparatus. In the midst of this activity time was found for a return to the problem of telescope-building, which had occupied his student days. Optical glass was procured and plans laid for the construction, under his personal supervision, of several objectives which were to embody his own ideas upon this art, and work was actually commenced upon one large reflecting telescope. But no stress of other work or other interests could displace Vulcan from his mind. A scheme was devised whereby he should be able to observe the planet at noon-day without the intervention of an eclipse. The hill upon which the observatory stands slopes sharply to the south. At the foot of this hill was dug a deep cellar with a tube extending from it through the soil, parallel to the earth's axis and terminating in a masonry pier at the top of the hill. A telescope was to be so mounted in the celler as to point up through the tube to a heliostat mounted at its upper end, by which rays of light coming from the sun or other celestial body might be directed into the telescope. The tube, fifty-six feet in length, was to serve as a long dew-cap and enable the observer to sweep close up to the sun's limb without being blinded by the stray light surrounding it. So confident was Watson of the success of this device, and that by its aid

Vulcan could be refound, that he did not hesitate to undertake its construction at an expense to himself of several thousand dollars.

He did not live to see its completion, nor the fruition of any of the plans which he had formed for the observatory. Signs, more easily recognized after his death than at the time of their occurrence, pointed to a diminishing vitality and to a weakening of his physical powers. There was, however, no diminution of an activity which exposed him daily to the inclemencies of an approaching winter, and his rotund figure and ruddy face seemed to give little cause for apprehension. Stricken down by a congestive chill, from which he partially rallied and then relapsed, he died November 22, 1880, within forty-eight hours after the suspension of his ordinary daily work.

Watson's scientific work was far from being the measure of his life, and any estimate of his career which did not take into account other sides of his character would be far indeed from the mark. The stern experiences of his boyhood had stunted the growth of qualities which a more genial lot might have developed in him, and in estimating his character as a man this early training must not be overlooked. It had taught him the value of money, and he eagerly sought its acquisition as a source of power. He engaged in business enterprises, and became an insurance agent, a photographer, a bookseller, a printer and publisher, and an insurance actuary, with moderate pecuniary success, but with the result of acquiring a peculiar power and influence over men of affairs, which he used to the marked advantage of the educational and scientific institutions with which he was connected.

The subject of life insurance early attracted his attention and interest, and for nearly half his life he was engaged in its practical workings. I cannot do better than quote in this connection the words of one of his colleagues in the University of Michigan, Hon. Thomas M. Cooly, long upon the supreme bench of that state. "Few knew so well as I did the valuable services he rendered to the people in placing the great interest of life insurance upon a solid foundation. He understood thoroughly the principles of this business and was impatient that irresponsible organizations, by deception and fraudulent contrivances, should draw money from the people under the false pretense of insuring their families against loss by death. He thought, too, that there should be home organizations, whereby the vast and steady flow of money from the state should be stopped, and the accruing profits from insurance retained and expended among our own people. When, at last, such an organization was perfected he was invited, quite unexpectedly to himself, to be its actuary, and so invaluable have his services been found that his judgment has come to be accepted as law by the able business men who have been at the head of its affairs. * * * Some of us had personal knowledge that more than one state legislature invited his assistance in framing insurance laws, and that he had large influence in preventing crude and mischievous legislation on a subject with which the general public is unfamiliar, and concerning which those who think they know it well are generally the most profoundly ignorant."

There lies before the writer of this sketch a letter from the secretary of the company whose actuary Watson was, confirming this estimate of his services and attributing the success of the company largely to his influence. Watson's long connection with insurance matters led, in his later years, to the preparation and publication of extensive tables—his Interest and Investment Tables—for facilitating commercial and financial computations.

As a college professor Watson had great popularity among his students, but it was not a popularity of the best kind. His class-room work was conducted upon the avowed theory that his duty was to help those who sought a knowledge of astronomy and not to coerce into study the indifferent and careless. The latter class flocked in great numbers to his lectures and were delighted with the fluency and easy grace which imparted a charm to his discourse, and which carried them over the allotted ground with little expenditure of time or thought. Watson's instruction was mainly given by lectures, and the felicity of his discourse cannot be better illustrated than by a scene which will not readily pass from the memory of those who witnessed it. He had been summoned as an expert witness in an action to recover the insurance on a building destroyed by a tornado, and was to testify in regard to the laws of storms. The examination began in the usual dry and formal manner, by direct question and answer, but the questions grew fewer and the answers longer until, their surroundings forgotten, judge and jury, attorneys and spectators, sat listening to a popular exposition of the science of meteorology, going far outside the scope of the case at bar.

Watson was singularly indifferent to the opinions of the community in which he lived—an indifference rendered the more remarkable by the fact that he took a lively interest in local affairs and local controversies. He had bitter enemies and they circulated reports, to the discredit of his personal character, which went uncontradicted and gained undeserved credence. It cannot be denied that a measure of truth attended many of these statements, but they were habitually distorted and magnified out of all proportion. He wished his life and character to be estimated by the world at large. His scientific reputation he valued more highly than local esteem. "Let that be established," he was wont to say, "and opinion here will fall in with it"—a view partly, but not entirely, justified by the event. Within the circle of his own family he was a generous man, and in his college relations his pre-eminent abilities were freely placed at the service of such of his colleagues as needed them. For the ordinary forms of social intercourse he had no taste, and held himself aloof from them, giving to his work hours that others spent in recreation, thus crowding more of achievment into the years of his life, but in the judgment of his friends, lessening their number.

Watson was elected a member of the National Academy of Sciences in 1868, and by his will the National Academy was made the residuary legatee of his estate, which is "to be aggregated, kept, and invested as a perpetual fund, the income fiom which shall be expended by said academy for the promotion of astronomical science." The academy has accepted this trust, and administers it in accordance with the following provisions of the will:

"In order to carry out the wish hereinbefore expressed as to the disposal of the income from the fund resulting from my estate hereby devised to said National Academy of Sciences, I do hereby direct that the designation ofthe particular objects and works which may be aided by this fund shall be determined, subject to approval by a vote of the academy, by a board of trustees, three in number, who shall be members of the academy, and elected after the first herein named by said academy whenever a vacancy may occur, by death or otherwise. The trustees so appointed shall hold said office unless voluntarily relinquished by them during the period of their membership in the said National Academy of Sciences, and I do hereby appoint and constitute *Julius E. Hilgard*, of the United States Coast Survey, and *Simon Newcomb* and *J. H. C. Coffin*, professors of mathematics, U. S. Navy, all of Washington, in the District of Columbia, to be the first board of trustees for the purposes herein named.

"It is my wish that the academy may, if it shall seem proper, provide for a gold medal of the value of one hundred dollars, to be awarded, with a further gratuity of one hundred dollars, from time to time, to the person in any country who shall make any astronomical discovery or produce any astronomical work worthy of special reward as contributing to our science. It is my further wish that provision be made for preparing and publishing tables of the motion of all the planets which have been discovered by me as soon as it may be practicable to do so; and I desire that in all cases the trustees and the academy shall act in harmony to obtain results of greatest possible aid to our science from the income fund resulting from my estate. I desire that results so obtained shall be published as speedily as possible in such manner as may be provided by the academy."

The amount of the fund, principal and accrued interest, was, in April, 1886, a little less than $15,000. The medal provided by the will was awarded but once. At the April, 1886, meeting of the National Academy it was, at the recommendation of the board of trustees of the Watson fund, "*Resolved*, That the Watson medal and the further sum of $100 in gold be awarded to Dr. Benjamin Apthorp Gould for his valuable labors for nearly forty years in promoting the progress in astronomical science, and especially for his successful establishment of the National Observatory of the Argentine Republic, as manifested in the six volumes of observations recently prepared and published by him."

I close this brief sketch of Watson's life with a list of his more important published works, omitting the numerous observations, ephemerides, and notices of the discovery of minor planets which are contained in the astronomical periodicals. In lieu of the latter there is appended a list of twenty-two planets discovered by him, together with the dates of their discovery.

A List of the more important Public Writings of James C. Watson.

On the Extraction of Roots: *Michigan School Journal* (1859).

On the Orbit of Pandora (55): *Brunnow's Astron. Not.*, vol. i., p. 59.

On the Orbit of Hestia (46): *Brunnow's Astron. Not.*, vol. i., p. 121.
A Popular Treatise on Comets: *Philadelphia*, 1861.
Correction of the Elements of the Orbit of a Comet: *Am. Jour. Sci.*, 1863, p. 218.
Investigation of the Orbit of Eurynome (79): *Astr. Nachr.* vol. lxiv., col. 23.
Theoretical Astronomy relating to the Motions of the Heavenly Bodies around the Sun in accordance with the Law of Universal Gravitation: *Philadelphia*, 1868.
Horological Instruments. United States International Exhibition, 1876. Reports and Awards. Group xxv., p. 56: *Washington*, 1880.
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List of Minor Planets discovered by James Watson.

No.	Name.	Date of Discovery.	No.	Name.	Date of Discovery.
79	Eurynome..	1863, Sept. 14	121	Hermione.........	1872, May 12
93	Minerva.....	1867, Aug. 24	128	Nemesis...........	1872, Nov. 25
94	Aurora.......	1867, Sept. 6	132	Æthra.............	1873, June 13
100	Hekate.......	1868, July 11	133	Cyrene.............	1873, Aug. 16
101	Helena.......	1868, Aug. 15	139	Juewa..............	1874, Oct. 10
103	Hera..........	1868, Sept. 7	150	Nuwa..............	1875, Oct. 18
104	Klymene....	1868, Sept. 13	161	Athor...............	1876, April 16
105	Artemis......	1868, Sept. 16	168	Sibylla.............	1876, Sept. 28
106	Dione.........	1868, Oct. 10	174	Phædra...........	1877, Sept. 2
115	Thyra........	1871, Aug. 6	175	Andromache.....	1877, Oct. 1
119	Althæa.......	1872, April 3	179	Klytæmnestra..	1877, Nov. 11

THE ANNUAL MOTION OF THE EARTH.

PROFESSOR JOHN HAYWOOD.*

FOR THE SIDEREAL MESSENGER.

To assist elementary pupils in geography and astronomy we make use of the artificial globes, terrestrial and celestial, and find them indispensable. By the aid of these the pupil acquires correct ideas of the form of the earth and its diurnal motion. Then, with sufficient thought and attention to the phenomena of day and night, of the rising and setting of the sun, moon and stars, he is able to place his knowledge, and can assure himself of the reality of the knowledge he has been acquiring.

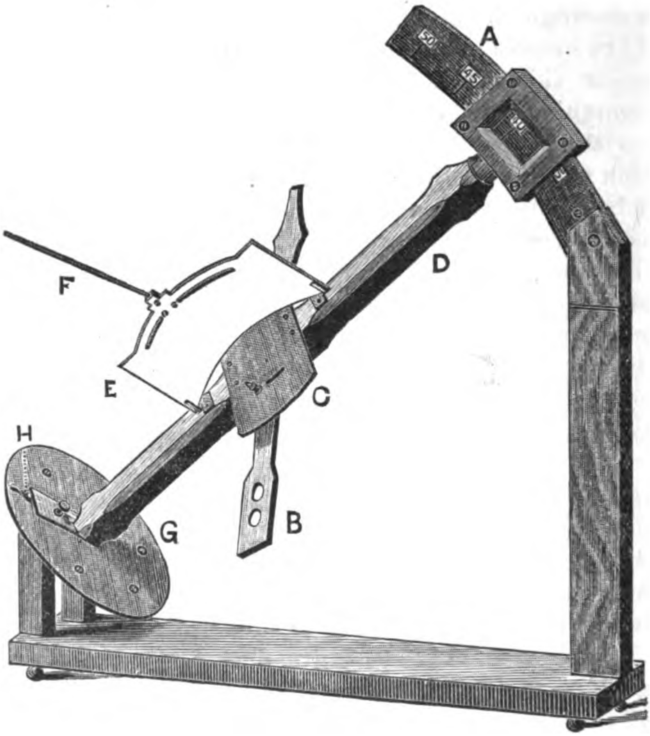
So, by the aid of the orrery and the like apparatus, a gen-

* Otterbein University, Westerville, Ohio.

eral idea of the situation of the earth in the solar system is acquired, and its relation to the sun and other planets. But it is not so easy to place the facts as they are learned and recognize them as he looks out upon the heavens. The difficulty springs from the fact that we must study the orbital motion from one position on the earth; and, therefore, we must distinguish between the effects of the diurnal rotation and the annual motion. The astronomer readily learns to overcome this difficulty for himself. But the teacher wants something that shall assist him to present the annual motion, with the readiness, the certainty, the completeness, with which the globe presents the form and diurnal motion.

It will be readily seen that one reason why the diurnal motion is more readily comprehended by the pupil is that the horizon does not change its position with respect to the axis of the earth; and the proposition that the earth turns on its axis towards the east, he soon is able to verify by his own observations. On the other hand, the horizon is continually changing its position in relation to the direction of the earth's motion in its orbit. This direction coincides with the tangent to the orbit. What is wanted, therefore, is an instrument which will readily and certainly show the tangent in its true position, whatever be the true position of the horizon. This is accomplished in the tangent index by combining a movement like that of the equatorial telescope about the terrestrial axis with a system of geocentric coördinates peculiar to the tangent. These are, first, the inclination of the tangent to the plane of the equator. This is the tangent declination. Second, the diedral contained between the planes of the two hour circles, viz., the hour circle of the sun, and the hour circle which contains the tangent. This diedral I have heretofore named the tangent hour angle. But Professor Young has expressed his disapproval of this use of the term, hour angle, as leading to confusion in its more legitimate use. Therefore, in deference to him, I now suggest the name, sun-tangent-equatorial angle, or, more shortly, sun-tangent angle. These two coördinates are computed and tabulated for use. There is also what may be called a local coördinate, the solar hour angle, or the true solar time of day, which, of course is to be taken from the ordinary clock or watch. The mathematical analysis of the index with its formulas is omitted here; as this was given in full with the tables in the SIDEREAL MESSENGER for November 1886.

The cut represents the tangent index, and one can easily from it obtain a pretty good idea of the manner of using it.



THE TANGENT INDEX.

A, Latitude arc. B, Tangent index. C, Tangent declination arc. D, Axis of the earth. E, Solar declination arc. F, Radius vector. G, Time circle. H, Time index and solar tangent equatorial arc.

The instrument is to be placed upon a horizontal table, and in the meridian, with the elevated end to the north. The north end of the axis is to be placed at an angle of elevation equal to the latitude of the place. This places the axis parallel to the earth's axis. The two axis may be considered coincident, with the center of the instrument at the center of the earth. Set the tangent at the declination for the date, also set the sun tangent angle for the date. Then turn the instrument on its axis until the time index points to the true solar time of day. The tangent index is now coincident with the tangent to the earth's orbit, and it points in the direction of the earth's motion in space. Also by keeping the time index in place by moving forward to the proper time, the index will continue to point in the same direction in space. Thus by this instrument we eliminate the perplexing diurnal motion and exhibit the direction of the annual motion pure and simple.

THE TANGENT INDEX TABLE FORMULAS AND DEMONSTRATION.

Table of Declinations and of Hour Angles.

The declinations are found in column D. The sign of any date is found at the head and foot of the column containing the date, + means north declinations, − means south declinations. H is the hour angle. There are two columns of H, and each of these has two columns of corresponding dates:

	H		D.		H	
−		+		−		+
March 20....	90° 0′	Sept. 23.....	23°27′	March 20...	90° 0′	Sept. 23
March 25....	89 11	Sept. 27.....	23 22	March 15....	90 49	Sept. 18
March 30....	88 21	Oct. 3.......	23 6	March 10...	91 39	Sept. 13
April 4.......	87 35	Oct. 8.......	22 39	March 5...	92 25	Sept. 8
April 9.......	86 53	Oct. 13.......	22 1	March 1...	93 7	Sept. 3
April 14.......	86 17	Oct. 17.......	21 14	Feb. 24......	93 43	Aug. 28
April 19.......	85 46	Oct. 22.......	20 19	Feb. 19......	94 14	Aug. 23
April 24.......	85 24	Oct. 27.......	19 13	Feb. 14......	94 36	Aug. 18
April 29.......	85 10	Nov. 1......	18 0	Feb. 9......	94 50	Aug. 13
May 4.......	85 4	Nov. 6......	16 40	Feb. 4......	94 56	Aug. 8
May 9.......	85 6	Nov. 11......	15 13	Jan. 31.......	94 54	Aug. 3
May 14.......	85 17	Nov. 16......	13 40	Jan. 26.......	94 43	July 29
May 19.......	85 36	Nov. 20......	12 2	Jan. 21.......	94 24	July 24
May 24.......	86 8	Nov. 25......	10 20	Jan. 16	93 52	July 19
May 29.......	86 34	Nov. 30......	8 34	Jan. 12.......	93 26	July 14
June 3........	87 12	Dec. 4.......	6 46	Jan. 7.......	92 48	July 9
June 8........	87 55	Dec. 9.....	4 55	Jan. 2.......	92 5	July 4
June 13........	88 42	Dec. 14.......	3 2	Dec. 29.......	91 18	June 29
June 18........	89 30	Dec. 19.......	1 9	Dec. 24.......	90 30	June 24
June 21........	90 00	Dec. 21.......	0 0	Dec. 21.......	90 00	June 21
−		+		−		+

Attention should be called to another feature of the cut, the radius vector and the solar declination arc. If the radius vector be adjusted for declination, and the plane of the arc be adjusted to coincide with the time index, the vector will point to the sun wherever it be in the heavens; that is at any hour of the day or night. Also the plane of the vector and tangent coincides with the plane of the ecliptic. We have therefore at the same time the relation of our horizon to the ecliptic.

Again we may conceive the radius vector as prolonged to the sun, and then extended still further 92,000,000 miles beyond the sun. This gives us a diameter of the earth's orbit, and the remote extremity is the place of the earth six months ago, or six month hence. Let us now conceive an index attached to that extremity of the diameter, parallel to the tangent index, but reversed, and it is readily seen that it represents the direction in space of the earth's motion in the oppósite part of its orbit, and at six months distance in time.

The full comprehension of the facts illustrated by this instrument, will still require thought and study. Illustrative apparatus cannot do away with these; but it may relieve the mental strain, and help it to a successful issue.

THE DISTANCES OF DOUBLE STARS.

BY W. H. S. MONCK, DUBLIN.

For The Messenger.

The difficulty of obtaining accurate measures of the stellar parallax, especially when very small, renders any approximate method of arriving at the same result of considerable interest. In the case of a binary system whose orbit has been computed, I need hardly say that if the mass of the system was known the parallax might be inferred. Doubts no doubt exist at present as to many of these computed orbits; but, unlike the measurements of parallax in which the later are necessarily improvements on the earlier, further observation is certain to remove (in time) all differences as to the orbit. If, under these circumstances we could make any reasonable assumption as to the mass of the system, the parallax and distance could be immediately inferred; and it is to be noted that the mass varies inversely as the cube root of the parallax, so that the latter will only be halved if the former is increased eight-fold. The most natural assumption to start with is that the mass of the system is equal to that of the sun (or rather the solar system). No known system seems likely to exceed or fall short of this in a degree exceeding eight to one; consequently, if the orbits are correctly computed, the parallaxes arrived at by this method are not likely to be more than double, or less than half, the true parallaxes; and even this degree of approximation is by no means devoid of value. The parallaxes arrived at by this method I venture to designate equivalent parallaxes; and, as the orbits of several binary stars have been differently computed by different astronomers, I give in each case the name of the astronomer whose orbit I have adopted. The following table contains forty-two binaries whose equivalent parallaxes are given. Most of these are small, and I hope to show on a future occasion that the average parallax of other binaries or double stars is still smaller.

	BINARY STAR.	COMPUTER OF ORBIT.	EQUIVALENT PARALLAX.
1.	α Centauri	Doberck	0.928″
2.	Sirius	Colbert	*0.623
3.	η Cassiopeiæ	Grüber	0.257
4.	70 Ophiuchi	Gore	0.228
5.	40 o² Eridani	Gore	†0.223
6.	ξ Boötis	Doberck	0.192
7.	ξ Ursæ Majoris	Duner	0.165
8.	6 Eridani	Downing	0.128
9.	ζ Herculis	Doberck	0.127
10.	γ Virginis	Thiele	0.125
11.	γ Comæ Australis	Gore	0.100
12.	τ Cygni	Gore	0.083
13.	85 Pegasi	Gore	0.080
14.	2173 Σ	Dunér	0.079
15.	η Coronæ Borealis	Doberck	0.076
16.	Castor	Thiele	0.076
17.	ζ Sagitarii	Gore	0.075
18.	42 Comæ Berenices	O. Struve	0.075
19.	44 ι Boötis	Doberck	0.075
20.	σ Coronæ Borealis	Doberck	0.066
21.	3121 Σ	Doberck	0.064
22.	ξ Scorpii	Doberck	0.060
23.	ζ Cancri	Doberck	0.058

* Latest measure, 0.380. † Latest measure, 0.223.

	BINARY STAR.	COMPUTER OF ORBIT.	EQUIVALENT PARALLAX.
24.	3062 Σ	Doberck	0.058
25.	ζ Aquarii	Doberck	0.055
26.	298 *O* Σ	Doberck	0.053
27.	β Delphini	Gore	0.052
28.	235 *O* Σ	Doberck	0.051
29.	1757 Σ	Gore	0.048
30.	δ Cygni	Behrmann	0.042
31.	ω Leonis	Doberck	0.036
32.	γ Leonis	Doberck	0.036
33.	γ Coronæ Borealis	Doberck	0.034
34.	τ Ophiuchi	Doberck	0.033
35.	λ Ophiuchi	Glasenapp	0.030
36.	36 Andromedæ	Doberck	0.031
37.	1819 Σ	Casey	0.030
38.	4 Aquarii	Doberck	0.028
39.	φ Ursæ Majoris	Casey	0.023
40.	234 *O* Σ	Gore	0.020
41.	400 *O* Σ	Gore	0.019
42.	14 Orionis	Gore	0.037

The intensity of illumination might, perhaps, enable us to conjecture whether the equivalent parallax was in excess or defect of the true parallax, and this intensity can be easily collected from such works as the *Harvard Photometry*. But there is a preliminary question not so easily disposed of. Supposing the density and illumination for each unit of surface to be constant, great brightness would indicate a smaller mass and larger parallax than that assumed by me; since the smaller the mass the greater will be the proportion which the illuminated surface bears to it. But, on the other hand, there seems reason to think that large stars are at a higher temperature and give more light per unit of surface than smaller ones; and if this is carried far enough to counterbalance the greater (proportional) extent of surface, great brightness must be regarded as a mask of greater mass and smaller parallax than is supposed in the table. The greatest brightness occurs where we should scarcely expect to find it on either hypothesis. Thus γ Leonis gives fully ten times as much light relatively to its equivalent parallax as Sirius, which in its turn is much brighter than α Centauri.

ON TELESCOPES OF SHORT FOCAL LENGTH.

PROFESSOR H. L SMITH.*

For THE MESSENGER.

I have more than once, in this journal and elsewhere, tried to say a word in favor of a considerable reduction in the focal length of the achromatic telescope. The usual ratio of about 15 to 1 for moderate sized telescopes, and 19 to 1, as in the Lick telescope, necessitates a dome of such size, and also the equatorial stand, that the mere cost of these is quite as much as, or more than, that of the telescope itself; and machinery to enable an observer to reach the eye end of the the telescope at different altitudes is always more or less troublesome. Tolles and Byrne each made for me a telescope 4¼ inches aperture, and about thirty-seven inches solar focus. The performance of these was entirely satisfactory. It is sufficient to repeat what I have before said. They would show all that any telescope of the same aperture would show, and, to say the least, equally well, and were as free from color.

Later Mr. Clacey of Boston made for me a telescope of 42 inches focal length and $4\frac{15}{32}$ inches aperture. This instrument proved to be in every respect the equal of any having the same aperture but usual focal length, and, with the others, was vastly more convenient to handle. With this telescope I made the following measurements of double stars, using a spherical rock crystal micrometer, differing, however, from Dolland's in having the sphere as field instead of eye lens. I need not enter into details of construction, but, as it was a repeating instrument, allowing any number of measurements to be taken, and with great rapidity with only two readings, and requiring no illuminating apparatus, and gave powers of about 175 and 300, with fine definition of the so-called spurious disks, I think the measurements of distance made with it would have probably as much accuracy as could be obtained by the best spider-line micrometer. The value of the scale as used in the Clacey telescope was determined by a great number of measurements of the apparent diameter of Venus in the months

* Hobert College, Geveva, N. Y.

of June and July last. Having determined the maximum value of the angle (when the sphere was rotated 45°), and calling this (r) the value for any other angle (θ) was determined from the formula: $\zeta = r \sin 2\theta$.

The stars in the following list which are not binary stars were measured simply as checks, and, as it is my first essay in this kind of work, I cannot claim any especial accuracy.

The position angles are really much more difficult to be observed correctly than might at first appear. The components must not only be in the exact center of field, or very near it, but should bear the test of rapid change from side to side repeatedly without being thrown out of straight line. Such as they are I give them below, and they will at least show the optical capacity of the telescope. The measurements were all made in the months of June and July, 1887:

	APPROX. A. R.	DEC.	POS.	DIST.
	h m	° ′	°	″
γ Virginis	12 36	− 0 50	338.96	6.12
Σ 1835, XIV. 69	14 18	+ 8 59	189.00	6.79
π Boötis	14 35	16 58	105.03	6.53
ε Boötis	14 40	27 32	327.79	2.47
ξ Boötis	14 46	19 33	259.60	3.02
λ Ophiuchi	16 25	2 14	41.05	1.38
ζ Herculis	16 37	31 48	87.50	1.44
α Herculis	17 09	14 31	116.47	4.99
ρ Herculis	17 20	37 15	311.66	3.73
95 Herculis	17 56	21 36	263.00	6.05
τ Ophiuchi	17 57	− 8 11	256.00	1.67
70 Ophiuchi	18 00	+ 2 32	5.77	1.95
ϵ^1 Lyræ	18 41	39 33	16.92	3.42
ϵ^2 Lyræ	18 41	39 29	133.36	2.52
δ Cygni	19 41	44 52	318.80	1.60
π Aquliæ	19 43	11 31	121.86	2.13
γ Delphini	20 42	15 44	272.51	11.00
ε Equlei, A. B.	20 53	3 54	284.40	1.20
Equlei, A. C.	20 53	3 54	77.01	10.77
61 Cygni	21 01	38 12	116.80	22.15
μ Cygni	21 39	28 15	119.50	3.79
ζ Acquarii	22 23	− 0 35	329.88	3.03

NOTE.—The Clacey objective with which the preceding observations were made having recently passed into the possession of Messrs. Warner & Swasey, I have been able to test still further the capabilities of short-focus glasses by the aid of Mr. Herbert A. Spencer, already so widely known for his unrivalled microscopical objectives, which are unsurpassed even by the exquisite combinations produced by Zeiss and Abbe at Jena. Understanding thoroughly the necessity of perfect figuring and centering, and having the necessary skill to do this, he was ready to undertake the construction of an objective of considerably shorter focal length than I was willing to risk; and a compromise was effected on a ratio of 7 to 1, and accordingly I am now in possession of an object glass almost 5 inches clear aperture (4⅞), and 35 inches solar focus; and the remarkable thing about it is, and illustrating the extreme care bestowed in the figuring and perfect centering of the lenses that the lenses have *never been touched since first taken from the polisher*, and since their centering (which was done optically, and with greatest care). No refiguring or retouching of any kind was required. The color correction is as perfect as with any telescope made with the same materials (Chance's glass) of the usual focal length. This little (so far as length is concerned) telescope bears a power of 400 on Saturn with great distinctness, and the views it gives of Jupiter and Mars are fully equal to any I have ever had with a telescope of five inches aperture. So far as double stars are concerned, the closest I have yet seen with is μ^2 Boötis. Such stars as λ Ophiuchi are widely separated with a power of about 200, and readily seen with 150. ζ Herculis, which is always troublesome with a refractor of less than six or seven inches (as the small companion falls on the first diffraction ring), I have seen quite widely separated, and with scarcely a trace of rings with a power of about 400; the discs neat and round. This magnification was produced using really a compound microscope, which Mr. Spencer prepared, having a single system specially corrected for the objective and an ordinary Huggenian for the ocular; with this arrangement and which appears to answer even better than the "Barlow lens," very high powers can be had withuot having recourse to minute lenses; I have however had almost if not quite as good results in this star with a Barlow lens made by Spencer, and giving nearly the same amplification using the ordinary negative eyepiece, which alone would still show the dusky companion with a power of about 225. Whatever may be the theoretical objections, or the difficulties for ordinary opticians, there seems to be no real necessity for such long tubes as are now usually supplied.

The little observatory which, with the dome and all complete, cost only some $40 (independent of the pier), and which is only 6½ feet internal diameter, is quite large enough to carry a 7-inch glass under it with ease, and I hope ere long to give some account of what such a glass will do. For photographic work one need hardly remark upon the immense advantage of reduction of focal length. Dr. Gill has spoken very favorably of a telescope of 3 inches aperture and only 18 inches focal length made for him by Schroeder. This was a triple object glass, and he seemed to think that this form would be necessary in order to effect the reduction in length. Mr. Spencer has demonstrated practically that this is not necessary, and, indeed, with the telescope made for me, there is less of outstanding (secondary) color about Jupiter (none at all with Saturn) than is usually seen in telescopes.

I had been thinking of mounting one of these short telescopes as a comet seeker, bending the tube in the middle at right angles, placing at the angle one of Brashear's flats of about half the diameter of the objective, and rotating, for altitude, about the eye tube somewhat as described by Mr. Hill for a reflector in the June number of this journal, and which is an ingenious modification of Miss Caroline Herschel's, as figured in Smyth's "Celestial Cycle," Vol. II.

THE GREAT LICK TELESCOPE.*

PROFESSOR E. S. HOLDEN.

The Lick Observatory is beginning to present a very different appearance, both by night and by day, from the one it lately had during its period of construction. At night the windows which have been so long dark, show the lamps of the astronomers gleaming through them. The shutters of the observing slits are open, and the various instruments

* Extracts from a private letter to a friend, published in the San Francisco *Times*, July 11, 1888.

are pointed through them at the sky. The actual work of observing has begun, and the purpose for which the Observatory was founded—to be "useful in promoting science"—is in the way of being acomplished. Professor Schaeberle, late of Ann Arbor, has commenced the long task which has been assigned to him, namely to fix with the very highest degree of precision possible to modern science, the position of the "fundamental stars" with the Repsold Meridian Circle. The time-service for railway use is now conducted by Mr. Hill (late assistant to Professor Davidson), which leaves Mr. Keeler free to make the necessary studies of the great star spectroscope, which is one of the most important accessories of the 36-inch equatorial. Mr. Barnard is assiduously observing comets and nebulæ with the fine 12-inch Equatorial, and getting the photographic appliances in readiness to be used with the great telescope. He has already discovered twenty new nebulæ, found in the course of his sweeps for new comets. To show you some of the advantages of our situation here, I may tell you that Professor Swift of Rochester has a fine 16-inch Equatorial by Alvan Clark, and has discovered many faint nebulæ by its use. Two nights ago Mr. Barnard was examining some of these excessively faint objects by means of the 12-inch telescope (which gives only a little more than half the light of Professor Swift's), and in the field of view where Professor Swift had mapped only one nebulæ Mr. Barnard found three, two being, of course, new. This is due, not only to the observer's skill and keenness of eye, but in great measure to the purity and transparency of our atmosphere here.

The Eastern astronomers have given up the observation of Olber's comet, which is now only about $\frac{7}{100}$ as bright as last year, but Mr. Barnard has succeeded in following it up to last night, when it finally became too faint to be seen even here. These observations, which are several weeks later than those of other observatories, are of real value, as they determine a larger arc of the comet's orbit and enable its motion to be fixed with a much higher degree of accuracy. Mr. Keeler is just reducing his observations of the faint satellites of Mars, made with the large telescope during the past months. You can gain some sort of an idea of the immense advantage of the great telescope in such observations, when I tell you, that the brightness of the satellites as observed by him was only about one-sixth of their brightness at the time of their discovery. We can then make satisfactory observations of objects which are *six times fainter* than those very minute satellites of Mars were when Professor Hall discovered them in 1877 with the great telescope at Washington. I am becoming familiar with the performance of the large telescope and learning how to get the very best work from it. It needs peculiar conditions; but when all the conditions are favorable its performance is superb. I am, as you know, familiar with the action of large telescopes, having observed for many years with the great refractor at Washington, but I confess I was not prepared for the truly magnificent action of this, the greatest of all telescopes, under the best conditions. I have had such views of the bright planets (Mars and Jupiter) of nebulæ, the Milky Way and some of the stars, as no other astronomer ever before had. Jupiter, especially, is wonderfully full of details that I had not begun to see before. The discs of his moons can be readily noted in smaller telescopes; but here they are full and round, like those of planets. I am almost of the opinion that the curve of Jupiter's shadow might be seen on the surfaces, under favorable circumstances, when the satellites suffer eclipse.

There is reason to believe that the satellites of Jupiter, like our own moon, present always the same face to their planet. This can be studied here to great advantage if the discs present any of the markings which are reported by other observers. The Milky Way is a wonderful sight, and I have been much interested to see that there is, even with our superlative power, no final resolution of its finer parts into stars. There is always the background of unresolved nebulosity on which hundreds and thousands of stars are studded—each a bright, sharp, separate point. The famous cluster in Hercules (where Messier declared he saw "no star" is one mass of separate individual points. The central glow of nebulosity is thoroughly separated into points. I have been specially interested in looking at objects which are familiar to me in other telescopes, and in comparing our views with the drawings made by Lord Rosse with his giant six-foot reflector. Theoretically his telescope should show more than ours, for his collected the most light. But the *definition* (sharpness) of his is far behind our own, as we constantly see. For example, the ring nebula in Lyra is drawn by Lord Rosse with no central star. At Washington one small star can be seen in the midst of the central vacuity, but here we are sure of seeing three such at least. These are interesting on account of their critical situation in the nebula, not simply as stars.

The great Trifid and Omega nebulæ are wonderful objects here. Not only is a vast amount of detail seen here which can not be seen elsewhere, but the whole aspect of them is changed. Many points that are doubtful with other telescopes are perfectly simple and clear here. I have always considered that one of the great practical triumphs of this telescope would be to settle, once for all, the doubts that have arisen and that will arise elsewhere. Now I am sure that we shall be able to do this, and in a way to end controversy.

Of course you understand that the period of construction here is not yet quite over, though, I am thankful to say it is nearly ended. We have been making our observations so far under great disadvantages, and now that we see the way out of most of them, and look forward to work uninterrupted by machinists and constructors we begin to realize the opportunity. It really takes time to understand how to utilize it in the very best way. A great telescope is not like an opera glass, which can be taken out of one's pocket, and which is at once ready for use. It is a delicate and complicated machine which demands a whole set of favorable conditions for its successful use. Every one of these conditions has to be studied and understood, so that it can be commanded and maintained. We have been busy night and day in this work and in completing the thousand arrangements and contrivances which are essential in order to turn this vast establishment from a museum of idle instruments into a busy laboratory where the inner secrets of the sky are to be studied. We feel sure now that in a comparatively short period we shall be in full activity. In the mean time every one of us is doing his best under the conditions.

CURRENT INTERESTING CELESTIAL PHENOMENA.

THE PLANETS.

Mercury will be in conjunction with the moon August 5, and, on the same day a few minutes later, the planet passes into its ascending node. August 10 it is in perihelion of its orbit; the 13th, in conjunction with Saturn; 23d, in conjunction with the sun; Sept. 6, in conjunction with the moon again, the planet being 3° 46′ south; Sept. 18, in conjunction wi :h Venus, Mercury being 1° 39′ south. About August 5 Mercury ought to be seen by naked eye observation, as it rises so much in advance of the sun.

Young observers who have not seen Mercury with the telescope nor by the unaided eye will be richly repaid for all trouble to get such observations. In the small telescope, under favorable times for observation, the phase of the planet is readily seen. If, however, the atmosphere is unsteady the teminator will not show the clean, definite outline that experienced observers now anxiously look for in order to gain more definite knowledge of its surface markings. When the air is clear and steady some phases of Mercury are hard to observe well because of the irradiation, for the terminator of phase will apparently extend beyond its actual outline. The reason for this is plain to students of elementary physics and does not need to be stated here. The young observer's note book may profitably contain the following points for Mercury.

1. "Mercury twinkles like a star," is the statement of some text-books on astronomy. Good observers do not believe this. Study the appearance of a bright fixed star and the atmospheric conditions under which Mercury is seen.

2. The terminator is uneven. Why? Is it uneven surface, or the effect of irradiation?

3. Small telescopes increase irradiation proportionately more than large ones.

4. The spots on the surface of Mercury do not seem to be permanent.

5. The half-moon phase is not, generally speaking, at greatest elongation, as the text-books often say.

Venus is too near the sun to be an object of interest during the months of August or September. The planet is moving southward in declination during both months and hence reaches a comparatively low altitude at meridian passage.

Mars is an evening star in the constellation of Libra, and will be in conjunction with the moon August 13, and also Sept. 10. On the last named day Mars will be in conjunction with Jupiter, the latter being 2° 12′ north. In his illustrated notes on the planets, June issue of the *Journal of the Liverpool Astronomical Society*, Mr. W. F. Denning particularly describes the surface of Mars, which has attracted unusual attention of late. He says that the canal-shaped markings of Chiaparelli were seen, but that their structure and aspect seemed to him very different from the appearance of those figured on Chiaparelli's charts. They are not so definite and hard in outline in Mr. Denning's 10-inch reflector, nor does he get the net-work of bold, straight lines seen by Chiaparelli with an 8-inch refractor at the Observatory of Milan. On the contrary Mr. Denning does see a great variety of markings which he finds it difficult to reproduce in drawing on account of the many delicate gradations of light and shade. He also noticed the bright regions near the seas lately as very conspicuous. The "Fontana Land," so-called in Green's charts, showed excessive whiteness in great contrast with the surrounding regions. It produced an effect like that of the brilliant ice cap. This raises the question whether the equatorial regions of Mars have great snow fields or not; or is it possible that astronomers have wrongly interpreted the cause of the polar spots? These markings have been seen with very small instruments, under favorable conditions, by experienced observers. The northern polar cap is more difficult to observe than the southern. April last Denning saw it in full moonlight, and noticed its projection beyond the limb of the planet. Webb attributes the cause of this to irradiation. The especially favorable opposition of 1892 is waited for with deep interest, because then the planet will be nearer than since 1877. The two minute satellites of Mars have been followed and systematically observed by the aid of the great Lick telescope during this late opposition.

Jupiter is now a noble object in the telescope. It will be in quadrature with the sun Aug. 19; in conjunction with β^1 Scorpii, Sept. 22, the planet being 28′ south of the star. That which attracted most attention at Carleton College Observatory during the last month was the appearance of the great southern belt. There was no especially marked change observed, but the depth of its color, the distinctness and unusual regularity of its outlines were noticeable features. The markings of Jupiter's surface can be seen by the aid of small telescopes having good defining powers, though the great red spot, which is now rather faint, requires a telescope of greater aperture for satisfactory observation. A point of some interest that should not be forgotten is the occultation of a 7.7 magnitude star by the planet Jupiter, August 7, at 9*h* 22*m* P. M., central time. The maximum duration is 358 minutes. This is the only predicted occultation of a star by a planet that we know of for the rest of the year 1888.

Saturn is not in position for observation for the months of August and September.

Uranus, August 5, will be about 1° east of a third magnitude star, known as δ in the constellation of Virgo. August 11 the planet is in conjunction with the moon, the latter being 4° 44′ north. Sept. 19 it is in conjunction with Mercury, and the same day, three hours later, Mercury is in conjunction with Venus, the three planets forming nearly a straight line north and south, little more than 1½° long.

Neptune is in Taurus, half way between the Pleiades and the bright red star, Aldebaran. It can be seen only by the aid of the telescope.

MERCURY.

	R. A. h m	Decl.	Rises. h m	Transits. h m	Sets. h m
Aug. 6	7 59.9	+20°40′	3 26 A. M.	10 57.1 A. M.	6 28 P. M.
16	9 18.1	+17 21	4 21 "	11 36.0 "	6 51 "
26	10 35.6	+10 40	5 28 "	12 14.0 P. M.	7 00 "
Sept. 5	11 42.2	+ 2 55	6 26 "	12 41.0 "	6 56 "
15	12 40.1	− 4 36	7 14 "	12 59.5 "	6 45 "
25	13 32.3	−11 18	7 54 "	1 12.1 "	6 30 "

VENUS.

	R. A. h m	Decl.	Rises. h m	Transits. h m	Sets. h m
Aug. 5	9 33.7	+15 56	5 26 A. M.	12 35.0 P. M.	7 44 P. M.
15	10 21.8	+11 46	5 53 "	12 43.3 "	7 34 "
25	11 08.1	+ 7 05	6 20 "	12 51.0 "	7 22 "
Sept. 5	11 58.0	+ 1 33	6 47 "	12 56.7 "	7 06 "
15	12 43.0	− 3 35	7 13 "	1 02.3 "	6 52 "
25	13 28.5	− 8 37	7 39 "	1 08.3 "	6 37 "

MARS.

	R. A. h m	Decl.	Rises. h m	Transits. h m	Sets. h m
Aug. 5	14 19.9	−15°17′	0 20 P. M.	5 20.7 P. M.	10 22 P. M.
15	14 42.7	−17 12	0 11 "	5 04.1 "	9 57 "
25	15 07.1	−19 02	0 04 "	4 49.2 "	9 34 "
Sept. 5	15 35.5	−20 53	11 59 A. M.	4 34.6 "	9 10 "
15	16 03.7	−22 21	11 54 "	4 23.1 "	8 52 "
25	16 32.8	−23 33	11 50 "	4 12.9 "	8 36 "

JUPITER.

	R. A. h m	Decl.	Rises. h m	Transits. h m	Sets. h m
Aug. 5	15 38.6	−18 44	1 52 P. M.	6 38.7 P. M.	11 25 P. M.
15	15 40.8	−18 54	1 16 "	6 01.6 "	10 47 "
25	15 44.1	−19 07	0 41 "	5 25.6 "	10 10 "
Sept. 5	15 48.8	−19 24	0 05 "	4 47.9 "	9 30 "
15	15 54.3	−19 42	11 32 A. M.	4 14.0 "	8 56 "
25	16 00.6	−20 03	11 01 "	3 40.9 "	8 21 "

SATURN.

	R. A. h m	Decl.	Rises. h m	Transits. h m	Sets. h m
Aug. 5	8 52.7	+18 15	4 35 P. M.	11 54.0 A. M.	7 13 P. M.
15	8 58.0	+17 55	4 02 A. M.	11 20.0 "	6 38 "
25	9 03.0	+17 35	3 30 "	10 45.7 "	6 02 "
Sept. 5	9 08.4	+17 13	2 53 "	10 77.8 "	5 22 "
15	9 13.0	+16 54	2 16 "	9 29.6 "	4 43 "
25	9 17.3	+16 36	1 43 "	8 54.5 "	4 06 "

URANUS.

	R. A. h m	Decl.	Rises. h m	Transits. h m	Sets. h m
Aug. 5	12 52.8	+ 4 57	9 30 A. M.	3 53.2 P. M.	10 16 P. M.
25	12 56.0	+ 5 19	8 13 "	2 37.8 "	9 02 "
Sept. 15	13 00.3	+ 5 46	6 52 "	1 17.7 "	7 44 "

NEPTUNE.

	R. A. h m	Decl.	Rises. h m	Transits. h m	Sets. h m
Aug. 5	4 01.3	+18 58	11 42 P. M.	7 04.1 A. M.	2 27 P. M.
25	4 02.3	+18 59	10 24 "	5 46.4 "	1 09 "
Sept. 15	4 02.3	+18 58	8 57 "	4 19.8 "	11 42 A. M.

Occultations Visible at Washington.

			IMMERSION.		EMERSION.		
Date.	Star's Name.	Magni-tude.	Wash. Mean T. h m	Angle f'm N. Point. °	Wash. Mean T. h m	Angle f'm N. P't. °	Duration. h m
Aug. 13	ξ^1 Libræ	6	8 52	19	Star 1.8′ N. of moon's limb.		
17	30 Sagittarii	6½	8 58	131	10 00	228	1 02
17	31 Sagittarii	6½	9 36	76	10 56	277	1 20
20	γ Capricorni	3½	6 02	77	7 05	265	1 04
20	δ Capricorni	2½	10 08	37	11 18	285	1 11
26	μ Ceti	4½	15 47	76	17 15	225	1 28
29	*m* Tauri	5½	14 20	107	15 21	216	1 01
30	χ^1 Orionis	4½	12 58	347	Star 0.4′ N. of moon's limb.		
30	χ^2 Orionis	6	13 00	167	Star 2.0′ S. of moon's limb.		
Sept. 1	79 Geminorum	6½	14 37	39	15 17	315	0 40
17	50 Aquarii	6	11 11	56	12 31	250	1 20
17	B. A. C. 7835	6½	14 46	70	15 48	243	1 01
18	ψ^1 Aquarii	4	12 29	9	13 19	291	0 51
18	ψ^2 Aquarii	4	13 22	93	14 25	208	1 03
27	15 Geminorum	6½	12 02	80	13 06	259	1 04
27	16 Geminorum	6½	12 32	169	Star 3.0′ S. of moon's limb.		
28	56 Geminorum	5½	13 19	165	Star 1.8′ S. of moon's limb.		

Phenomena of Jupiter's Satellites.

Central Time. d	h m				Central Time. d	h m			
Aug. 7,	7 41	P. M.	II	Tr. In.	Aug. 25,	6 49	P. M.	III	Sh. In.
7,	9 07	"	III	Ec. Dis.	25,	7 16	"	II	Sh. Eg.
8,	7 02	"	I	Tr. In.	31,	7 28	"	I	Tr. In.
8,	8 28	"	I	Sh. In.	Sept. 1,	7 17	"	II	Tr. Eg.
8,	9 26	"	I	Tr. Eg.	1,	7 19	"	II	Sh. In.
8,	10 42	"	I	Sh. Eg.	1,	7 52	"	III	Tr. Eg.
9,	7 23	"	II	Ec. Re.	1,	8 08	"	I	Ec. Re.
9,	7 55	"	I	Ec. Re.	8,	6 38	"	I	Oc. Dis.
14,	7 45	"	III	Oc. Dis.	8,	7 22	"	II	Tr. In.
14,	9 52	"	III	Oc. Re.	9,	7 21	"	I	Sh. Eg.
15,	9 06	"	I	Tr. In.	10,	7 14	"	II	Ec. Re.
17,	7 06	"	I	Sh. Eg.	12,	6 58	"	III	Ec. Re.
23,	7 31	"	II	Oc. Dis.	16,	7 03	"	I	Sh. In.
23,	8 16	"	I	Oc. Dis.	17,	6 26	"	I	Ec. Re.
24,	6 48	"	I	Sh. In.	19,	6 27	"	III	Oc. Re.
24,	7 45	"	I	Tr. Eg.	26,	6 53	"	II	Sh. Eg.

Great Red Spot on Jupiter—Times when its Zero Meridian passes the Centre of Jupiter's Disc.

Central Time. d	h m		Central Time. d	h m		Central Time. d	h m	
Aug. 1,	8 53.3	P. M.	Aug. 18,	7 58.8	P. M.	Sept. 4,	7 06.4	P. M.
3,	2 40.5	A. M.	20,	1 47.0	A. M.	6,	12 54.7	A. M.
3,	10 32.0	P. M.	20,	9 38.6	P. M.	6,	8 46.3	P. M.
4,	6 22.6	"	21,	5 29.3	"	8,	2 33.8	A. M.
6,	12 10.8	A. M.	22,	11 17.5	"	8,	10 25.4	P. M,
6,	8 01.4	P. M.	23,	7 08.2	"	9,	6 16.1	"
8,	1 49.6	A. M.	25,	12 56.5	A. M.	11,	12 04.4	A. M.
8,	9 41.1	P. M.	25,	8 48.1	P. M.	11,	7 56.1	P. M.
9,	5 31.7	"	26,	4 38.8	"	12,	3 46.8	"
10,	11 19.9	"	27,	10 27.1	"	13,	9 35.2	"
11,	7 10.6	"	28,	6 17.7	"	14,	5 25.9	"
13,	12 58.8	A. M.	30,	12 06.0	A. M.	15,	11 14.3	"
13,	8 50.3	P. M.	30,	7 56.7	P. M.	16,	7 05.0	"
15,	2 37.7	A. M.	Sept. 1,	1 45.0	A. M.	18,	8 45.0	"
15,	10 29.2	P. M.	1,	9 36.6	P. M.	19,	4 35.8	"
16,	6 19.9	"	2,	5 27.4	"	20,	10 24.1	"
18,	12 08.1	A. M.	3,	11 15.7	"	21,	6 14.9	"

Phases of the Moon.

	Central Time. d	h m	
New Moon	Aug. 7,	12 20.9	P. M.
First Quarter	14,	10 44.0	A. M.
Full Moon	21,	10 20.3	"
Last Quarter	29,	8 17.9	"
New Moon	Sept. 5,	10 56.1	P. M.
First Quarter	12,	3 59.9	"
Full Moon	19,	11 24.3	"
Last Quarter	28,	2 30.2	A. M.

Solar Prominences. The new Fauth & Co. spectroscope belonging to Carleton College Observatory is being employed in connection with the 8¼-inch equatorial in the study of the solar chromosphere and prominences. The spectroscope is provided with a fine prism and a diffraction grating of speculum metal ruled by Brashear with Professor Rowland's ruling engine, 14,400 lines to the inch. There are 27,700 lines upon the grating, each about an inch and three-eighths in length, giving a ruled area about 2 by 1⅜ inches. Thus far the grating only has been used, and has given great satisfaction. The lines of the principal spectrum are very distinct and widely separated. Some very satisfactory and exceedingly interesting views of the chromosphere and prominences have been obtained in the great *C* line in the red, with the slit opened from a half to one and a half millimeters. A millimeter at the focus of the 8¼-inch equatorial corresponds to about 67″ of arc. None of the prominences observed so far have had a height greater than 80″, but some have shown much more of detail in this structure than is ordinarily shown in drawings of these phenomena. One, especially, was observed June 25, at 3:45 P. M., which was full of minute detail, which at 5 P. M. had completely changed. On June 28 a very rapidly changing eruptive prominence was observed on the N. E. limb of the sun, at about 50°. From 3:50 to 4:15 P. M. five sketches were made, each showing marked difference in detail. July 18, at 11 A. M., a very low prominence was observed on the west limb, lying very near, if not exactly over, a large spot which had been seen near the edge of the disc on the preceding day and was surrounded by brilliant faculæ. The peculiarities of this prominence were its extraordinary brightness, exceeding that of the chromosphere itself, and a long extension down through the chromosphere into the black line of the photosphere. H. C. W.

The total eclipse of the moon, July 22, was a beautiful sight. The atmosphere was very clear and the copper color of the moon in its total phase was certainly stronger than ever before seen by us. The predicted time for all phases observed was very closely verified.

Professor W. A. Crusenberry, Garfield University, Wichita, Kansas, observed the eclipse with a 6½-inch reflector. He reports that from 10:58 P. M. until the moon left the shadow, the telescope was quite constantly used. The air was clear but unsteady. "The copper hue of the moon's disc, contrary to commonly published statements, was plainly visible on the dark side fifteen minutes after the moon entered the shadow, and to within fifteen minutes of its leaving the shadow. While the moon's disc was half covered, and during totality, the well known craters and other markings could be distinctly seen on the shaded part."

Professor Comstock, Director of the Washburn Observatory, Madison, Wisconsin, observed twenty-two occultations of stars, 9 to 10.5 magnitude, during the eclipse.

Eclipse of the Sun. The fifth and last eclipse for the year 1888 will occur August 7. It will be a partial eclipse of the sun visible only in the Arctic ocean, Norway and Sweden, portions of Denmark and Greenland and the extreme northern parts of North America and Asia. Less than two-tenths of the diameter of the sun will be covered.

Minor Planets. Mr. Borrelly's supposed discovery of a new minor planet on May 12, turns out to be (116) *Sinora.* So Palisa's discovery of May 16 is number (278), and has been named *Paulina.*

EDITORIAL NOTES.

The next issue of this journal will be for the month of October. The full description, with illustration, of the new Observatory of Carleton College, which was promised for this month, must be deferred until next time, as the cuts are not ready.

Professor H. A. Howe, department of Mathematics and Astronomy in Denver University, Colorado, has visited nearly all the prominent observatories in the United States recently. His tour has been one of inspection and counsel with astronomers to aid him in constructing his own new observatory which is to go forward as rapidly as possible. His visit at Carleton Observatory on July 18, for a single day, was a genuine delight to us, socially, mathematically, astronomically and every other way, for it brought back to us vividly the times of 1876 when we worked together, as students, in the Cincinnati Observatory, under that most genial and helpful instructor, Professor Ormond Stone, now Director of the Leander McCormick Observatory, University of Virginia.

At the last meeting of the Board of Trustees of Carleton College, Dr. H. C. Wilson was elected Assistant Professor of Astronomy. This is the first permanent position, for an assistant professor that the college has established in any of its departments. This institution is only twenty years old, and yet its official management has been able to honor thus one of its most worthy graduates, a member of the class of 1880.

Fifty Years of American Astronomy was the title of an address delivered June 25, by Professor T. H. Safford, Director of the Field Memorial Observatory of Williams College, at Williamstown, Mass. This semi-centennial occasion was one to commemorate the erection in 1838 of the first college observatory in the United States. Mr. David Dudley Field, of New York, was fittingly chosen to preside, as he was the founder, in 1869, of the Field Memorial Professorship of Astronomy in Williams college, and five years later, the generous donor of the Field Memorial Observatory for the same institution.

The MESSENGER hopes later to publish the address of Professor Safford, which is said to be a most important piece of historical research, and therefore richly deserving a permanent place in the general and popular records of our science.

The Study of Meteorites. Last month we published two of the three main propositions which Professor Newton made the basis of a paper "Upon the relation which the former orbits of those meteorites that are in our collections, and that were seen to fall, had to the earth's orbit." The third proposition, not then known, was: "The perihelion distances of nearly all the orbits in which these stones moved were not less than 0.5 nor more than 1.0, the earth's radius vector being unity."

We were sorry that we were not able to get the whole paper for our June issue. It was published entire in the July number of the *American Journal of Science*.

Comet a 1888 (*Sawerthal*). March 30. Tail very bright along the central axis, much fainter on either side and again brighter along the edges. Probably three tails. Nucleus elongated in direction of axis, or double.

June 1. There are three tails—the central one bright, the

MARCH 30.

JUNE 1.

others very faint. The tail to the right is slightly shorter and fainter than the one to the left. Nucleus round.

Evidently the change in the appearance of the tail can be accounted for by increase of distance for March 30, until the fainter parts disappeared. F. P. LEAVENWORTH.

Haverford College Observatory.

Observation of Comet 1888 a (Sawerthal.)

1888, Haverford Mean Time.	*	No. of Comp.	Comet — Star.		α	δ	log p Δ for α	for δ
h m s			m s	′ ″	h m s	° ′ ″		
May 2, 15 41 12	1	23 5	+ 2 36.72	+ 5 15.2	23 28 46.22	+ 27 52 14.3	n 9.694	0.623
6, 15 20 32	2	24 7	—2 17.24	—7 3.8	23 37 56.92	+ 29 54 19.8	n 9.709	0.628
20, 15 36 8	3	30 5	—0 37.23	—2 .91	0 7 1.47	+ 35 57 37.5	n 9.716	0.492

Mean Places for 1888.0 of Comparison Stars.

*	α	Red to App.	δ	Red to App.	Authority.
	h m s	s	° ′ ″	″	
1	23 26 10.08	—0.58	+ 27 47 10.3	—11.2	Weisse's Bessel 524
2	23 40 14.72	—0.56	+ 30 1 35.2	—11.6	Weisse's Bessel 832
3	6 7 39.01	—0.31	+ 35 59 58.7	—12.1	Weisse's Bessel 158

May 6, Nuclues faint and ill-defined, perhaps on account of clouds.

May 20. Nucleus round and well defined surrounded by an envelope much elongated in a direction at right angles to the axis of the tail. Tail much fainter than the envelope. Nucleus estimated of the 8 magnitude as compared with the 9th magnitude comparson star. On March 30, the nucleus was observed to be decidedly enlongated in the direction of the axis of the tail.

A comparison of the observation of May 20, with the ephemeris computed by Professor Boss, *Astronomical Journal*, No. 171, page 22, gives O – C; $\Delta\alpha = -2.5s$, $\Delta\delta = -25''$.

F. P. LEAVENWORTH,

Haverford College Observatory, May 26, 1888.

Salaries at Lick Observatory. The Mining and Scientific Press, (San Francisco, June 23)issued a special edition of 32 pages, called the Lick Observatory edition. In that paper will be found the most complete account of this great Observatory that has yet appeared in print. Accompanying the descriptive reading matter, which fills thirteen pages, is found over thirty cuts, large and small, giving views of the buildings, grounds and instruments. The pictures of Mr. Lick, the founder, and Professor Holden, the Director, are also given.

The salaries of the observing corps are as follows:

Professor Holden, as Director and Astronomer $5,000; S. W. Burnham, astronomer, $3,000; J. M. Schaeberle, astronomer $2,000; J. E. Keeler, astronomer, $1,400; E. E. Barnard, astronomer, $1,200; C. B. Hill, assistant astronomer, secretary and librarian, $1,000. This number of the *Press* is an excellent one to file for reference.

Elements of the Great Comet of 1882 (Comet II., 1882). In the year 1884 Mr. Winlock, of the United States Naval observatory, drew my attention to the orbit of Comet II., 1882, recommending that a determination of the elements be made from observations of the United States Naval Observatory.

Although the determination of the elements was completed in 1884, other work and subsequent travels in Europe prevented the further prosecution and publication of the work.

As the elements computed by me are, as far as I am aware, the only elements of the Comet II. 1882 determined exclusively from meridian observations of the United States Naval Observatory, and as the orbit presents many interesting features I here give the elements of this comet determined by me:

ELEMENTS OF COMET II. 1882.

$T =$ (1882) Sept. 17.0076723 Wash. M. T.
$\pi - \Omega = 69°\ 36'\ 9''.01$
$\Omega = 346\ \ 1\ \ 6.93$ } Mean Equinox.
$i = 141\ 59\ 54.00$
$\log a = 1.9066282$
$P =$ 718.862 years.
$\varphi = 89°\ 12'\ 31''.61$
$\log q = 7.8859571 - 10$

COMP. OBS.

	$\cos \beta\ d\lambda$	$d\beta$
Sept. 19.	0''.00	0''.00
Nov. 15.	00 .11	00 .42
Dec. 4.	0 .00	0 .00

From other Washington observations and repeated calculations the values of 704 years, 712 years, and 716 years for the period of this comet, were obtained.

The period of 718.862 years obtained from the meridian observations seems, therefore, to be very near the truth.

Baltimore County, M. D. GUSTAVE L. RAVENÉ.

The Markings of Jupiter. Some observers are calling attention to the color of the prominent belts on the planet Jupiter, claiming that a reddish tinge is more noticable of late than usual, and suggesting that the color here shown so much resembles that of the great red spot that possibly the same causes are directly or remotely concerned in producing both phenomena.

J. A. Brashear, of Allegheny City, is now in Europe on a vacation trip. In June he was in London, Paris and Munich. In August in Berlin and Glasgow. He expects to attend the meeting of the British Association Sept. 5. He will visit the principal observatories of Europe and distinguished makers of astronomical instruments.

Value of Filar Micrometer. One of the methods given by *Chauvenet* for determining the value of one turn of the filar micrometer is to measure the angular space, between two stars (for example), and divide the known angle by the divisions of the micrometer subtended thereby, etc. Of course the most easily practicable method with an equatorial is to measure the $\Delta\delta$ directly, and then divide the known $\Delta\delta$ in seconds of arc (corrected for refraction), by the observed turns of the micrometer. *Chauvenet* suggest certain pairs of stars in the "Pleiades."

I have found the stars 12 and 13 Comæ an excellent pair for applying this method. The declinations, and proper motions have been well determined, and are found in various catalogues. Doubtless better values may easily be found for those I have used, which are as follows:

		δ, 1888.0	
Authority.	Wt.	12 Comæ.	13 Comæ.
Yarnall	1	+26°28′05.9″	+26°43′——
Safford	2	04.6	10.9″
Harvard ('72.)	2	03.8	10.8
Harvard ('75.)	2	03.5	11.1
Adopted δ	=	+26°28′04.24″	+26°43′10.93″
Precession	=	− 19.997″	− 19.984″
Proper motion	=	+ 0.0035″	− 0.0197″
R. A. 1888	=	12*h* 16*m* 52.5*s*	12*h* 18*m* 41.4*s*

In this pair we have a difference of about 906″, about the largest practicable with the usual micrometer eyepiece and with the stars only two minutes of arc apart. and of the same magnitude.

The value of one turn of the micrometer belonging to the equatorial of this observatory, I have determined from transits of stars of various declinations, etc., = 23″.087. A set of eight determinations by above pair, taken last night gave $\Delta\delta = 39t.211$: the distance, corrected for refraction, being 906″.2, we have the value of one turn = 23″.111; a set of transits of ϑ Boötis immediately afterwards gave one turn = 23″.104. CHAS. B. HILL.

Chabot Observatory, Oakland, Cal.,
May 23, 1888.

Professor Newton's article on the orbits of aerolites is reprinted in Nature, July 12.

Old and New Astronomy. Parts II. and III. of this new work by Mr. Proctor have been received. Part II. concludes the second chapter, which has for its theme "Ancient and Modern Studies of the Earth's Shape," and begins chapter number three. Two full-page stereographic charts in colors, representing the northern and southern hemispheres of the earth, appear early in the second chapter. Following these are cuts illustrating the effects of the earth's curvature on bodies at a distance on its surface; the effect of refraction in diminishing the apparent cnrvature; illusions affecting the earth's appearance as seen from a balloon; how to measure the curvature; the earth's true figure, showing the comparative height of the atmosphere, and, finally the various modes of mapping its surface. These illustrations pertaining to the study of the earth's shape are good, but we wonder at the use of filling fifty-one pages on this theme with so much of detail. Chapter III. discusses the apparent motions of the sun, moon and planets, referring first to the notions of the ancients and their modes of study, and the values of the obliquity of the ecliptic obtained by them. Then the reader is asked to follow the sun's progress through the twelve signs of the Zodiac, which path is illustrated by twelve full-page maps, each showing the relation of a particular sign to the constellation of the Zodiac, by the same name, and others contiguous to it. Next is given the way in which Hipparchus determined the position of the sun's perigee and apogee, and the ground of his error relating to the eccentricity of the sun's apparent orbit. This is a piece of interesting history and valuable in detail. The supposition setting forth how the ancients *may* have begun the study of the moon and pursued it, is a good piece of imagination and quite like that which often occurs in this new work at the beginning of new subjects. Nothing need be said against it, if the reader is aware that such easy and convenient introductions are no part of the known facts, or that they necessarily at all belong to the history of these noble themes. The emphasis should be placed on "probably," "doubtless," "perhaps," and such key words in these lengthy passages. That the author should take pleasure in making Milton responsible for things he never said, is natural in view of his own expressed vulgar views of sacred things or pious men of every age. To match this, we think somebody ought to make sport of the efforts made by the distinguished Adams, of Cambridge, and the younger Hill, of Washington, because they have not succeeded yet in getting the moon "in gear." Aside from a few real blemishes like these, chapter number three is a good one.

Brilliant Aurora. Mr. Geo. H. Peters, of Hartford, Conn., noticed a bright aurora June 3. It commenced at 9 o'clock P. M. and lasted thirty minutes. First a distinct arch was seen; at 9:15 streamers appeared in the northeast 35° high moving towards the west, gradually fading out and entirely disappearing in half an hour. There were no sun spots to be seen on that day or the following one.

Photographic Study of Stellar Spectra at Harvard College Observatory is shown in the second annual report by Professor E. C. Pickering of work done by the assistance of the Henry Draper Memorial. Two telescopes are constantly at work at the Observatory on photography every clear night. Four assistants take part in making the pictures, and five ladies are employed for measurements and reductions. The various investigations reported are:

1. Catalogue of spectra of bright stars.
2. Catalogue of spectra of faint stars.
3. Detailed study of the spectra of bright stars, and
4. Faint stellar spectra.

Two fine full-page plates show respectively the present location of the various photographic telescopes, and several cuts illustrating the work named above.

The mode of testing the sensitive plates is by exposing them to the polar sky, and the spectrum shown is that of the Pole-star. The star trails are very distinct in the illustration.

From the *Observatory* we learn that arrangements have been made for a redetermination of the longitude between Paris and Greenwich. Four observers, M. le Commandant Bassot and M. Defforges, from Paris, and Mr. Turner and Mr. Lewis, from Greenwich, are to take part in the work so as to have a double check on the personal equation.

An Astronomer's Summer Trip is the title of an article by Professor Young in the July number of Scribner's magazine. It will be remembered that Professor Young, of Princeton, with a party of observers, went to Europe to observe the total eclipse of the sun which occurred Aug. 19, 1887. The reason why Professor Young was especially interested in observing this eclipse was largely owing to a question that had been raised by Mr. Lockyear and others, as to the real existence of the so-called "reversing layer" of the sun's atmosphere which layer owes its scientific recognition mainly to an observation made by Professor Young himself during the eclipse of 1870. Of that observation he says:

"The slit of the spectroscope, attatched to a powerful telescope, was adjusted tangent to the sun's image at the precise point where the last ray would vanish under the advancing moon. A few moments before totality the spectrum still preserved in the main its familiar appearance except that certain lines usually only flickering and faintly bright at the sun's limb were now steady and conspicuous; this was specially true of the magnesium lines and the mysterious lines of the corona. The other countless dark lines remained hard and black. But the moment the sunlight vanished the dark lines instantly flashed into colored brightness, shone for two or three seconds, and then quickly faded away, leaving still visible only those which had been bright before totality. Of course, in the two or three seconds during which the phenomenon lasted, it was not possible to be quite sure that *all* the dark lines were thus reversed, and in this uncertainty lies the opportunity for varying interpretations of the phenomenon. The natural interpretation, in the light of what was then known, was that this bright line spectrum, which flashed out so beautifully, is due to a thin sheet of gaseous matter, overlying the luminous clouds which constitute the so-called 'photosphere,' and containing, in the vaporous form, all the substances which reveal themselves to us by the dark lines of the ordinary spectrum."

This much has been given that one of the important questions in the mind of astronomers for study might be understood and remembered by all our readers. It is already known to all that bad weather prevented all observation by this party, which must have been a great disappointment to them, in view of all the preparation, travel, waiting and anxiety that preceded the unpropitious day. But the account of Professor Young's visit to many of the leading

Observatories of Europe, with the illustrations and descriptions of the same, is delightful reading. The hospitality of these noted men, a glance at their work and their instruments, must have furnished some compensation for other losses however keenly felt.

M. Perrotin of France has noticed and traced four of the parallel canals of Mars recently, three of them starting from the "Seas" of the sonthern hemisphere, near the equator, and running northward up to the north polar ice-cap.

Topeka Astronomical Society. A. W. Waters, of Topeka, recently writes that an astronomical society is being formed in the above named place. It is in the contemplated plan to build an Observatory for the uses of the society and, possibly, to undertake original work. Mr. Waters is certainly interested in astronomical study and deserves encouragement and useful assistance.

We are pleased to learn with some degree of certainty, though not from official sources, that H. V. Egbert is now assistant in the Washburn Observatory at Madison, Wis. Astronomers generally know of his efficient astronomical work at Dudley Observatory, Albany, N. Y., during the seven years that he held a like position in that Observatory. It is a good thing for strong young men to come West.

The New Thirty-foot Dome, made by Messrs. Warner & Swasey, of Cleveland, for Carleton College Observatory is completed and in place, and is now taking its last coat of paint. It is constructed wholly of iron and steel, and its entire weight is 23,000 lbs. It is moved by a wire rope extending round the dome on the inside, and finally over two pulleys to another on the shaft of a wheel two feet in diameter, grooved in its circumference to receive a large rope that is placed within easy reach of the observer's hand. The movable part of the dome weighs over ten tons, and it is quickly set in motion by a vertical pull of 15 pounds. Its manipulation every way seems as perfect as human skill can make it. Messrs. Warner & Swasey have solved the question of making a dome for easy manipulation and apparent durablity.

Ciel et Terre for June republishes Professor Newcomb's address at the dedication of the observatory at Syracuse, N. Y. It appeared in the January and February numbers of this journal, and was translated into the French by E. Lagrange.

The June number of *Knowledge* contains a very *remarkable* review of Professor Langley's New Astronomy. American astronomers should read it.

The Royal Alfred Observatory. Director C. Meldrum favors us with a copy of his annual report for the year 1886. Meteorological, magnetic and solar observations constitute the body of the report. It is interesting to notice that sunspots were observed on 285 different days of the year, faculæ on 197, and that the number of photographs of the sun was 533, the largest number in any year since 1875.

The Moon and the Weather at Batavia (*Java*).—In the appendices to the volumes of observations at Batavia, Dr. van der Stok publishes studies of the influences of the moon on the meteorological elements. He finds an appreciable effect on the cloudiness. The cloudiness there increases with the increase of the distance of the moon above the horizon, reaching its maximum at the superior meridian transit and its minimum at the inferior one. Thus the influence of the moon appears to be felt when she is below the horizon, which excludes the hypothesis of its being the result of direct radiation. There is also greater cloudiness at full than at new moon. In each case the extreme difference averages about 5 per cent. The temperature, too, proves to be somewhat higher when the moon is below than when she is above the horizon, and in October and November the difference amounts to almost one degree Fahrenheit. The lunar effect is more marked in the west than in the east monsoon.

Batavia is especially suited to the study of the atmospheric tides, as irregular barometric disturbances are unknown there. The existence of such tides is more and more completely proved as the number of observations increases; but the tides are small, though not so small as the mechanical theory of tides requires.

Dr. H. C. Wilson, of Carleton College Observatory, has been employed to deliver two lectures on astronomical themes during the first days of this month at the summer school of Mahtomedi Chautauqua Assembly. His themes will be illustrated, by the aid of the lantern, with pictures prepared for the occasion, some of them being drawings of solar prominences made at the telescope during the last month.

Errata. Mr. Monck of Dublin, Ireland, calls our attention to the following errors in our last issue:

Page 236, line 15 from end, for "confined" read "comprised."

Page 237, first line of table, for "Leebyer" read "Seeleger."

Same page, first line of table, for 9.5 read 6.5.

In the note on the dissipation of comets for "De Vico" read "Di Vico."

BOOK NOTICES.

"The New Astronomy" is the title of an important book, written by Professor S. P. Langley, secretary of the Smithsonian Institution, at Washington, and recently published by Messrs. Ticknor & Co., Boston, Mass. In the June number of this journal a notice of this book appeared by another who spoke well of its merits but rather too briefly to draw deserved attention to the character and value of its contents. This is the purpose of a second and a fuller notice.

The first chapter of The New Astronomy is a study of the spots of the sun. The author begins by noticing the difference between the instruments and apparatus used by the ancients in determining the places of the heavenly bodies, and those found in the modern observatory like that of Greenwich or Washington. The contrast is surprisingly great in favor of the modern instruments of precision, in power, utility and adaptation. The author says the chief object of the astronomer, in all the past until recent years, has been to learn exactly *where* the heavenly bodies are on the celestial sphere at any given time. The further question now is, What *are* they? What is their constitution? What is their relation to ourselves? When applied to the sun, moon and stars, these are the questions of the New Astronomy, sometimes called solar physics or celestial physics.

A picture of the sun's corona and chromosphere, with illustrations of distance, introduces the reader to some fine photographs of the surface of the sun as a whole, as seen through the telescope and photographed in 1870. Though these pictures are small they are useful in giving the general reader a correct idea of what a good telescope reveals of the surface of the sun to the eye of an experienced observer. The well-known picture of Nasmyth's "willow leaves," with Sir John Herschel's explanation of their nature, stands in striking contrast with those beautiful and inimitable drawings of sun spots which were observed by the author in the months of March and December of 1873. The minutiæ of detail that these drawings show in easy relief is most won derful when the reader remembers that such parts of a sun spot in its active stage are changing so constantly and rapidly as to greatly tax the skilful artist to catch them and bring out a harmonious whole; yet this very thing is necessary to furnish all this abundant data for philosophic study of the later phases of solar physics. The author leans toward Faye's theory of the sun spots in regard to vertical circulation, and cautiously says that his "cyclone theory" has some evidence for its support. The second chapter deals with the sun's surroundings. A large number of views of the solar corona, on occasions of the total eclipses of the sun since 1869, find place in a connected account of the more important observations of this strange phenomenon for the last ten years. What the corona is, or how it is to be explained, Professor Langley frankly says the most learned do not know. The evidence whether it is a gas or not is conflicting, although the green coronal line of the spectroscope seems to say plainly, that it contains an unknown gas of extreme tenuity. It is possible to think of the corona, especially in its outer parts, as made up of minute dust particles like those of the meteoric train, and it is also possible to believe that it is *partly* a phenomenon caused by the diffraction of light, as argued so well by Professor Hastings after his observations of it at Caroline

Island in 1883. Professor Langley, however, does not think that this latter theory is sufficient to explain the corona as a whole, for he does not believe it to be a "phantasm" dependent only on the changes which the presence of the moon may bring, but rather an appendage belonging to the sun and therefore having a real existence.

The author next describes the chromospere of the sun, that envelope rising here and there into prominences of a rose and scarlet color, invisible in the telescope, except at a total eclipse, but always visible through the spectroscope. This thin envelope appears to be formed by heated gas issuing through the pores of the entire visible surface of the sun, and, overlapping it, makes a literal lake of fire, whose waves of flame heave and toss like those of the fiercest conflagration the imagination can picture. These flames are evidently "connected with that uprush of heated matter from the sun's interior forming part of the circulation which maintains both the temperature at its surface and that radiation on which all terrestrial life depends." They are the signs of what is going on beneath the surface of the sun, but more than this The New Astronomy has little to say.

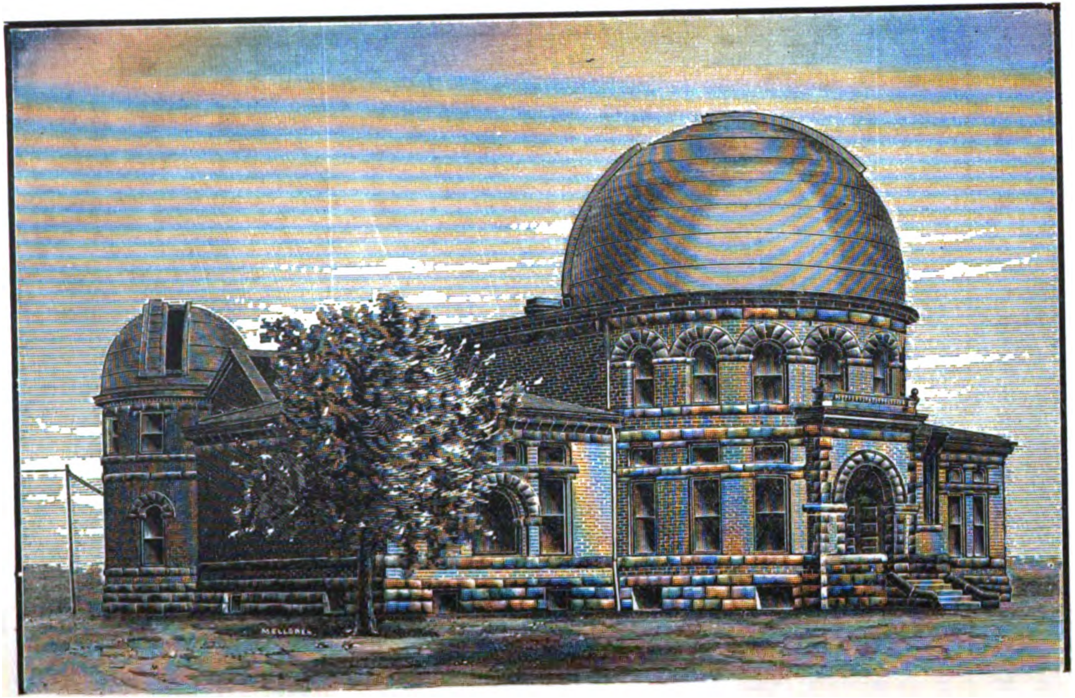
In the third chapter, the sun's energy, the author enters on his own special field of labor and original research for years, and to this part of his studies we wish to give special attention, and hence reserve what we have to say till our next issue.

(TO BE CONTINUED.)

An Elementary Treatise on the Integral and the Differential Calculus. With Numerous Examples. By EDWARD A. BOWSER, LL. D., Professor of Mathematics and Engineering in Rutgers College. Ninth Edition. New York: D. Van Nostrand, 23 Murray street, 1887. 12mo., cloth, pp. 305. Price $2.25.

By courtesy of the publisher, we have recently, for the first time, had the pleasure of examining the series of Mathematics published since 1880 by Professor Bowser of Rutgers College, New Brunswick, N. J. The calculus we have read with unusual interest, because we think it so well adapted to the class room. The statement of principle is clear and exact, without needless verbiage. As an example of this we quote the author's remarks limiting the meaning of the terms infinite and infinitesmal. He says, "An infinite is not the largest possible quantity, nor is an infinitesimal the smallest; there would in this case be but *one* infinite or infinitesimal. Infinities may differ from each other and from a quantity that transcends every assignable quantity, that is, from absolute infinity. So may infinitesimals differ from each other, and from absolute zero." This is what every teacher of the calculus knows, and is often called upon to explain; but how rarely do the text books specialize such points that are all important for the beginner to give him right notions, which he may get for himself as he starts in this new and difficult field of study. We are glad to see that the author has adopted the method of *infinitesimals* in explaining the fundamental principles of the subject, for it is certainly to be preferred to the method of *limits*. The later chapter on *limits* makes the work complete so far as theories of both methods are concerned. This book covers the usual ground of the latest and best books on this branch, and it is especially commended for its numerous examples, its illustrations and its applications. Teachers who desire a large number of examples for students to solve will be gratified with what is contained in this book, and the student who masters them all will certainly not lack a good knowledge of the elements of the Calculus.

We have also received, by the same author, An Elementary Treatise on Hydromechanics, An Elementary Treatise on Analytic Mechanics, and An Elementary Treatise on Analytic Geometry. Notices of these books will appear in the next number of this journal.



ASTRONOMICAL OBSERVATORY,
Carleton College, Northfield, Minn.

THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE,

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

VOL. 7, NO. 8. OCTOBER, 1888. WHOLE NO. 68.

CARLETON COLLEGE OBSERVATORY.

According to promise, we now give a brief description of the building and the instrumental outfit of the new Observatory of Carleton College. The grounds belonging to the College are located in the northeastern part of the city of Northfield, and the site of the Observatory is nearly in the extreme northeastern part of the College "campus." The building stands on an eminence with abruptly sloping sides on the north, east and south, around the base of which is a beautiful ravine through which flows in tortuous path, a living brooklet, that has fitly won the name of Silver Creek. The nearest building is the old observatory at the distance of about 330 feet. Gridley Hall is next, and twice as far to the southwest.

There is little obstruction to the horizon at any point that is hurtful for observation of any kind.

In excavating for the foundation of the building, the soil was found to be clay and loam to the depth of ten feet, and below this was a thick stratum of coarse gravel in which was placed the footing of all piers for the astronomical instruments. These piers are stone and cement laid in solid masonry, and stand wholly independent of the building and of the ground to their respective bases.

The frontispiece of this number of the MESSENGER gives a faithful view of the building as observed from the southwest, showing the main entrance to be from the south, and into the semi-circular portion on the first floor.

The length of the building, east and west, is 80 feet; north and south, 100 feet. The material of the outer walls is the St. Louis red brick and the trimming and finish are the Lake Superior red sand stone. The clock-room is on the first floor of the main building, and is 27 feet in diameter. The large circular pier for the 16-inch equatorial is in the middle of this room, suitably cased to the height of 7½ feet and provided with shelves and glass doors for the display of specimens of meteors, astronomical photographs, and other objects of interest to the science. Opposite the doors leading to the east and west wings from the clock-room, large recesses were made in the equatorial pier in which are hung the sidereal and mean time clocks, the former facing the door of the east wing or Meridian Circle room, and the latter the door of the west wing, or Astronomical Library. The cases for these clocks are made of cherry and neatly carved, and they form part of the general case before mentioned. By this arrangement, it is believed that the clocks are placed as favorably as possible, at small expense, for temperature and stability of position. They are twelve feet apart, on nearly opposite portions of this solid stone pier, and hence synchronization was not expected, and no evidence of it has been noticed during the last year. The clock-room is provided with good heating apparatus, by which nearly uniform temperature can be maintained in very cold weather. As an experiment to save fuel at such times, four inch tubes were laid in the pier leading from the basement where the steam heating apparatus is, to the recesses, or air chambers behind the clocks, so that a determinate quantity of heat could be carried to these chambers if troublesome irregularities of temperature should occur in the larger clock-room without. The attempt to supply heat in this way has not yet been tried, as the ordinary radiators of the clock-room have been, so far, amply sufficient for the varying temperatures of one Minnesota winter, with only ordinary care. This is known by systematic records of thermometers placed inside the clock cases. Though not yet carefully tested there is little doubt but that the central massive stone pier has had a favorably modifying influence in steadying the temperature of the clock-room. The clocks referred to were made by The E. Howard Clock and Watch Company of Boston, Mass., and are respectively numbered 195 and 196. At another time a showing of the kind of work these clocks have done will be made as it has been learned from an extended series of observations of stars for fundamental places by the aid of the Repsold Meridian Circle. In this clock-room is also the Chronograph, Chronometer Case containing a Bond Chronometer, No. 374, meteorological instruments and the table of telegraph instruments used in transmitting the daily time signals to railways and cities using the Standard Central Time furnished by the Observatory. The following table will show the extent of this service:

TABLE.

COMPANY.	MILEAGE.
Chicago, Milwaukee & St. Paul Railway	2,350
Northern Pacific Railway	3,280
St. Paul, Minneapolis & Manitoba Railway	2,685
Chicago, St. Paul, Minneapolis & Omaha Railway	1,355
Chicago, St. Paul & Kansas City Railway	1,092
Minneapolis & St. Louis Railway	550
Minneapolis & Pacific Railway	288
Minneapolis & Sault Ste. Marie	494
St. Paul & Duluth	152
Total	12,246

The immediate care of the time for this service and the Observatory is given to Miss C. R. Willard, who is responsible for the observations and reductions of star-places for time, care of the clocks and their records and telegraphing time-signals twice each day. The east wing, as shown in cut, is devoted to the Repsold Meridian Circle. A full description of the room and instrument, with a page cut illustrating it, was given in MESSENGER, No. 59, so recently, that repetition now is unnecessary.

The west wing contains the library for astronomy and mathematics. It is the same size as the Meridian Circle room, 26 by 22 feet and 11¾ feet high. The cut shows the windows on the south side. On the west and north, there are two rows of small windows, twenty in all, placed high in the walls giving ample light for library purposes and increasing its shelf room very considerably. This room is used as a study and office for the Director of the Observatory, and for Dr. H. C. Wilson, Assistant Professor of Astronomy. As a library room its advantages are greatly enjoyed. The library now contains about 1,400 bound volumes chiefly pertaining to astronomy and mathematics, and is constantly growing, nearly as rapidly as the real needs of the various lines of work in the Observatory demand. Its most generous friend and benefactor is a prominent Trustee of the college who has already contributed about $2,000 to its support, and is planning larger things for the future.

Adjoining the library, on the east, with a door into the hall-way, leading from the clock-room in the main part of the building, is a small study or class-room designed for the accommodation of special students in astronomy or mathematics. It is 12 by 18 feet in size and is provided with blackboards of ample size, made of fine, large slabs of the Pennsylvania slate. Though small, this room has proved to be one of the most useful in the Observatory. On the opposite side of the hall, before referred to, is the janitor's room, 11 by 13 feet. Next to this room is the door-way leading to the basement and the stairs to the second story and the large equatorial observing room. The hall leading to the north from the clock-room, opens into the prime vertical room, which is 13 by 14 feet, and 11¾ feet high. In it is mounted, in the prime vertical, a 3-inch Fauth transit instrument, on an independent, rectangular pier 34 by 18 inches, and 35 inches high, above the foor. The roof of this room is provided with shutters exactly like those belonging to the meridian circle room. On the north side of the building, and connected to it by the prime vertical room, is a class and lecture-room twenty-four feet square with two outside entrances. Behind the rostrum in the west side is a clear white wall space, sixteen feet long by nine and one-half feet high, prepared especially for the projection of pictures by the stereopticon. This room will comfortably seat fifty students for lecture or recitation purposes, and to this end chairs have been provided with facilities for taking notes. From the cloak-room of the north entrance is the stairway leading to the small equatorial room with open shutter as shown in the cut. In this observing room is mounted the Clark 8¼-inch equatorial which was built for Carleton College in 1878. It is a fine telescope and is now as good as on the day of its first mounting. The pier supporting it is carried up from the basement with solid masonry of stone and cement to the floor of the observing room. Above this floor it is built of brick to the height of seven feet, and cased with wood. The brick base was found not to be sufficiently firm for a proper support of the equatorial, so a cast iron rectangular cap, of the size of the top of pier, and three-fourths of an inch in thickness, was furnished. Through the corners of this piece four iron rods were run and imbedded into the angles of the pier and finally very securely anchored in the cap-stone below. This arrangement gives sufficient rigidity to the equatorial for all ordinary observations. How it will stand the test of photography remains yet to be seen. More will be said about this when the trial has been made, for which the observers are now almost ready.

As this article is becoming much too long for the patience of our readers, we fear, we must leave till another time further description of instruments and the two fine domes built by Messrs. Warner & Swasey, of Cleveland, Ohio, and notice of astronomical work now in progress.

CRITICISM OF A NEW THEORY OF SOLAR HEAT AND GRAVITATION.

EDWIN S. CRAWLEY.*

For THE MESSENGER.

The following article, which is essentially a review, is the result of a perusal of Mr. J. H. Kedzie's "Speculations upon Solar Heat, Gravitation and Sun Spots." Mr. Kedzie unites the consideration of these three subjects in a single volume because, according to the system which he puts forward, they owe their origin to a common cause. Mr. Kedzie lays no claim to being a professional scientist; he calls himself a layman in the work; yet, it seems, considering the meagre success that has attended the labors of even the greatest scientists in these fields, we ought to welcome and give due consideration to all suggestions that are thoughtfully and earnestly presented. Mr. Kedzie's ideas seem to possess these merits, although at times he has trodden upon debatable and even upon untenable ground. But whatever faults we find with his theory, let us give him all due honor for advancing a theory of solar energy at least as plausible as any, and for attempting the solution of one of the greatest problems of modern physics—one which curiously enough has been much neglected by the world of science—the cause of the action that we call gravity.

* University of Pennsylvania.

Since scientists have become convinced that the enormous amount of energy continually poured forth by the sun must be made up to him in some way, there has been no lack of discussion and theorizing as to what constitutes this vast magazine upon which he draws. It need not be repeated here what has been the outcome of all this speculation. No theory has ever been advanced that has stood the test of critical examination, and none that has been adopted by scientists at large.

The theory of gravitation has fared even worse. Newton in announcing the law of gravitation took care to state expressly that the idea of one body acting upon another at a distance without the intervention of some medium was unphilosophical and absurd. Whatever may be the *cause* of the force whose law he discovered, he knew it could not be in reality, what it is always called, an *attraction*. Beyond this the theory of gravitation has made no advance; on the other hand it has in some cases seemed almost to take a step backward; for so accustomed are we to speak of it as an *attraction*, and so powerful is the influence of custom that many have appeared to take it for what it is called regardless, or at least forgetful, of the difficulties that lie in the way of such a view. The few theories that have been advanced to account for this universal force have been easily demolished, and the case really stands to-day in about the same position as when Newton left it.

The great advance, however, that has been made in physical research since Newton's time, and especially of late years, is bringing this problem daily more and more within the possibility of solution.

I shall now explain as briefly and clearly as possible Mr. Kedzie's theory. I shall confine myself entirely to the application of it to solar heat and gravitation, the application to sun spots being rather a side issue.

The foundation stone of his whole structure is the conservation of energy. His argument is this: It has been demonstrated to the satisfaction of the scientific world that the amount of energy in the form of heat put forth by the sun is constant or practically so; and that therefore he must have access to some well nigh inexhaustible reservoir of energy upon which he can draw to make up for the waste caused by his radiation. All theories that attempt to derive this supply in any way from the sun himself have been efficiently controverted, and are besides opposed to the doctrine of the conservation of energy. It must come therefore from an outside source. Now it is sufficiently evident that it cannot come of itself, but must be conveyed by some medium, and the only medium in contact with the sun is ether; hence the ether must be the vehicle. (It is generally conceded that there are good reasons for denying the existence of any other interstellar atmosphere.) For ages upon ages the suns of space, whose number we cannot conceive, have been pouring into the ether of space vast stores of energy in the form of heat. What has become of it all? It must have been conserved in some way. If so then there must be some outlet for the energy thus continually injected into the ether in the form of heat. It must equally be true that the amount of energy conducted from the ether must be equal to that given to it. In other words each of these solar bodies which are capable of radiating such intense heat into space must also have the power of laying hold upon the faint and cold radiations that reach him from his companion suns, and by their means continually refresh himself. Small as is the amount of energy thus received by any sun from a single one of his companions, the total derived from all the stars that stud the firmament will be equal to the total amount of energy thrown off; or, if it is not, his temperature will steadily decrease until an equilibrium is established. The details of this grand interchange of energy, which, whatever objections may be found to it, can still claim for itself that combination of grandeur and simplicity which we find to be characteristic of so many of the seemingly complex phenomena of nature, are conceived by Mr. Kedzie as follows: The suns of space emit by radiation energy in the form of intense heat; these rays or waves of heat, as they are borne onward through the ether, lose to some extent the special form of vibration which constitutes the form of energy we know as heat, the energy thus lost reappearing in another form borne by vibrations of the ether differing in character from the heat waves, but of a form which these latter, as their amplitude becomes less, have a tendency to adopt. The other form of energy thus developed at the expense of the heat is gravitation. All space is thus filled with ether bearing in straight lines in every conceivable direction by means of its vibrations these two forms of energy, heat and gravitation. Upon contact with the solar surface all the energy inherent in the ether vibrations that is not in the form of heat is restored to that form. Thus the dim rays of the stars that to us are so cold and feeble, because our eyes can detect only the luminiferous and not the force-bearing waves, become such potent agencies when they reach the solar surface. The surface of the earth is not adapted, as is that of the sun, for restoring the force waves to those of heat and thus our orb is saved from being a "tophet of fire." It has been able to reach its present condition mainly on account of its small bulk, for when it separated from the sun at its moment of birth it must have been of the same condition and temperature as its parent orb; but, having so much more surface in proportion to its mass, it was unable to appropriate from the ether enough energy to make up for its greater proportionate radiation, the radiation being proportional to the surface, and the amount of energy received from the ether being proportional to the mass. Thus the earth has, as noted above, cooled down to such a condition that it can no longer change the energy inherent in the ether back to heat.

In this connection Mr. Kedzie has done some contradictory theorizing. It is perfectly consistent with the application of his theory to gravitation, which he makes further on, to say that a body will take energy from the ether in proportion to its mass, each molecule taking its fixed amount of energy so to speak, but in applying the same theory to solar heat he says something very different. In order to explain why it is that the sun receives heat from the surrounding ether he conceives that the *surface* of the sun possesses some power of seizing upon the energy contained in the ether and transforming it back to heat. In that case the sun must receive energy from the ether in proportion not to its mass, but to its surface, unless we conceive that the whole mass of the orb throughout its every molecule possesses the same power of transforming all energy into heat. This, however, is inferentially denied by the author's attempt to endow the photosphere, and the photosphere only, with this power. He suggests that the peculiar vapor-like formation of the photosphere may be caused by carbon suspended in a state of possibly ultimate subdivision in the solar atmosphere, and that the effect of the ether waves upon this is similar to; if not identical with, the action of an electric current meeting carbon in its circuit as we are familiar with it upon the earth. He merely suggests this knowing that the presence of carbon in the sun has never been proven. He gives some good arguments, however, in favor of this view based upon terrestrial analogies in the behavior of carbon. If the solar bodies receive energy from the ether in proportion to their surfaces, as well as radiate it in that proportion, then the earth, when separated from its parent, even though much its inferior in bulk, must have still presented the same conditions of surface as the sun, and could never have cooled more rapidly than he has done. This view of the case being obviously untenable, if there be any truth in the theory, it must be that the heavenly bodies receive energy in proportion to their masses and radiate it according to their surfaces. Thus each will reach a point of equilibrium whose temperature will be lower the smaller the body.

Mr. Kedzie's theory of gravitation is very closely associated with that of solar heat. In fact he makes them, as has already been indicated, correlative forms of energy. Starting with the fact, which everyone must admit, that one body cannot act upon another at a distance without the intervention of some medium, and assuming that the ether is the only universal medium, he argues that the force exerted by every particle of matter in the universe upon every other particle, that we call "attraction of gravitation," must use the ether as a vehicle. Further, since it is impossible to suppose such a tenuous substance as the ether to be capable of exerting a pull, the gravitative effect must be the result of a push.

His theory, therefore, is that all space is filled with rays or waves of force, darting in every conceivable direction, which in the beginning started as heat rays from the infinity of solar bodies scattered through space, and by the process of transformation, referred to above, have been metamorphosed into the correlative form of energy, the force of gravitation. These waves of force impinge upon every molecule of every body in the universe. If they affect any body equally upon all sides their combined effect will be null, and the body will remain motionless, but if two bodies are in proximity, as, for example, the earth and the sun, each one will cast a "dynamic shadow" upon the other. That is, each molecule of one will intercept a ray of force from each molecule of the other and hence will prevent the second from being acted upon on the side turned toward the first just to that extent, that is, to an extent proportional to the number of molecules of the first body or to its mass. The bodies will therefore tend to approach each other, and, since the action just described is mutual, the magnitude of this tendency to approach will be proportional to the product of their numbers of molecules, that is, to the product of their masses. Moreover, it is easy to see that this action would share the other well-known property of the attraction of gravitation, that of being proportional to the square of the distance. According to this theory every point in the universe becomes a centre towards which rays of force from every direction converge. Hence a body at a unit's distance from another will intercept from the latter just four times the number of rays of force that the same body would intercept at a distance of two units from the second; since the law here for rays converging to a point must be the same as for those radiating from a point.

This attempted explanation of two of the greatest mysteries of science is certainly a bold and novel one. Let us not on that ground, however, refuse it due consideration. For while it seems that many grave objections to it can be found, yet it may be a step in the right direction; the first, perhaps, that will ultimately lead to the true solution. As stated above, it has the advantage of simplicity. It fully recognizes the absurdity of action at a distance, and in its attempt to explain the mutual gravitative influence of material bodies by the intervention of a medium (the only philosophical way of looking at the question), use is made of the ether. This, it seems, is quite in keeping with the custom of nature in other fields of using the same instruments for as many purposes as possible.

So much for the theory taken as a whole. When we come to view it in its details, we find numerous cases in which it seems to be opposed to many well established facts, and in one or two instances to be inconsistent with itself.

The degradation or transformation of waves of heat into waves of another character or form, the bearers of gravitative force, is the first point to which we will turn our attention. If this is the true state of the case we have an instance of one form of energy passing spontaneously into another form. Has this ever been observed in any other instance? The author simply states that as the waves of heat lose more and more their amplitude as they become more widely dispersed in space from their center ot radiation, they tend spontaneously and gradually to pass into this other force-bearing form of wave. He makes no real attempt to explain it, based upon anything but the briefest deductive argument put forward merely as a suggestion; and indeed confesses himself unable to do more. Yet he adopts it provisionally, as being a necessary adjunct to his theory. Now it seems to me quite as absurd to imagine such a transformation of energy taking place without any cause acting to produce the change as to imagine that a body moving through void space in a straight line could suddenly, or, to make the comparison more exact, gradually change in direction of motion. If this transformation takes place in some of the rays, why not in all? It is true that the number of stars that are dark to our vision exceed by millions those that we can see; but the telescope which reveals their presence to us shows also that if we fail to see them unaided, the fault is due to us and not to the failure of their light. Neither are the star beams absolutely cold, as Mr. Kedzie has implied. In some instances the heat received from an individual star has been measured, and, though very small, it is still finite.

Another vital feature of Mr. Kedzie's theory is the necessity of having these force waves darting in every conceivable direction through space; that is, no more in one direction than in another. Now, since the force waves come ultimately from the stars, it is easily seen that to render such a condition of things possible the stars must be sown upon the heavens with the greatest regularity, any given area of the celestial dome containing approximately the same number of solar orbs. Mr. Kedzie frequently in his book implies that this is a fact about which there is no question. Does it require more than a glance at the heavens on any clear night to show the fallacy of such an assumption? Nor do our eyes deceive us here. The telescope reveals the same disparity in the arrangement of the stars, showing how, as we approach the galaxy, the number of stars of all magnitudes visible in a given area of the heavens increases with marked rapidity until, when the galaxy itself is reached, their number is countless. An approximate estimate of the shape and dimensions of the material universe has even been attempted, based upon the observed differences in the number of stars in equal areas of the heavens. Every one must see, therefore, that if the gravitative impulse originates as Mr. Kedzie supposes, then it will be strongest in what may be spoken of roughly as the plane of the galaxy. But if this were true bodies upon the parts of the earth turned toward the more sparsely sown regions of the heavens would weigh less than bodies of equal mass upon other parts of our planet. In fact during the earth's diurnal revolution bodies in any one place would pass through a great range of weights by being brought continually under different parts of the heavens and in the course of the day under all parts. The conclusion is obvious.

Let us now glance at a point which the author has entirely overlooked, although it follows directly from the doctrine of the conservation of energy. He says that these rays of force impinging upon a cold body such as the earth produce the effect of gravitation, the earth tending to fall under their influence toward the sun in virtue of the loss of pressure on the side of the planet turned toward the sun due to his intercepting a part of the force rays on that side; but, on the other hand, when these same waves impinge upon the solar surface they become changed to heat in proportion (as is stated before, where another inconsistency is pointed out) to the mass of the sun. It follows therefore that the sun and other solar bodies cannot possess the property of gravitation; for if all the energy they receive from the ether waves, or, in fact, if any of it, is transformed to heat, then none or only a part is left to give them the push required to make them conform to the law of gravitation. Is

Mr. Kedzie ready to deny the universal application of the law of gravitation? If his theory were true the p ortof the law in regard to the "product of the masses" would be true only in the case of cold bodies. That he would never consent to take such a stand I am fully convinced, for he has a true respect for the well established facts of science. But if he were inclined to such an attitude we could still answer him very simply. In the class of double stars known as binary systems where one solar body revolves about another, or rather both revolve about their common center of gravity, we have visible proof that hot bodies are no exception to Newton's law.

One cannot read this theory without being reminded of Le Sage's theory of ultramundane corpuscles. This of Mr. Kedzie's, however, is essentially different from the older one, and it seems is free from the defect that was fatal to the latter. The energy in this case is conveyed by a wave motion and if unused in producing a gravitative effect it need not turn to heat but may be reflected or may pass on in a way similar possibly to an electric current through a conductor. In fact whenever no gravitative effect is produced it must be because equal impulses are received on opposite sides of the body; and hence the phenomenon would be more analogous to two currents passing in opposite directions along the same conductor.

Although we have found fault with Mr. Kedzie's theory in so many of its most important parts, yet in some of its fundamental principles it seems to the writer that he has taken a very good stand and the value of his work consists in his having presented a clear view of the nature of the problem to be solved. This is always an essential introduction to the right understanding and correct solution of every problem, yet in how many cases do men of science, men who ought to know better, go to work without having taken properly this preliminary step. Particularly is this the case in a field like that of astronomy where it is almost impossible to restrain the imagination from soaring far beyond the legitimate pale of fact and where it is so much more difficult to prove or to refute the results of even fanciful speculation because it is impossible to reproduce the conditions in terrestrial experimentation. The sooner we come to realize distinctly that it requires an expenditure of energy to curve the planets in their orbits around their central orb no less than to keep up the seemingly eternal fires of the solar bodies the better it will be for our investigations into these two great problems. We must not forget that some medium is necessary as well for conveying energy in the form of gravitation from one body to another as for conveying it in the form of heat. Now it is inconceivable that the result of gravitation as we observe it could be produced by a pull, since there is no connecting link between the bodies to exert the pull; hence it must be the result of a push. Since the ether is the only medium of which we are cognizant filling all space both interstellar and intermolecular it is most natural to look here for the medium. This view of the case is strengthened when we remember that there is continually poured into the ether from the solar bodies enormous stores of energy in the form of heat and that this energy must all be conserved, must all go somewhere and do something. It seems to me that if we could learn more about this most mysterious and subtle medium we should make a great step forward toward the solution of many of the puzzles of physics. We should then know more of the ultimate nature of force and matter. If we learn these lessons from Mr. Kedzie's book, he will not have written in vain.

ON COMPANION ASTEROIDS.

BY W. H. S. MONCK, DUBLIN, IRELAND.

For THE MESSENGER.

Professor Kirkwood, in his recent work on The Asteroids, notices some coincidences between the elements of adjacent pairs, naming Hilda and Ismene, Sirona and Ceres, Fides and Maia, and Fortuna and Eurynome. "Such coincidences," he observes, "can hardly be accidental. Original asteroids, soon after their detachment from the central body may have been separated by the sun's unequal attraction on their parts. Such divisions have occurred in the world of comets. Why not also in the cluster of minor planets?"

By "adjacent pairs," Professor Kirkwood means those which stand next to each other in respect of mean distance. But had he extended his view he would have seen, I think, that many pairs not strictly adjacent in this respect exhibit similar traces of a common origin. Their number is far too great to be explained by chance, and, moreover, the coincidences often occur between asteroids which depart widely from the general average. Take, for instance, Lachrymosa and Calliope, which, so far as mean distance is concerned, are separated by Kolga, but whose eccentricities are the second and third lowest in the entire table:

	Mean Dist.	Eccen.	π	☊	i
Lachrymosa	2.8926	0.0149	127°52′	5°43′	1°48′
Calliope	2.9090	0.0193	62 43	4 47	1 45

The close approach to circularity in these orbits renders the difference in the longitude of the perihelion less important. It is curious, however, that in the same element only is there any material difference between the orbits of Fides and Maia referred to by Professor Kirkwood, but which I give here for the purpose of comparing them with another pair, Clytie and Frigga, as the elements of all four exhibit no inconsiderable likeness:

	Mean Dist.	Eccen.	π	☊	i
Fides	2.6440	0.1758	66°26′	8°21′	3° 7′
Maia	2.6454	0.1750	48 8	8 17	3 6
Clytie	2.6652	0.0419	57 55	7 51	2 24
Frigga	2.6680	0.1318	58 47	2 00	2 28

If the longitude of the perihelion may be treated as unimportant we have another pair agreeing remarkably with the above save that the ascending nodes differ by 180°, viz.:

	Mean Dist.	Eccen.	π	☊	i
Alceste	2.6297	0.0784	245°42′	188°26′	2°56′
Eunomia	2.6437	0.1872	27 52	188 26	2 56

To which latter pair perhaps Hestia may be added.

I add some other pairs which seem to be worthy of enumeration, viz.:

	Mean Dist.	Eccen.	π	☊	i
1. Bianca	2.6653	0.1155	230°14′	170°50′	15°13′
2. Asporina	2.6994	0.1065	255 54	162 35	15 39
1. Angelina	2.6816	0.1271	125 36	311 4	1 19
2. Garumna	2.7286	0.1722	125 56	314 42	0 54
1. Astræa	2.5786	0.1863	134 57	141 28	5 19
2. Calypso	2.6175	0.2060	92 52	143 58	5 7
1. Juno	2.6683	0.2579	54 50	170 53	13 1
2. Clotho	2.6708	0.2550	65 32	160 37	11 46
1. Brunhilda	2.6918	0.1150	72 57	308 28	6 27
2. Dynamene	2.7378	0.1335	46 38	325 26	6 56
1. Kolga	2.8967	0.0876	23 21	159 47	11 29
2. Hypatia	2.9163	0.0946	32 18	184 26	12 28

	Mean Dist.	Eccen.	π	Ω	i
1. Aline	2.8078	0.1573	23°52′	236°18′	13°20′
2. Arethusa	3.0712	0.1447	32 58	244 17	12 54
1. Sophrosyne	2.5647	0.1165	67 33	346 22	11 36
2. Ambrosia	2.5758	0.2854	70 52	351 15	11 39
1. Clio	2.3629	0.2360	339 20	327 28	9 22
2. Ilse	2.3795	0.2195	14 17	334 49	9 40
1. Melpomene	2.2956	0.2177	15 6	150 4	10 9
2. Hebe	2.4254	0.2034	15 16	138 43	10 47
1. Gallia'	2.7710	0.1855	36 7	145 13	25 21
2. Istria	2.8024	0.3530	45 0	142 46	26 33

As additional pairs I may mention Olympia and Lætitia, Felicitas and Terpsichore, Eunice and Electra, Liberatrix and Urda, Cœlestina and Ceres (a closer approach, I think, than Sirona coupled with Ceres by Professor Kirkwood. Caroline seems to belong to this family), Œnone and Polyhymnia, Bellona and Chryseis, Ida and Coronis, Eudora and Eos, Scylla and Atala, Hypatia and Walpurga (almost as close as Hypatia and Kolga in the above table. Kolga, in fact, though separating Lachrymosa and Calliope as regards mean distance, belongs to different family of asteroids), Eurynome and Plithia (Althea belongs to this family), Beatrix and Abundantia, Scylla and Atala, Tyche and Martha, Aschera and Pompeia, Io and Cleopatra (with Melibœa as a third sister), Asterope and Clytemnestra, Lumen and Alexandra, Dejanira and Thalia (with Adeona as a third sister), Adria and Phædra, Loreley and Philosophia and many others.

A glance at the list will show that the resemblance frequently extends beyond a single pair and embraces what may be called a family—a circumstance which is known to occur in the case of comets also. I may perhaps notice specially however that the curious triple pair Fides–Maia, Clytie–Frigga, Alceste–Eunomia is almost matched by another triple pair similarly circumstanced, viz., Clio–Ilse, Baucis–Helena and Melpomene–Hebe.

Professor Kirkwood's suggestion that the comets of short period are displaced asteroids is worthy of consideration. The variations of light observed in some of them are cometary rather than planetary characteristics. An examination of their spectra (especially of those which are known to vary in their light) with a powerful instrument might do something to solve this interesting question. Unless the cometary characteristics are impressed on them by the perturbations which displace them from their original orbits (and I do not see why it should do so), we must suppose that they possessed these characteristics originally if Professor Kirkwood be right.

OBLITERATION FROM ILLUMINATION.

BY HENRY M PARKHURST.*

In the use of the wedge for photometric purposes, in the first reduction the scale is assumed to be uniform. Determining by other means the magnitude of a star extinguished at the thick edge, and of a brighter star extinguished at the thin edge, it is assumed that other stars extinguished by the same wedge at the same points will be of the same magnitudes; and that stars extinguished between these two points will be of magnitudes exactly porportional to the relative distances of the points of extinction from the edge.

If the wedge is of neutral-tint glass, and if there is no moonlight or twilight illuminating the field, this will be true within the limits of the errors of observation.

In determining the effect of moonlight or of twilight, it will be useful to consider the very much greater and similar effect of daylight.

It will be noticed at once that the illumination of the field of the telescope by the daylight tends to obliterate stars. It is the same effect that is observed in the absence of the wedge, and in the absence of the telescope. Yet it may be a question whether the absorption of the illumination is not equal to the absorption of the light of the stars themselves, whatever the amount of the absorption, and whether the resultant effect will not be equal in all parts of the wedge, and therefore disappear in differential observations.

The most decisive observations I have made for the purpose of determining that question, were made in July. I placed over the object-glass of my telescope of 9 inches

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aperture, a glass plate with an opening 3 inches in diameter. This plate was varnished, so as to thoroughly scatter the light passing through it. I covered the opening, in the observations to which I especially refer, with small paper caps with apertures differing successively by half a magnitude, the sizes of the caps being arranged so that each should intercept the same amount of light.

At 5 P. M., with the 9.5 mag. opening, Arcturus was scarcely visible in the open field, its locality being exactly made known by a large finder in which it was easily seen. The slightest touch of the telescope made it necessary again to refer to the finder. At 5*h* 26*m* I first succeeded in seeing it through the clear glass carrying the wedge, with the slide in position for use. *It passed entirely across the wedge without being extinguished.* It was still so faint that 5*m* later I could not find it in the open field upon the first setting by the finder. From evening observations the value of this wedge had been ascertained to be about 2.3 mag. As affected by the daylight illumination it did not exceed one-tenth of this amount.

On July 6 I repeated the experiment with three smaller openings. It required about 20*m* for the approaching twilight to cause the star to become visible with a half magnitude smaller cap. Yet in each case within 4*m* of first glimpse, the star passed entirely across the wedge unextinguished. This would indicate that the effective value of the wedge, the same I had used before, was only .1 mag.

From these observations it appears that with an amount of illumination sufficient to produce an obliteration of 8 mag. to 9.5 mag., the effect of the wedge was diminished from about 2.3 mag. to not much more than .1 mag. Yet it may still be a question whether the diminution would be appreciable with the illumination of a small moon, or with the ordinary illumination of the dark sky.

The formulæ showing the amount of the effect of illumination upon obliteration have been obtained by an indirect process; and they still need further verification and correction; and for some purposes the law is not yet established. Although these formulæ manifestly fail under certain conditions, they will probably give the corrections necessary in the use of the wedge, with different apertures, with different eye-pieces, and with very little moonlight or twilight, with an accuracy much exceeding that of the observations. And they will enable us to determine the second differences in the use of the wedge resulting from the fact that the illumination of the back-ground upon which the stars are extinguished becomes less towards the thick end of the wedge.

Commencing an hour before sunset, in the fall of 1886, I observed continuously certain known stars until the end of twilight, with duplicate shades, the second shade consisting of two superposed shades of the same glass as the first. By a comparison and plotting of the results, I deduced the two formulæ:

$$C' = 1.84 - .181\sigma,$$
$$C'' = 4.09 - .340\sigma.$$

In any wedge assumed to come to an absolutely sharp edge, there are three equidistant points, the first at the sharp edge corresponding to the absence of the shades, the second at the point where the absorption is equal to that of the shade C′, and the third at the point where the wedge is twice as thick. In these formulæ the terms relate to the dark sky, and to the obliteration σ produced by an illumination greater than that of the dark sky.

With a black sky, in the absence of all illumination, the first term for the shade C″ should be exactly twice that for the shade C′; and the difference in the formulæ furnishes the means of determining approximately the amount of the obliteration of the dark sky, with the aperture and eye-piece used in the observations.

In the above equations, for the last terms I write

$$-\sigma + .819\sigma,$$
$$-\sigma + .660\sigma;$$

and adjust the last terms of these expressions so that the second shall be the square of the first. This produces the terms

$$-\sigma + .815\sigma,$$
$$-\sigma + .664\sigma.$$

Replacing the equations, thus adjusted, in their original form, and multiplying the first by 2, we have

$$2(1.84 - .185\sigma) = 4.09 - 336\sigma,$$

as the equation the solution of which gives S, the value of σ for the dark sky as compared with the absolutely black sky.

This value of σ, which I call S, = 12.06 mag. It is liable to an uncertainty of perhaps 5 magnitudes, from the uncertainty of the original formulæ; and it is also liable to the criticism that a black sky has an illumination an infinite number of magnitudes less than that of the dark sky; and on the other hand to the criticism that it is improbable that a telescope would show stars twelve magnitudes fainter if transported above our atmosphere. It is a confessedly weak point in my computation, that in applying my formulæ to the use of the wedge with a black sky, I am carrying them into a region of uncertainty, the main dependence in establishing them being upon daylight illumination as affected by the shades. Applying them to a dark sky illumination is still within the region of uncertainty. Yet the other terms being adapted to this value of S, it may be largely in error without appreciably affecting the results obtained from the formulæ as a whole.

The same principle that has been applied to three equidistant points in a wedge applies to each layer into which a wedge may be supposed to be divided. From the above formulæ we may directly derive the wedge formulæ,

$$W = a - \sigma + b^{a}\sigma;$$

in which W represents the absorption at the point *a*, measured either in thickness or from the sharp edge of the wedge; and in the latter case measured either in distance or in the time taken by an equatorial star in traveling the distance. The unit of W being 1 mag., the unit of *a* corresponds to that point of the wedge where, with a black sky, a star would appear 1 mag. fainter from its absorption. *b* is a constant, its logarithm being [9.9782], obtained by dividing the logarithm of .815 by 4.07, which would be the first term for the shade C′ with a black sky, or by dividing the logarithm of .664 by 8.14, the first term for C″ with a black sky, making S = 12.06 as already explained.

The convenient use of the wedge and formula requires its tabulation. A subsidiary table having been formed, it is easy to construct a working table for each wedge in use.

Next arises the question of the correction for the difference of magnifying power or of aperture. This is a single question; for if there is any difference practically between doubling the magnifying power and halving the aperture I am confident that it will not appreciably affect the results.

But while the ratio of the illumination with different apertures or eye-pieces can be readily determined, there is no constant ratio between obliteration and illumination. In my day observations to obtain the effect of changing my eye-pieces, I found that the higher the magnifying power the sooner the star was lost; but this was attributable to the tremulousness of the telescope produced by sliding the eye-pieces, which was not necessary with the lowest power. In my observations of the asteroid Massalia, on June 6, I exchanged two eye-pieces, equivalent to a difference of aperture corresponding to 1 mag. The result could be approximately explained by assuming an obliteration nearly equal to the illumination, subtracting this obliteration from the standard, and also multiplying it by the correction for obliteration given in the table. Perhaps this will be sufficiently accurate for the adaptation of the correction for second differences, for such apertures and eye-pieces as will be likely to be used. But my observations in July seem to show a different ratio in the daylight. In these observations in July the illumination was changed by a cap covering the perforated glass and leaving only the illumination of the central opening as compared with the full illumination, which was only .3 mag. less than that of the complete aperture. The illumination from 5*h* 26*m* to 8 P. M. was thus varied 4.2 mag. in frequently alternating observations. My deduction is a ratio of not more than one-fifth. I cannot be satisfied of the correctness of either ratio until I have discovered the "missing links" connecting the two in one series. Yet the amount of the obliteration to be allowed for will usually be so small that it will be much safer to apply the correction than to continue to employ a uniform scale.

In my variable star work in 1886 I made many observations at different ages and distances of the moon from the observed stars, one series being in December, 1886, at a time when Gore's Nova Orionis was within 2° of the full moon. I did not succeed in discovering any satisfactory law covering all these varying conditions; but I discovered two empirical modes of computation, one adapted to values of obliteration less than 2 magnitudes, and the other adapted to values exceeding 2 magnitudes, the two coinciding in the neighborhood of that value, which gave satisfactory results.

My observations in the twilight, already referred to, and others made for the purpose of verification, gave me a satisfactory table of the obliteration from the twilight at all stages from sunset down to the absence of all twilight.

But there is still another table, of the combination of the two, as important as either, which I have not yet succeeded in forming, although I anticipate being able to form it when the law of the effect of change of aperture is more definitely settled. Such a table will be most needed when there is a small moon, and when observations are to be made in the west which cannot well be deferred until twilight ends. It will not do to add the two amounts of illumination; one-fourth of a magnitude from each source, added together, would make less than a half magnitude; and on the other hand, it will not do to add them by the table for the addition of magnitudes; for by that table they would make a whole magnitude, which is still further from the truth.

Whenever the stars to be observed are sufficiently bright, I prefer to observe them with my deflecting photometer, (described in Harvard Annals, Vol. xviii, in a paper, No. 3, just issued,) which is unaffected by illumination, or rather, in which illumination affects all magnitudes equally. But the largest logarithmic cap available with a given aperture cuts off about four-fifths the light. A wedge with an absolutely sharp edge will therefore permit the observation of stars 1.7 mag. fainter than can be seen in the deflecting photometer. Until the obliteration caused either by the moonlight or twilight or by the two combined equals 1.7 mag. faint stars are observable with the wedge which cannot be observed in the absence of illumination by the other method. This covers a period of more than half an hour before the end of twilight, and up to the quadrature of the moon. With that illumination, the logarithmic caps fail to show stars within 3.4 mag. of their lower limit, and the stars excluded by that limitation will still be observable by the wedge. But even with an accurate knowledge of the fomulæ, this advantage will be much restricted by the difficulties in their application, arising from variability of the sky during the observations.

It was my intention to make observations during the month of July, which would furnish additional information upon the questions I have left vague and undecided. But there was not a single clear evening upon which they could be made. This is the explanation of the unfinished condition of these results; and my apology for this premature publication consists in the fact that the neglect of the source of error now demonstrated to exist may lead to systematic errors in wedge observations.

ON THE VALUE OF ONE REVOLUTION OF A MICRCMETER SCREW.

PROFESSOR GEORGE C. COMSTOCK.

For The Messenger.

The article by Mr. Hill in the August number of the Messenger upon the determination of the value of a revolution of the micrometer screw of an equatorial telescope leads me to suggest that the method of measuring differences of declination for this purpose deserves wider application than seems to be given it. But in order to secure in this way the best results attainable, there are certain conditions to be fulfilled which ought to be kept clearly in mind. These are:

(a) *The difference of declination of the two stars must be accurately known*, not only at some epoch at which the stars may have been well observed with one or more meridian circles, but at the epoch at which they are to be used. This involves a knowledge of the proper motions of the stars and in case their positions are taken from different catalogues, of the systematic corrections to those catalogues.

(b) *The difference of declination should be as great as is practicable*, since the effect of an error here upon the resulting value of the screw diminishes directly with the value of $\Delta\delta$. In order to secure a large value for $\Delta\delta$, stars may well be selected whose difference of declination is much greater than the diameter of the field of any micrometer eye-piece, provided the intervening space is occupied by a sufficient number of other stars to permit of the whole difference of declination being measured in a series of steps. Thus, supposing the two given stars to be *a* and *b* and the intermediate ones *x*, *y*, *z*, we have the difference of declination of *a* and *b* equal to

$$(a-x)+(x-y)+(y-z)+(z-b)$$

This process of subdividing the arc may be extended as far as desired and evidently there is no necessity of knowing the declinations of the intermediate stars since they disappear in the summation.

(*c*) *The stars should be near the pole of the heavens*, in order that they may be observed at all seasons of the year in as nearly as possible the same position of observer and instrument. This condition is of especial importance if the effect of temperature upon the value of the screw is to be investigated.

These three conditions are approximately fulfilled by the pair of stars *43 H Cephei* and *Bradley 95* which I have used in investigating the value of the micrometer screw of the large equatorial of the Washburn Observatory. The magnitudes and approximate positions of the stars for 1888.0 are:

43 H Cephei	4.3 mag	R. A. = 0h 53m 34s	Decl. = +85°39′
Br. 95	6.2 "	= 0 57 19	" = +86 33

The stars lie on the border of the galaxy and the space between them is occupied by a considerable number of stars between the 8th and 10th magnitudes. The particular set of these stars which I have found most convenient for use is given in the following table in which Δx denotes the difference of declination of two consecutive stars and Δy the corresponding coördinate measured on a great circle perpendicular to Δx and reckoned positive in the direction of increasing right ascensions:

Stars.	Magnitudes.	Δx	Δy
43 H Cephei – a	4.3...... 9.5	+2.7′	+6.5′
a – b	9.5...... 9.	6.0	+1.4
b – c	9. ...... 8.8	2.6	–6.6
c – d	8.8...... 9.	5.5	+2.1
d – e	9. ......10.	5.7	+2.8
e – f	10. ...... 9.	7.3	–0.6
f – g	9. ...... 9.	6.4	+4.0
g – k	9. ...... 8.5	7.7	–2.1
k – l	8.5...... 9.	5.6	–4.0
l – Br. 95	9. ...... 6.2	4.3	+1.2

With a smaller telescope and larger field of view than the one here used (12′) a smaller number of steps would, of course, suffice to cover the distance.

The observing program which I have adopted for measures of this pair has been the following: Determine the parallel and clamp the position circle at its proper reading. Bring a pair of stars into the field of view so that they are symmetrically placed with respect to the center of the field. Start the driving clock and measure the difference of declination by the method of double distances, usually three bisections in each position of the movable thread. Note the temperature as often as convenient. The difference of declination of each pair of stars in the arc having been measured, the measures are to be corrected for differential refraction and for the convergence of the declination circles of the stars. If Δx denote the measure, $\Delta\delta$ the corrected difference of declination, this last correction is expressed by the equation:

$$\Delta\delta = \Delta x + \tfrac{1}{2}\Delta x(\sin \Delta y \tan \delta)^2$$

To obtain the value of $\Delta\delta$ in seconds of arc I have made a discussion of 143 observations of 43 H Cephei, and 72 observations of Br. 95 extending from Bradley, 1752, to Washburn Observatory observations of 1888. To avoid the effect of systematic errors in the catalogues I have made use of those authorities only in which the positions of both stars are given, and in which the effect of such errors may be supposed nearly eliminated in taking the difference of the coördinates. From this discussion I find that the difference of declination referred to the mean equinox of the beginning of any year, t, is expressed by the formula

$$\Delta\delta = 3215''.98 \pm 0''.11 - 0''.076\,(t-1865) - 2''.81\left(\frac{t-1865}{100}\right)^2 - 0''.75\left(\frac{t-1865}{100}\right)^3$$

The difference of declination for any year, computed from this formula must be reduced to the apparent equinox of the date of observation by the expression:

$$\text{Reduction} = -\{0''.011\tau + [8.906]A + [8.210]B + [8.365]C + [7.475]D\}$$

in which τ, A, B, C, D, are the star numbers given in each volume of the American Ephemeris and the numbers enclosed in brackets are logarithms whose characteristics have been increased by 10.

As an example of the results obtained in this way I give the following three determinations of the value of one revolution of the micrometer screw of the 15½-inch telescope of the Washburn Observatory:

Date.	Observed Value.	Temperature.	Red. to 0°F.	Value at 0°F.
1888, July 28,	10″.4374	74°F.	−0″.0104	10″.4270
" 30,	.4379	78	.0109	.4270
Aug. 31,	.4331	56	.0078	.4253

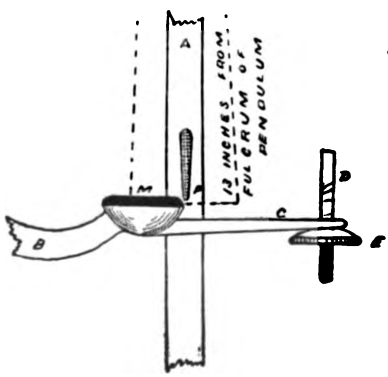
The value of the temperature coefficient of the screw has not yet been well determined and the reductions to 0° F. are somewhat uncertain.

ON A MAKE-AND-BREAK-CIRCUIT FOR ASTRONOMICAL CLOCKS.

BY WILLIAM R. BROOKS.*

For The Messenger.

In my studies and experiments upon a new printing chronograph, I desired an efficient make-and-break electric circuit device. That is to say for the purpose of unlocking the escapement of the chronograph every alternate second (a spring operating it in the opposite direction in the intervening second), I needed a device which should close, and *hold the circuit closed* one second, open and *leave it open* during the next second, and so on. The arrangement I represent in the annexed sketch fulfils all the requirements so admirably, and without disturbing the rate of the clock, that I am sure it will prove useful to others, and in other directions. For instance, to operate a sounder, to make audible the beats of the clock at a distance, it is much better than the *double click* of the sounder by the usual methods. By this arangement we have the *single* down click one second, then the *single* up or back click the next second. By regulating the tension spring of the sounder the up and down clicks may be made perfectly uniform in intensity.



The accompanying sketch gives a front view of my arrangement. A is a part of the pendulum rod shown broken off both above and below. P is a platinum knife projecting outwards and downwards from the rod at a point 13 inches from the top or fulcrum of pendulum. The arc of vibration at this point is small, in my clock less than one inch. M is a mercury trough *considerably longer* than half the length of the vibration of the platinum knife, P. The mercury trough is supported by the

* Smith Observatory, Geneva, N. Y.

arm, B, which is pivoted to the left hand side of the clock case (not shown in the sketch), also by the arm C, resting upon the thumb-nut E, threaded on the stud D, the latter being fastened to the top of the case. The pendulum is represented as hanging perpendicular, or in the middle of its arc. When the pendulum is in this position the mercury trough M is so adjusted sidewise to the left hand of the platinum knife that they just clear each other. One pole of the battery is connected to the platinum knife, the other pole to the mercury trough in the usual way. The dotted lines show the arc of vibration of the pendulum at this point.

The instant the pendulum passes the middle of its arc swinging to the left hand, the platinum knife enters the mercury and closes the circuit. As the trough of mercury is considerably longer than half the length of the arc of vibration, —and this is the gist of the device,—the circuit remains closed until the pendulum returns to the middle of its arc, or just one second. The circuit is then broken, and remains open just one second as the pendulum swings to the right and returns. It is easy to adjust the mercury trough so that the periods of open and closed circuits are equal to within one-two hundredth of a second.

The arm B may be made hollow to connect with a reservoir of mercury if desired. I have not found it necessary, as once filling of the trough M will last for several weeks. By means of the nut E the mercury trough may be lowered away from the platinum knife when not in use. The Daniell gravity cell is the best form to use.

This device has been in use by me for nearly a year, and is perfectly satisfactory in all respects. It is only after such a test that I now recommend it to my fellow workers.

CURRENT INTERESTING CELESTIAL PHENOMENA.

THE PLANETS.

Mercury will be in conjunction with the moon, south 8°09′, Oct. 6, at midnight; at greatest elongation east from the sun, 25°14′ on the 8th at 10 A. M.; in conjunction with Venus, 3°09′ south from the latter, Oct. 9 at 5 P. M.; stationary in right ascension on the 20th, after which it will begin to retrograde; at inferior conjunction with the sun Oct. 31 at 6 P. M. central time, at which time Mercury will be only 10′ south of the sun's south limb. Mercury will not be in favorable position for observation in the northern hemisphere at the elongation of this month, because of its southern declination.

Venus will not be in favorable position for the same reason during this month, although it will set from 50*m* to 75*m* later than the sun. It is 1.5 times the sun's distance from the earth, yet its disk is almost wholly lighted, so that it will be a quite conspicuous "evening star" in the southwest. Venus will be in conjunction with the moon Oct. 6, and again Nov. 5, being about 5° south of the moon in both instances.

Mars sets about three hours later than the sun during the whole month, but his altitude is now so low that observers in northern latitudes will get little satisfaction out of him. Quite a considerable amount of matter has been published in the periodicals of the last two months concerning the so-called "canals" of Mars. In *Astronomical Journal*, No. 178, Professor Hall states that he examined the disk of the planet on eighteen nights, from June 1 to July 2 (with the 26-inch equatorial at Washington), but "was not able to see anything like the regular canals drawn by European observers, although the usual reddish and dark spots and markings were visible nearly every night." In No. 181 of the same journal Professor Holden publishes the results of observations made with the great Lick telescope from July 16 to Aug. 10, 1888, with a plate giving fac-similes of twenty-one drawings made by himself and Professor Keeler, together with copies of seven drawings made by Professor Holden with the 26-inch equatorial at Washington, five of them in 1875, one in 1877 and one in 1879. In nearly every one of these drawings some of the canals are shown, and Professor Holden says, "With regard to the canals it appears that we have not seen any of them double, although many of the more important have been sketched as broad bands covering the spaces on M. Schiaparelli's map which are occupied by pairs of canals and by the space separating the members of each pair." He also says later, after speaking of the unfavorable conditions under which these observations were made, "we have, however, seen enough of the workings of the great telescope on Mars and other objects to know that its powers are amply adequate under favorable conditions; and we confidently expect the next two oppositions to furnish the most conclusive evidence on these highly interesting questions." The numbers of *L'Astronomie* for August and September contain interesting articles on this subject by Camille Flammarion, the editor, and Professor Terby of Louvain, with many drawings showing some of the canal-shaped markings. In *Ciel et Terre* for August 1 and 16 Professor Terby gives a complete review of all the observations of these markings, with some splendid plates of drawings made this year by Schiaparelli at Milan with his new 18-inch refractor, and by Perrotin at Nice with a 30-inch refractor. All of these go to completely confirm the discoveries made by Schiaparelli in 1877 and 1881–2, as to the existence of the canals and of their duplication. In May last Professor Perrotin announced that one of the small continents had disappeared, being inundated by the bordering sea. Later drawings show that this continent has reappeared, and has much the same appearance as in 1877 and 1878; showing that the inundation, if such it was, has subsided. It has been suggested by M. Fizeau in a note to the French Academy (*Comtes Rendus*, June 25), that the canals on Mars point to a glacial condition on the surface of that planet similar to that which once existed upon the earth, but of much greater extent in consequence of the lower temperature prevailing on Mars, and exhibiting in consequence movements and ruptures of a much more pronounced character.

Jupiter will be in conjunction with the moon 3°33′ south, Oct 8, 6.40 P. M. He will not be in favorable position for observation because of low altitude and approach to the sun. Very little has been published recently concerning this planet. The ephemeris of the red spot is not given this month because it can be seen with very great difficulty, if at all.

Saturn is again coming into good position for observation in the morning. This planet may be found in the east between Cancer and Leo, rising at midnight about the middle of the month. Saturn will be in conjunction with the moon Oct. 28, and will be occulted by the moon Sept 30, *22h 17m*, Washington mean time.

Uranus is in unfavorable position for observation at the present time.

Neptune is in the constellation of Taurus north and west of the Hyades, and will have a retrograde motion during the month. This planet will be in conjunction with the moon Oct. 22, 0*h* 57*m*, Washington mean time.

MERCURY.

	R. A. h m	Decl.	Rises. h m	Transits. h m	Sets. h m
Oct. 5	14 18.6	−16°39′	8 25 A. M.	1 18.9 P. M.	6 21 P. M.
15	14 52.1	−19 50	8 32 "	1 13.0 "	5 54 "
25	14 51.0	−18 49	7 47 "	0 32.8 "	5 18 "
Nov. 4	14 17.3	−12 20	5 59 "	11 12.8 A. M.	4 26 "

VENUS.

Oct. 5	14 15.0	−13 21	8 06 A. M.	1 15.5 P. M.	6 25 P. M.
15	15 03.3	−17 33	8 33 "	1 24.2 "	6 16 "
25	15 53.5	−21 01	9 00 "	1 35.0 "	6 10 "
Nov. 4	16 45.7	−23 31	10 25 "	1 47.8 "	6 11 "

MARS.

Oct. 5	17 03.5	−24°25′	11 46 A. M.	4 04.0 P. M.	8 22 P. M.
15	17 35.6	−24 55	11 40 "	3 56.2 "	8 12 "
25	18 08.0	−25 01	11 34 "	3 49.1 "	8 04 "
Nov. 4	18 40.8	−24 40	11 25 "	3 42.6 "	8 00 "

JUPITER.

Oct. 5	16 07.9	−20 24	10 30 A. M.	3 08.0 P. M.	7 46 P. M.
15	16 15.7	−20 46	10 00 "	2 36.4 "	7 13 "
25	16 24.0	−21 07	9 30 "	2 05.4 "	6 40 "
Nov. 4	16 32.9	−21 28	9 02 "	1 34.9 "	6 08 "

SATURN.

Oct. 5	9 21.1	+16 20	1 12 A. M.	8 22.6 A. M.	3 33 P. M.
15	9 24.5	+16 06	12 37 "	7 46.6 "	2 56 "
25	9 27.4	+15 54	11 58 P. M.	7 06.5 "	2 15 "
Nov. 4	9 29.7	+15 45	11 25 "	6 32.9 "	1 41 "

URANUS.

Oct. 5	13 04.8	− 6 15	6 27 A. M.	0 05.3 P. M.	5 44 P. M.
15	13 07.1	− 6 30	5 54 "	11 28.5 A. M.	5 03 "
25	13 09.0	− 6 41	5 14 "	10 51.5 "	4 29 "
Nov. 4	13 11.8	− 6 57	4 38 "	10 14.3 "	3 50 "

NEPTUNE.

Oct. 5	4 01.3	+18 54	7 36 P. M.	2 59.4 A. M.	10 23 A. M.
15	4 00.5	+18 52	6 56 "	2 19.3 "	9 43 "
25	3 59.6	+18 49	6 15 "	1 39.1 "	9 03 "
Nov. 4	3 58.5	+18 46	5 37 "	12 58.7 "	8 20 "

THE SUN.

Oct 5	12 47.6	− 5 06	6 03 A. M.	11 48.2 A. M.	5 33 P. M
10	13 05.9	− 7 00	6 09 "	11 46.8 "	5 24 "
15	13 24.4	− 8 53	6 16 "	11 45.6 "	5 15 "
20	13 43.2	−10 42	6 22 "	11 44.7 "	5 07 "
25	14 02.3	−12 26	6 29 "	11 44.1 "	4 59 "
30	14 21.7	−14 07	6 36 "	11 43.7 "	4 52 "
Nov. 4	14 41.4	−15 41	6 43 "	11 43.7 "	4 45 "

Occultations Visible at Washington.

Date.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean T.	IMMERSION. Angle f'm N. Point.	EMERSION. Wash. Mean T.	EMERSION. Angle f'm N. P't.	Duration.
			h m	°	h m	°	h m
Oct. 10	14 Sagittarii	6	6 36	1	Star 8.4′ N. of moon's limb.		
13	30 Capricorni	5½	10 57	75	12 03	242	1 06
14	39 Aquarii	6½	12 29	14	13 09	297	0 40
15	74 Aquarii	6	5 25	72	6 43	244	1 18
16	B.A.C.8274	7	10 33	55	11 56	241	1 23
20	μ Ceti	4½	5 26	63	6 21	255	0 55

Phenomena of Jupiter's Satellites.

	Central Time. d	h m			Central Time. d	h m	
Oct.	2,	6 35 P. M.	I Tr. Eg.	Oct.	17,	5 32 P. M.	I Oc. Re.
	2,	7 36 "	I Sh. Eg.		18,	5 06 "	I Tr. Eg.
	3,	6 57 "	II Sh. In.		18,	5 55 "	I Sh. Eg.
	3,	7 25 "	II Tr. Eg.		19,	5 30 "	II Oc. Dis.
	7,	6 45 "	III Sh. In.		25,	5 36 "	I Sh. In.
	9,	6 21 "	I Tr. In.		25,	6 56 "	III Ec. Re.
	9,	7 17 "	I Sh. In.		25,	7 07 "	I Tr. Eg.
	12,	7 01 "	II Ec. Re.		28,	5 09 "	II Tr. Eg.
	14,	7 10 "	III Tr. In.		28,	6 31 "	II Sh. Eg.

Phases of the Moon.

		Central Time. d	h m
New Moon	Oct.	5	8 34.2 A. M.
First Quarter		11	11 29.9 P. M.
Full Moon		19	3 09.0 "
Last Quarter		27	7 55.7 "

Minima of Algol, (β Persei; R. A. 3h 01m; Decl. +40°31′).

	Central Time. d	h m	Central Time. d	h m	Central Time. d	h m
Oct.	4,	7 08 P. M.	16,	6 24 A. M.	24,	8 51 P. M.
	7,	3 57 "	19,	3 13 "	27,	5 40 "
	10,	0 46 "	22,	12 02 "	30,	2 29 "
	13,	9 35 A. M.				

o Ceti (*Mira*). This wonderful variable star is now near its maximum. On the morning of Sept. 12 I compared it with several stars in its vicinity. It was brighter than γ, ζ, θ, η or τ Ceti but not so bright as α Ceti. I estimated its light as half way between that of α and ζ Ceti, and equal to that of γ^1 Eridani. These last estimates would give about 3.2 as the magnitude of Mira on that date. H. C. W.

Comets. The study of comets during the last two months has been considerable and may briefly be summarized as follows:

Comet 1888, I, discovered by Sawerthal in February last, was probably not seen later than the middle of August, at which time its computed brightness was 0.019, unity being its light at the time of discovery. The observations of David Gill, at the Cape, for the months of February and May are in *A. N.*, No. 2849. The singular changes in the tail of the comet, which took place between May 20 and June 11, are well drawn by A. Kammermann in the same number. The *Monthly Notices* of the Royal Astronomical Society for June contains a full series of observations of this comet from Greenwich and Radcliffe Observatories, and drawings by Robinson for May 23, and by Becker, at Dun Echt, for May 21. Orbits have been computed by Rev. G. M. Searle and Professor Lewis Boss, *A. N.*, No. 171.

The point raised by Mr. Searle that the orbit is probably elliptical is well taken. A first computation of such an orbit, using observations not entirely satisfactory, gave a period of revolution of 1648 years. The following elements kindly communicated by Professor Winloch, of the United States Naval Observatory, are of interest in this connection:

Elements of Comet 1888 I. The following elements were computed from the Albany observation of March 17, and Washington observation of March 30 and April 16:

$$T = 1888, \text{ Mar. } 16.86205 \text{ Gr. m. t.}$$

$$\left.\begin{array}{l} \omega = 359°35'\ 5.1'' \\ \Omega = 245\ 42\ 45.8 \\ i = \ \ 42\ 18\ \ 9.0 \end{array}\right\} 1880.0.$$

$$\log q = 9.844070.$$

The deviation of the middle place is $+3'8''$ in longitude, and $-55''$ in latitude, but the agreement of Oppolzer's "cot J°" with "cot J" shows that no further refinement of the parabolic hypothesis will materially improve these differences. The orbit, as we know, is decidedly elliptic.

ELIZABETH BROWN DAVIS.

Columbian University, Washington, 1888.

On and about April 7, 1888, this comet was seen in England and America with the naked eye. April 11 its tail was longest, being 5⅓ degrees.

In *A. N.*, No. 177, there is the record of an observation for July 28, which is the latest we have noticed. At the time of its disappearance the comet was in the southern part of the constellation of Cassiopeia, and its distance from the earth was about 217,000,000 miles, and from the sun about 280,000,000.

Comet b, 1888, is Encke's. Telegraphic notice of the reappearance of this comet was received by a dispatch from the *Science Observer*, Aug. 5, with the following position:

1888, August 3.2571 G. M. T.
$\alpha = 12h\ 12m\ 53.5s.$
$\delta = 17° 27' 19''$

In *A. N.*, 2849, is an ephemeris of this comet by H. Kreutz, of Kiel, extending from July 15 to Oct. 27, in Berlin M. T. During the month of October the comet, by this ephemeris, will be in the northern part of the constellation of Canis Minor and eastern Hydra. The comparison of the appearance of Encke's comet as drawn by Professor A. Hall of Washington for Dec. 2, 1871, and that of Sawerthal for May 21, 1888, is interesting as shown in the *Monthly Notices* for June.

Comet c, 1888 (*Brooks*). While sweeping in the northwestern heavens on the evening of Aug. 7, 1888, I discovered a comet near Lambda Ursa Majoris, or in approximate right ascension, 10*h* 5*m*, declination north 44°30′. I was soon able to detect motion, which was easterly at the rate of about one degree a day. The head was brightish, and a faint tail was visible, about one-third of a degree in length. The tail has the very unusual appearance of being pointed nearly in the direction of the sun, instead of directly from that luminary. I have observed the comet nearly every evening except in the presence of a nearly full moon. At my last observation, August 30, it was about one and a half degrees southeast of Cor Coroli and on the early morning of the previous day must have passed very near to that star. Although farther from the sun than at discovery, the comet has been approaching the earth, so that its apparent brightness is fully maintained up to this time.

Smith Observatory, WILLIAM R. BROOKS.
Geneva, N. Y., Aug. 31, 1888.

From observations on August 10, 14 and 19, Professor Boss, of Dudley Observatory, Albany, computed the following elements and ephemeris:

$$\begin{aligned} T &= 1888 \text{ July } 30.25 \text{ G. M. T.} \\ \omega &= 57°49'22'' \\ \Omega &= 101\ \ 5\ 47 \\ i &= 74\ \ 3\ 37 \end{aligned} \Bigg\} 1888.0$$

$$\log q = 9.95424.$$

The motion of the comet is southeast and during the first half of the month it will be in the constellation of Serpens and pass the star δ on the north about 2° on the 2d inst. The table shows that the comet is receding from the earth.

Faye's Comet, 1888, *d*. The return of this periodic comet was first observed at Nice, 1888, Aug. 9.6183, G. M. T. It was then in $a = 5h\ 0m\ 27.6s$; Decl. +20° 0′ 42″, with daily motion east 2*m* 44*s*, and south 2′. During the present month the comet will be moving through the constellation of Orion, northeastern part, near the small stars of the left hand of the figure.

EPHEMERIS FOR 0*h* BERLIN M. T.

1888	α	δ	log *r*.	log Δ.
	h m	° ′		
October 3	7 15.8	+13 22	0.254	0.213
7	23.3	12 37		
11	30.4	11 51	0.259	0.200
15	37.1	11 4		
19	43.3	10 16	0.265	0.186
23	49.1	9 28		
27	7 54.5	+ 8 40	0.271	0.173

A. N., No. 2849. H. KREUTZ.

Comet e, 1888 (*Barnard*). Late in the evening of Sept. 3, I received a telegram from Professor Barnard, of the Lick Observatory, announcing the discovery on the morning of the same day of a comet in R. A. 6*h* 52*m* 14*s*, Decl. +10° 59′. The following morning Professor W. R. Brooks telegraphed the discovery of a comet in R. A. 6*h* 45*m*; Decl. +11°. As the two objects are identical it follows that he is entitled to the honor of independent discovery.

As no claim has been sent me antedating Professor Barnard's discovery, he, as far as now appears, is entitled to the Warner comet prize of $100. LEWIS SWIFT.

Warner Observatory, Sept. 13, 1888.

The following letter from Professor Brooks concerning his independent discovery of this comet is very interesting reading. The temporary name of this comet might well be called Barnard-Brooks:

The comet discovered by Mr. Barnard, Sept. 3, was independently discovered by myself the following morning, Sept. 4. Although very sure of its cometary character, I was not able to detect motion on the morning of discovery, its motion was so exceedingly slow. I telegraphed, however, to Dr. Swift; my telegram leaving here at 9:30 A. M., Sept. 4. Barnard's telegram, via. Harvard, did not reach Geneva until noon of that day, over two hours after my telegram was sent, and being delivered through the post office, Barnard's announcement was not received by me until the next morning, Sept. 5.

I have observed the comet every morning since discovery, up to this writing, and it appears to be growing brighter and increasing in size. It has moved only a very short distance in the field of discovery in the three days elapsing. The comet this morning was by no means faint—I could see it with the 9-inch reflector in moderate twilight. The comet is nearly round with some central condensation.

WILLIAM R. BROOKS.

Smith Observatory, Geneva, N. Y., Sept. 7, 1888.

Minor Planets. No new asteroids have been found since May 16, the last number being 278. No 275 has been named *Sapientia.* No. 277 only, now, is without a name.

EDITORIAL NOTES.

Subscribers will please remember that the MESSENGER is published only ten times during the year; for the current year vacation months were July and September. The first cover page always gives the consecutive number in the whole series.

So many questions pertaining to Astronomy are asked by young observers, from month to month, that we have often thought of printing the more important of them with brief answers, that all such readers may have the benefits of the inquiries and thoughts of all.

There has recently been unusual call for complete sets of the MESSENGER from the beginning of its publication in

March, 1882. The full set can not longer be supplied because some numbers of the first volume are out of print. If there should be soon received ten more orders for the first volume at $5 each, a supply of the missing numbers of this volume would be reprinted. The attention of subscribers and those in charge of the public and private libraries is kindly asked to favorably consider this suggestion.

The new text book of general astronomy by Professor C. A. Young, of Princeton, which is now in the printer's hands, appears, by the first 200 pages of its advance sheets, to be just the work that the instructor of college classes and other institutions of higher education most needs. We are now using these advance sheets with a college class in astronomy with very great satisfaction. When the book is completed we can speak more intelligently and specifically of its merits.

The Lick Observatory is manifestly a busy place, a place of earnest scientific work, as every one knew it would be who has knowledge of its men, and the unequaled facilities of its instrumental equipment. Within the last two months several articles have appeared from the pen of Professor Holden, the director, in leading popular and scientific magazines in this country and Europe. Besides these, other popular articles and scientific notes incident to the daily work of his corps of astronomers have frequently appeared in the leading daily papers of the United States. This is as it should be, for Lick Observatory will, in this way, be a source of knowledge and power in the popular thought of the world that will be justly and enviably grand. Professor Holden has earned the privilege of the high opportunity now open to him.

Hypothetical Parallax of Binary Pairs. I notice in the August number of THE SIDEREAL MESSENGER, page 290, an interesting paper by Mr. W. H. S. Monck on the Distances of Double Stars. In this paper Mr. Monck deduces what he calls the "*equivalent*" parallax of various binary stars from the (reasonable) assumption that the (unknown) mass of each pair is equal to the sun's mass. I think we should not change accepted names in science without good cause, and it seems to me that the name which the originator of the idea (Professor Hugo Gyldén) proposed in his work, *Die Grundlehren der Astronomie* (1877), page 365, ought still to be applied to parallaxes estimated in this way. Professor Gyldén named such a parallax of a binary pair its "*hypothetical*" parallax, which exactly describes it; and this name has been adopted by all computers who have heretofore made tables similar to that of Mr. Monck. It appears to me that this designation ought not to be altered. I feel sure that Mr. Monck will readily agree to this slight change of nomenclature, not only because it is a more exact one than his own, but also on account of the deference which we all owe to the distinguished astronomer who first proposed this means of estimating stellar distances. EDWARD S. HOLDEN.

Mt. Hamilton, Lick Observatory,
August 13, 1888.

Elements and Ephemeris of Barnard's Comet, 1888 by J. M. Schaeberle, astronomer of Lick Observatory. [Communicated by the Director.] From observations made by Mr. Barnard on Sept. 2, 4 and 6, I have computed the following elements and ephemeris:

$$\left.\begin{array}{rl} T = & \text{Nov. } 22.904 \\ \omega = & 358^\circ\ 8.9' \\ \Omega = & 9\ \ 4.3 \\ i = & 164\ 35.8 \\ \log q = & 0.10546 \end{array}\right\}$$

$$\text{For the middle place } O-C \begin{cases} \Delta\lambda \cos\beta = -0'.7 \\ \Delta\beta \quad\quad\ = -0'.1 \end{cases}$$

Ephemeris for Greenwich, mean noon:

DATE.	α	δ	LOG Δ
	h m s	° ′	
Sept. 5,	6 52 4	+10 52	0.296
9,	6 51 28	10 35	.267
13,	6 50 17	10 16	.236
17,	6 48 25	9 53	.202
21,	6 45 42	9 27	.164
25,	6 42 13	+ 8 55	0.120

Rectangular coördinates to the equator:

$$x = r.[9.99961] \sin (\ 81^\circ 15'.0 + v)$$
$$y = r.[9.99551] \sin (171\ \ 35\ .8 + v)$$
$$z = r.[9.17305] \sin (155\ \ \ 5\ .0 + v).$$

As the change in the geocentric place between the extreme dates was less than 20′ of arc, the above elements can only be regarded as a first approximation. J. M. SCHAEBERLE.

J. C. Houzeau. Astronomy has lost another of its most devoted and eminent followers by the death of *Jean Charles Houzeau de Lehaie*, at Shaerbeek, Belgium, July 12, 1888. He was honorary director of the Observatory of Brussels, having retired from the active duties of director, because of ill health, in 1883. *Ciel et Terre*, Aug. and Sept. 1, devotes considerable space to a sketch of his life and memorial addresses by several of the most eminent members of the Belgian Academy.

Houzeau was born at Mons, October 7th, 1820, and pursued his first studies at the college in that place. Later the young man found need of taking regular university studies and went to Paris where he studied under the Faculty of Sciences for two years but did not seek to obtain an academic degree. He had already at the age of 19, begun his career as a writer, by furnishing to the local papers of Brussels several popular articles on the new practical applications of science. In 1843 he became a voluntary assistant in the observatory of Brussels and in 1846 was appointed regular assistant; but in 1849 the government forced him to leave the observatory, because of his democratic principles and ideas of individual liberty and social equality, which he did not hesitate to make known through the public press. From 1854 to 1857 he was employed as a private individual in the geodetic survey of Belgium, refusing to serve as a functionary of the state. In 1857 he came to the United States, attracted by the free institutions of the great American republic and settled in Texas, where he occupied himself with agriculture, surveying and the study of nature. But soon the war of the secession broke out and he found himself in trouble again because of his anti-slavery views. He escaped from Texas at the peril of his life, disguised as a Mexican teamster, to the Mexican border. In 1863 he went to New Orleans and was soon placed at the head of an anti-slavery journal, *The Tribune of New Orleans*, which he edited for six years. In 1870 he abandoned journalism and went to live in quiet in Jamaica. In 1874 the death of Quetelet left the observatory of Brussels without a director and Houzeau had the honor of being recalled to his own country and placed at the head of the institution, which as a subordinate he had been forced to leave years before. He accepted the position reluctantly in 1876, and at once reorganized the Observatory bringing it into efficient working condition as the numerous publications since that date will testify. In 1882 he took charge of an expedition to observe the Transit of Venus at San Antonio, Texas. The fatigue of this expedition so affected his health that he was obliged to give up the active direction of the Observatory.

We owe to Houzeau a large number of scientific papers upon a wide variety of topics, but those by which he will be remembered are his *Uranometrie Generale*, a catalogue of the magnitudes of the stars which are visible to the naked eye, *Vade-Mecum de l'Astronomie*, and *Bibliographie Generale de l'Astronomie*, the last two being general reference books to that which has been published concerning astronomical subjects. The last work is not completed, two large volumes having been published and others in course of preparation. M. A. Lancaster, Houzeau's co-laborer in this work, will endeavor to carry it on to completion.

Ring Nebula of Lyra. Speaking of this interesting object recently, Professor Holden, of Lick Observatory, says:

There is no object in the heavens which is better known to possessors of both large and small telescopes than the ring nebula in Lyra. It is the brightest of the nebulæ, and its wonderful shape makes it an interesting link between a planet with rings, like Saturn, and the primitive formless nebula which Laplace assumes as the starting point of his nebular hypothesis. It has important analogies to rings of stars and to star clusters also.

This bright nebula has been looked at by every amateur and professional astronomer, by every large and small telescope in the world.

Sir John Herschel describes it as a ring and figures a small star following it. Lord Rosse, with his six-foot reflector, gave five small stars outside of it and none inside. Mr. Lassell, with his four-foot reflector, figures it with thirteen faint stars in an oval outside and one inside the ring. So I saw it with the Washington refractor of twenty-six inches aperture in 1875.

Our first look at this nebula with the thirty-six-inch telescope showed a great variety of new detail, and a careful examination has disclosed to us not only the single star inside, but likewise eleven others inside the inner oval or projected on the bright nebulosity between the outer and the inner ovals. Not only this, but it is obvious that the plan on which this nebula is built is that of a series of ellipses or ovals.

There is first the ring of faint stars outside the nebula; then the outer and inner bounding ovals of the nebulosity, next a ring of faint stars around the edges of the interior ring, and finally a number of stars situated on the various parts of the nebulosity and outer oval.

The object is entirely a new one in its appearance and in its suggestions as seen here.

Telescopes of Short Focal Length. In the last number of this Journal, I mentioned something of the performance of Spencer's 35-in. Achromatic, 4⅞ in. aperture. Since that article was written I have tested it still further, in connection with Professor Brooks and Mr. Spencer, with the following results: Jupiter with 120, very clearly exhibited details of the belts and shadow of satellites as well shown as with any telescope of the usual length for same aperture. λ Ophiuchi, easily separated with power of 100; ζ Herculis with 150, and 350.

As this star is generally supposed beyond the power of a 3-in. achromatic, I contracted the aperture of the "Spencer" to 2½ inches, and could now, with a power of 350, just detect the companion touching the enlarged spurious disc; with an aperture of 3¾ inches, the small star was well separated, though faint; but with the full aperture, the much more minute discs made them appear widely separated, and the small star quite conspicuous. I have several times seen η Coronæ in contact, with power 350; with a slight difference in the magnitude of the components.

With a still higher power (something over 400, as near as I could determine it), I have readily elongated the companion of γ Andromedæ. δ Cygni is readily seen with 350 but not with lower powers, and the companion of Antares with 150. Debilissima (between 4 and 5 Lyræ,) I could hold steadily with 350, but not with lower power. On the contrary, the companion of α Lyræ is best seen with about 100, and with these, observations were made when the moon was about half full. H. L. SMITH.

Hobart College, Aug. 18, 1888.

Detroit Observatory. With those who know the University of Michigan best, it has come to be expected that that great institution will honor its own worthy sons with places of responsibility, almost as often as opportunity arises. The latest example of this is the appointment of Professor W. W. Campbell to the place in the Observatory made vacant by the resignation of J. M. Schaeberle, now at Lick Observatory.

Professor Campbell graduated at the University of Michigan in 1886, and for the next two years filled the chair of Mathematics and Astronomy at the University of Colorado. His duties in the Observatory of Ann Arbor are to give instruction in spherical and practical astronomy, and to engage in the general work of the Observatory.

Lunar Eclipse, July 22. Professor Holden, speaking of the eclipse of July last, says:

The following account of the observations of the lunar eclipse just passed, is all that can be given until the work is reduced and discussed:

Mr. Keeler used a small spectroscope attached to the twelve-inch equatorial and examined the spectrum of all points on the dark part of the moon which appeared in any way remarkable. The spectrum in all parts was continuous and varied only in brightness. He could see the Frauenhofer lines just inside the edge of the umbra, but not in the deep shadow.

One occultation was observed, and the color changes of light were noted.

Both Mr. Hill and Mr. Keeler thought the color of the eclipsed moon was remarkably red. They noted that the limb of the moon, when nearly out of the umbra, was bright orange.

In the center of the umbra the color was dusky red, and the inner edge of the umbra was of a somewhat greenish-gray tint, blending into the red of the central shadows.

Mr. Barnard with the twelve-inch equatorial, made six negatives before and six after totality. With the six-inch equatorial he observed all four contacts with the shadow, and also the contact of the shadow with a number of lunar craters.

The observations were made to determine the extent of the interior illumination of the earth's shadow.

The large equatorial was used by Professor Holden and Professor Schæberle to make accurate drawings of the progress of the shadow across the face of the moon and to make careful notes of the variations of tone and color.

Forty-seven drawings were made at the telescope and eleven with the naked eye. From these a complete history of the whole phenomenon can be obtained.

The eclipse was peculiar only by the great intensity of the coppery hue of the disc.

The Seth Thomas precision clocks are coming into notice for astronomical purposes at some points in the West.

Observatory at Iowa College. Iowa College at Grinnell, Iowa, is rejoicing in the possession of its new Observatory, which has been in use since April last. The equipment at present consists of an excellent 8-inch refractor by the Clarks, mounted equatorially with driving apparatus by Rev. H. G. Sedgwick, of Davenport, Iowa. Strong efforts are being made by the president, Rev. G. A. Gates, and professor of mathematics, Rev. S. J. Buck, to secure other instruments so that the outfit may be complete for the purpose of instruction and of maintaining a time service. They are planning at once for the erection of a transit house and the acquisition of transit instrument, sidereal and mean time clocks and chronograph. Both of these gentlemen visited Carleton Observatory during the past summer, the latter spending several days studying the instruments and plan of building. They are enthusiastic with the idea of building up a good working Observatory. We wish them all possible success.

Richard A. Proctor. Since our last issue, another distinguished astronomer, Professor Richard A. Proctor, has gone to his long home. He died of yellow fever at the Willard Park hospital, in New York City, Wednesday evening, Sep. 12. For some time past his home has been at Oaklawn, Fla., where his family at present resides. On Monday preceding his death, he arrived at New York, and engaged passage for Europe, intending to sail on the following Saturday. He was suddenly taken ill, and skillful physicians at once recognized his adversary as none other than that terrible enemy, the yellow fever. This was unexpected to every one, as no case of the fever had been reported from Oaklawn this year. He lived but a few hours, and his sudden death must have been a severe shock to his dear family and his large circle of friends.

Richard Anthony Proctor was born at Chelsea in England, of worthy parentage, March 23, 1837. His preparatory studies were pursued in private schools, after which he entered King's College in London. He later attended St. John's College at Cambridge from which he graduated with honor in 1860. In 1866 he was elected Fellow of the Royal Astronomical Society, and an honorary Fellow of King's

College, London. In 1872–3, he was editor of the Proceedings of Royal Astronomical Society. In 1869 he, among the first, advocated the theory of the solar corona and inner solar envelope which is now most generally accepted, and which the later studies of Professor C. A. Young verified to a high degree of certainty.

Mr. Proctor's grand work, as a popular writer on scientific subjects and lecturer on astronomical themes, is too well and favorably known to need comment.

The following are the more important works published by him during his busy life: Saturn and his System was the first, revised in 1882; Gnomonic Star Atlas, 1865; Constellation Seasons, 1869; Half Hours with the Telescope, 1868; Half Hours with the Stars, 1869; Other Worlds than Ours, 1870; The Sun, Elementary Lessons in Astronomy, 1871; School Atlas of Astronomy, Essays on Astronomy, Orbs around Us, Elementary Lessons on Physical Geography, 1872; Light and Science, The Moon, The Border Land of Science, The Expanse of Heaven, The Universe and the Coming Transits, 1873; Transit of Venus Past, Present and Future, 1874; Light Science for Leisure Hours, Easy Lesson's in the Differential and the Integral Calculus; The Geometry of the Cycloid and probably some others that do not occur to us at present. The magazine entitled *Knowledge*, which he edited, uniformly maintained a high rank as an exponent of science in popular language. But, undoubtedly, his greatest work was that on which he was engaged at the time of his death, viz., The Old and New

Astronomy. Astronomers everywhere will deeply regret that he laid down his pen when this difficult and noble task was only half done. Few are the scholarly astronomers who will volunteer to step into his place to finish the work. The MESSENGER is indebted to Editor Haskell of the Minneapolis *Tribune* for the use of the good picture of Mr. Proctor accompanying this note.

Observations of Comet *c* 1888 (*Brooks*), at Carleton College, with an 8¼-inch refractor and filar micrometer, by H. C. Wilson:

Date.	Northfield mean time.	$\Delta\alpha$	$\Delta\delta$	Comparisons.	Star.
	h m s	m s	′ ″		
Aug. 8	10 36 37	+0 33 30	−1 51.6	10.4	1
11	9 52 27	−0 30.47	+7 13.8	10.6	2
16	10 02 04	....	+3 13.2	.2	3
16	10 41 47	+2 11.14	....	4.	3
22	10 03 53	+0 29.08	−0 52.8	10.6	4
24	9 23 09	+1 37.96	−5 01.4	12.4	5
24	9 23 09	+0 44.81	....	12.	6
24	9 42 03	....	−2 54.1	.2	6
30	8 44 25	+0 09.76	−4 15.5	10.8	7
Sept. 1	9 40 21	+0 03.99	+7 47.7	10.8	8

	α app.	log pΔ	δ app.	log pΔ
	h m s		° ′ ″	
Aug. 8	10 56 51.16	9.553	+44 47 41.7	0.900
11	10 39 28.51	9.663	+44 48 50.8	0.857
16	....	....	+44 09 07.2	0.849
16	11 18 51.35	9.605	....	....
22	12 05 11.	9.686	+42 11	0.832
24	12 19 59.45	9.723	+41 15 28.8	0 781
24	12 19 59.	9.723	....	....
24	....	....	+41 15	0.805
30	13 02 13.25	9.726	+37 47 50.0	0.718
Sept. 1	13 15 36.21	9.698	+36 25 29.2	0.786

Assumed places of comparison stars:

Star.	α 1888.0	Red. to app.	δ 1888.0	Red. to app.	Authority.
	h m s	s	° ′ ″	″	
1	10 16 18.66	−0.80	+44 49 32.2	+1.1	Weisse X, 276.
2	10 39 59.75	−0.77	+44 41 35.0	+2.0	Radcliffe 2554, A. N. 1637 (Berlin 1865.0).
3	11 16 40.94	−0.73	+44 05 50.8	+3.2	Radcliffe 2674.
4	12 04 42.70	−0.59	+42 11.9	+5.0	D M 2276.
5	12 18 22.01	−0.52	+41 20 24.7	+5.5	Radcliffe 2852.
6	12 19 15.20	−0.52	+41 17.9	+5.6	D M 2293.
7	13 02 03.89	−0.40	+37 51 58.3	+7.2	Radcliffe 2964.
8	13 15 32.55	−0.33	+36 17 34.0	+7.5	Bonn VI, 2363.

From the observations of Aug. 11, Aug. 24 and Sept. 1, which depend upon comparatively well determined comparison stars, I have, with the assistance of Miss C. R. Willard, computed the following elements of the orbit of this comet:

$$\begin{aligned} T &= \text{July } 31.0899, \text{ Greenwich mean time.} \\ \pi &= 160°40'58'' \\ \Omega &= 101\ 26\ 30 \\ i &= \ 74\ 11\ 22 \\ \log q &= 9.955462 \end{aligned} \quad \left.\begin{matrix} \\ \\ \\ \end{matrix}\right\} \text{Mean equinox 1888.0}$$

The representation of the middle place gives $(c-o)$; $\Delta\lambda \cos\beta$, $+1''$; $\Delta\beta$, $+6''$. H. C. WILSON.

Ephemeris of Comet c. The following ephemeris is by Kreutz in *A. N.*, No. 2855, and from elements that compared very closely to those given above. Places from Oct. 7 to 15 are given as probably all that can be used because of faintness of the comet.

1888.	α (h m s)	δ (° ′)	log r	log Δ	L.
Oct. 7	15 52 40	+10 21.6	0.1697	0.2937	0.26
8	55 35	9 46.3			
9	15 58 27	9 11.7			
10	16 1 16	8 37.7			
11	4 2	8 4.4	0.1842	0.3101	0.22
12	6 46	7 31.7			
13	9 27	6 59.6			
14	12 6	6 28.2			
15	16 14 43	5 57.4	0.1983	0.3265	0.19

Relative Distances of the Inner Planets from the Sun. Rollin A. Harris, Jamestown, N. Y., kindly sends a copy of his thesis presented to the Faculty of Cornell University for the degree of Doctor of Philosophy. The title is "The Theory of Images in the Representation of Functions." The article fills a number of the *Annals of Mathematics* (No. 3, Vol. 4.) The note and diagram, showing a curious way of illustrating the relative distances of the minor planets from the sun will appear next time.

Wolsingham Observatory. On August 13, a remarkably bright line, apparently F, was observed in the spectrum of R. Cygni. The observation was confirmed on Aug. 22, and by Dr. Copeland the same night, who measured the line. Dunér observed the star (79.3.16; 80.5.14; 82.10.6), and found a weak III type spectrum. An extraordinary change would seem to have taken place in this star. T. E. ESPIN.

1888, Aug 25.

Queries by Correspondents. 1. When the moon was half eclipsed, July 22, why did the limb in the shadow appear so bright while other portions of the shaded disc were not as bright as in the lunar eclipse of January last? D. H. R.

We did not notice anything unusual in the comparative brightness of the limb and other portions of the eclipsed disc referred to. The difference noticed we thought only due to the contrast of shadow and illuminated disc. During totality the outlines of prominent features were very distinct, and the disc strongly of the copper color. These features impressed us more than others.

2. Why was the ring of light broader at the top and bottom than elsewhere as shown in the accompanying figure? D. H. R.

We have no note of such a difference in our observations, nor recollection of seeing it. Possibly some readers of THE MESSENGER may have noticed the above phenomenon, and will give us the benefit of their observations.

3. Have you any recent information concerning the star of Bethlehem? M. A. MC H.

There is no such star known to science. The Scripture references to the Star of the East are best understood, as we believe, by thinking of the phenomenon as wholly miraculous. Every time the planet Venus is bright enough to be seen in the daytime people easily imagine that the wonderful star has again appeared. The mistake of confounding Tycho Brahe's new star with the Star of Bethlehem, so-called, has often been made. There is an unsteady faint star in the constellation of Cassiopeia, near the place where Tycho Brahe saw his wonderful new star burst out suddenly in 1572. It is possible that this eleventh magnitude star may be the same one that he saw, and that its occasioned apparent unsteadiness may be symptoms of another similar outburst, but the real probability of such an event is too small to deserve much attention. Astronomers watch it, of course, because of its unusual appearance at times.

4. Can you tell me the Greek letter for the star marked in

Burritt's chart, "Sach Naschiran, Capricornus," also what the name signifies? S. W. F.

The spelling of the above star name in Burritt is probably "Sad Nachirah," and this name is placed against the third magnitude star δ. Whitall names the fourth magnitude star γ Nashirah. These names are from the Arabic *Sa'ad al Naschira*, and mean "the record of cutting off," the Sea-Goat slain. It is doubtful to which star the Arabic name was first applied, as best records differ.

5. Have this star and δ Capricorni companions? S. W. F.
Neither are recorded as having companions.

6. In an article in the September *Century* Professor Holden refers to a few star distances, giving the same in miles. Are there any tables published showing all such known distances of the stars?

There are tables showing the distances of some, but we can not just now state where they may be found. A table of distances could easily be constructed for all stars of known parallax. Such a table, if expressed in the unit of the velocity of light per second, would not help us *very* much in comprehending the magnitude of the universe. Possibly some of our readers may give us more information on this point.

7. Would it not be well to extend the tables of the rising and setting of the planets *two* months in advance of publication instead of one?

We have thought of doing something like that. We will give tables in the November issue running till Dec. 15. Possibly that will answer the wishes of all.

Science Observer Code. Those using the Science Observer Code for telegrams of announcement of astronomical discoveries, positions, orbits, etc., will remember that the new code goes into effect at the beginning of this month. John Ritchie, Jr., (Box 2725, Boston, Mass.), is in charge of this matter.

Mr. J. A. Brashear, of Allegheny City, has returned from his European trip. The attention paid him by most prominent astromers abroad was an honor to American science.

Errata. In last issue the word "not" is omitted from line 10 from end, p. 290; and in line 6 from end, p. 292, the word "mask" should be "mark." In this number, p. 352, "Winloch" should be "Winlock;" p. 349, "Comtes" should be "Comptes."

We notice in the September *Observatory* that minor planet 278 is given the name *Adelheid*. That name belongs to No. 276. No. 278 is *Paulina*.

THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE,

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

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THE EFFECTS OF ROTATION UPON THE FLUID ENVELOPE OF A REVOLVING SPHERE.

SEVERINUS J. CORRIGAN.

FOR THE MESSENGER.

If any one should enunciate the proposition that sun-spots and their periodicity, terrestrial storms (the word storm being, in this connection, taken as signifying a rotary motion of the earth's atmosphere, around what is called the storm centre), the oceanic circulation, and the seismic phenomena, are due primarily to one and the same cause, and that this cause is determinable, the bare announcement would undoubtedly be considered as rash in the superlative degree. To entitle such a proposition to even the slightest consideration by the scientific world, it is absolutely necessary that it should be amenable to a rigorous mathematical demonstration or proof, and furthermore, that this proof should be well buttressed by facts derived solely from observation; for, as is well known, the concordance of theory and observation is the life and soul of modern science; without such concordance theory must ever remain a barren ideal, at least so far as the practical advancement of science is concerned. With a thorough understanding and appreciation of the requirements aforesaid, I think that I am warranted in making the statement or proposition above mentioned. The hypotheses, the truth of which I hope to demonstrate, may be stated explicitly as follows: I hold that, on any spherical or spheroidal body, such as the sun or the earth, rotating around an axis and whose mass exerts under the "law of gravitation" a centripetal attracting force which varies inversely as the square of the distance, any particle of a fluid envelope on the equator will have a *tendency* to a greater *angular* velocity than that possessed by a particle situated nearer to either pole, and that by the perturbing action of other bodies of the system an actual difference of *angular* velocity is developed. I hold that this difference of velocity will be productive of vortices in a fluid envelope, and that these vortices will be subject to a periodicity dependent upon the periodic variation of the perturbing force; *i. e.*, mainly upon the the periodic time of the perturbing body. It is obvious that the direction of rotation of these vortices will be dependent upon the direction of the angular velocity of the matter in which they are formed, and upon which side of the equator they are situate; thus, if the velocity be eastward and the vortex on the north side of the equatorial circle, the vortical rotation must be in a direction contrary to that in which the hands of a watch move, and the rotation of a vortex on the south side of the equator, will be in an oposite direction, or with the hands of a watch. I hold that, in the fluid envelope of the sun, these vortices are the sun-spots, and that, in the fluid envelope of the earth, *i. e.*, the atmosphere, they are the rotary storms. In a solid envelope such as the earth's crust, they will be torsional strains and any relaxation of the solid matter, under this stress will cause what is called an "earthquake."

The fundamental principles upon which I base the whole fabric of proof of the truth of the aforesaid hypotheses, and which can, I think, be regarded as axiomatic, may be succinctly stated as follows: First; An infinitesimal particle of solar matter rotating around the Sun's axis is subject to the action of solar gravitation, and the latter force, in conjunction with the *linear* velocity of rotation, makes the particle as really a planet as is the mighty Jupiter. Second; In like manner, each infinitesimal particle of terrestial matter rotating around the axis of the earth, and subject to the latter's attractive force, is as really a satellite as the moon. Third; That the same is true of any particle on any planet. Fourth; That each particle moving, or rather endeavoring to move in its respective orbit is subject to perturbation by other bodies of the solar system, in the same manner as is any planet or satellite.

As stated above, it is necessary, in order that these hypotheses may be entitled to a proper consideration, to submit them to a rigorous mathematical investigation; it is also obvious that the proper course of procedure is to first compute the orbit of a particle of either solar or planetary matter situated at any known distance from the center of attraction, and endowed with a known *linear* velocity.

To do so it is necessary to have recourse to the general equations which express the several functions of orbital motion. From the fundamental equations of planetary motion are derived the following well known expressions:

$$\frac{V^2 r^2 \sin^2 \psi}{k^2} = p. \qquad (1)$$

In this equation, V represents the *linear* velocity of any body, great or small, moving in an orbit around the center of gravity of an attracting mass; r is the radius-vector of the body, or its distance from the center of attraction; ψ is the angle which the direction of the linear velocity makes with the radius-vector; and k^2 is the unit of acceleration, or the acceleration impressed in unit time, upon any body at unit distance from the center of an attracting mass by the latter's "force of gravity." The value of k^2 is determined by the equation

$$k^2 = \frac{4\pi^2 a^3}{t^2\,(1+m)} \qquad (2)$$

When the acceleration due to the sun is to be considered, a may represent the mean distance of any planet, and t its period of revolution in the orbit.

When the acceleration produced by the mass of any planet is to be computed from equation (2), a may represent the mean distance of any satellite revolving around the planet, and t will be the period of revolution of the satellite. As is well known, the mean distance of the earth is taken as the unit of distance, for the purpose of determining the acceleration due to the sun's mass, and the value of t is the sidereal year. The value of k thus determined is the well-known constant log 8.2355814. In order to obtain k for the purpose of determining the orbit of a particle of terrestrial matter, we must use the mean distance of the moon, as the unit of distance, and t will be the time of the moon's sidereal revolution, expressed in mean solar days, the day being taken as the unit of time. For the orbit of a particle on Mars, Jupiter, Saturn or Uranus I take the mean distance of the *first* satellite of each planet, and the corresponding period of revolution, but any other satellite can be used for the determination of k. As the rotation period of Neptune is unknown, we cannot determine the orbit of a particle upon that planet, by this method.

The *linear* velocity, V, in equation (1) is determined for the sun or for any planet, from the respective rotation periods and circumferences of these bodies. The unit of time being the mean solar day, the *linear* velocity must be expressed accordingly. The value of r in equation (1) will, in the case of a particle upon the surface, be the value of the radius of the sun or of any planet under consideration. The direction of the velocity in the case of a particle on the circumference will, of course, be at any instant, at a right angle to the radius; therefore $\sin \psi = 1$.

The quantity, p, in the second member of equation (1), is the semi-parameter of the orbit, or the ordinate at the focus, if we take the major-axis as the line of abscissæ. Having by means of the above mentioned known quantities, determined the value of p, the other principal elements of the orbit of a particle can be derived from the following equations:

$$a = \frac{k^2}{\frac{2k^2}{r} - V^2} \qquad (3)$$

$$e = \sqrt{1 - \frac{p}{a}} \qquad (4)$$

$$q = \frac{p}{1+e} \qquad (5)$$

In these equations, a represents the semi-axis major of the orbit of the particle, e is the eccentricity of the orbit, and q is, in the case of the sun, the perihelion distance, and in the case of the earth, the distance of the perigee; while for any other planet, it represents an analogous quantity. The above written equations are general and applicable to all cosmical bodies, but for sake of illustration I purpose to apply them first to the case of a terrestrial particle, because, in this wise, we can most readily take into account and compare the results derived from theory with those determined, independently, from actual observation and measurement.

Conceive the earth to be a *sphere* whose radius is equal to the known polar radius, and that this sphere is at rest; *i. e.*, that it does not revolve upon an axis; then let a motion of rotation, equal to that which is actually observed, be instantaneously impressed upon it; the problem now presented for solution may be stated as follows: What form of orbit will an infinitesimal particle of matter, situate upon the surface of the earth, tend to describe under the joint action of terrestrial gravitation and the *linear* velocity due to rotation? We see, from the above equations, that the form of orbit is dependent upon the value of the semi-parameter p. Considering equation (1), we preceive that, when V is 0, p also becomes 0, in other words the particle will simply be drawn, in a *straight* line, toward the centre of gravity or the focus. We know that at the poles $V=0$, and that its maximum value is on the equator, therefore the effect produced by rotation, upon a particle situated on the circumference of the equatorial circle, will be considered first.

For the determination of the value of k, from equation (2), we take the mean distance of the moon as unity, or $a = 1$, the sidereal period of the moon as 27.32166 days, and the lunar mass as .012285, the mass of the earth being unity. The resulting value of k will be expressed by a number whose log is 9.3616728.

The equatorial *linear* velocity V, of a terrestrial particle when the equatorial circumference is taken as a function of the polar radius r, will be represented by a number whose log is 9.0178790, and the value of r by a number whose log is 8.2185113. The value of p, derived from the substitution of the squares of these quantities in equation (1), will be a number whose log is -5.7494350; this is, of course, in terms of the moon's mean distance. The value of p in miles will therefore be found by adding to the last mentioned logarithm the logarithm of the moon's mean distance in miles, or 5.3780691; this will give log 1.1275041, or 13,412 miles, as the value of the semi-parameter. The latter becoming thus known, we can, by means of equations (3), (4), and (5), obtain the values of the semi-axis major, the eccentricity and the distance of the perigee. Equation (4) shows the orbit to be an ellipse of great eccentricity, in fact one very closely approximating a straight line. The semi-axis major, $a = 1978.28$ miles, $e = .996604$, and $q = 6.72$ miles. Some interesting and important results flow from a consideration of the orbit represented by these quantities.

Should this orbit be drawn to a scale suitable for the pages of this magazine it would appear to deviate but little from a straight line, therefore in the following diagrams the proportions of the ellipse are greatly exaggerated for the purpose of illustration.

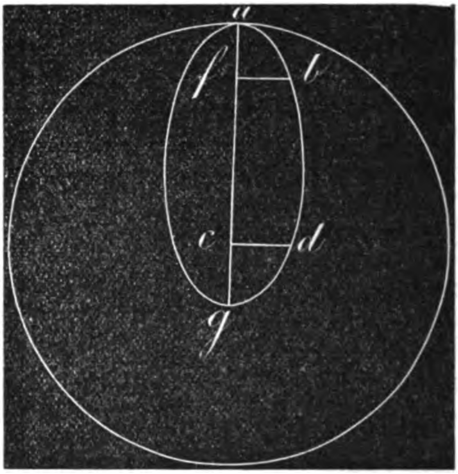


FIG. 1.

Let the circle in the above depicted figures represent the equatorial circumference of the earth, regarding the latter as a sphere whose radius is equal to the polar radius, and which is at rest. Let *a* be a particle on this circumference, and let it be instantaneously impressed with a motion directed toward the right, and equal to the eastward rotational velocity actually observed, then, if it were not constrained by the resistance of the terrestrial substance to remain upon the surface, the particle would describe the ellipse whose elements are given above, and which is depicted in *Fig.* 1. It can be readily seen that instead of falling directly to the "centre of gravity," at *c*, the particle would, after falling through the quadrant, be found at *d*, or the extremity of the semi-parameter *p*, which is represented in *Fig.* 1, by the line *cd*. This line may be regarded as representing a radial force, or a force directly upward from the earth's centre and urging the particle outward from the surface. We also see that at the other focus, *f*, of the ellipse, there is another semi-parameter, *fb*, equal to *cd*, which may also be considered as representing a force. It is to be noted especially that this latter has its origin at the focus *f*, which is, according to the determination above mentioned, 6.72 miles below the circumference, and that it is, therefore, *not* a tangential force; this fact is to be kept clearly in mind, because for the purpose of substantiating the views which I have enunciated it is a vital one. If we now consider a particle at *a* in *Fig.* 2, a quadrant farther advanced than the particle in *Fig.* 1, we may regard it as being acted upon in the same manner, and to the same degree, as is the particle at *a* in *Fig.* 1.

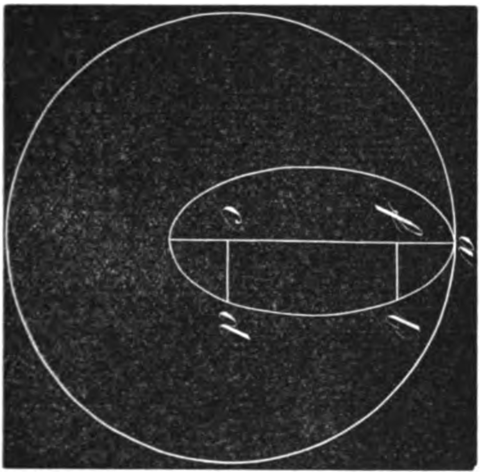


FIG. 2.

The orbit of the former particle will be an ellipse whose elements have the same values as those of the ellipse shown in *Fig.* 1, but the semi-axis major of this second ellipse, will be at a right angle to the corresponding axis of the first ellipse; therefore the semi-parameters representing the forces, regarding these as existing simultaneously, will also be at a right angle to each other. In *Fig.* 1, we see the particle *a* at the *beginning*, and in *Fig.* 2, at the *end* of a quadrant. In the case of continuous rotation, the particle will be, at the same instant, at the beginning of one quadrant and at the end of another; therefore the two equal forces represented by the semi-parameters, at a right angle to each other, may be superposed,—one will be the radial or uplifting force *cd*, and the other the force *fb*, proceeding from the focus *f*. The mathematical reader will probably say that the forces so found are only the radial and the tangential forces which have been heretofore considered in the discussion of the effects produced by the rotation of the earth, and, in the main, this reader would be right, but he must also notice that what is called the tangent force, is not, in this case, such. The effect of the radial force *cd* is, as has been stated, to move the particle at *a* on the equatorial circumference upward to a distance of 13.412 miles, which is the value of *p*, derived from equation (1). If we now consider the case of particles situated at an infinite number of points around the equatorial circumference, it is obvious that they will all be acted upon, in the same manner, and to the same degree, as is the particle we have just considered. The plane of the orbit shown in *Fig.* 1 lies in the plane of the equator; let us now consider it to be moved through all degrees of inclination, from 0° to 90° on either side of the equator, the major axis of the orbit lying throughout in a meridian plane. We see from (1) that the value of p (r, k and $\sin \phi$ remaining constant) will vary as V^2. We also know that the linear rotational velocity V varies from a maximum at the equator to 0 at the poles; therefore the value of p, or the uplifting force, will be a maximum, or 13.412 miles at the equator and 0 at the poles. It is manifest, also, that the direction of the orbital velocity of the particle at *a*, on the equator, is eastward, parallel to the plane of the equator, but that as the inclination increases, the direction of this velocity will change, so that in latitude 90° it will be at a right angle to the equatorial plane. Just as we have considered an infinite number of particles around the equatorial circumference, so we may consider an infinite number of particles on a meridian circumference, and also an infinite number of these circumferences. This done, we will have considered an infinite number of particles covering the whole surface of the earth. I now claim that we have, in this process, a means of determining the figure of the earth, and not only the figure of the latter but also that of any other cosmical body whose radius r, *linear* rotational velocity V, and constant of acceleration k^2, are known. For although we have considered only the surface particles, the same reasoning applies to all others, and the effect upon all is expressed generally by equation (1). Furthermore, it is *not* necessary that we should take into account the density of the various strata of the earth, or of any other body, in order to obtain a knowledge of its figure, for all the infinitesimal particles constituting these bodies may be regarded as of equal density and all are acted upon in an analogous manner according to equation (1). Although the *rationale* of the above claims may be apparent to many, I bear in mind the condition referred to at the beginning of this article, viz., that in order to entitle the hypotheses herein advanced to the right of consideration by the scientific world, it is necessary that they should be found concordant with the results derived from observation. Therefore I have computed by means of the first equation the figure not only of the earth, but also of the Sun, Mars, Jupiter, Saturn and Uranus, from their known rotational velocities, radii and accelerating forces, the last quantities being determined from equation (2), by means of the motions and distances of their respective *first* satellites.

In the case of the earth, I have shown that equation (1) gives 13.412 miles as the value of p or the uplifting force.

Taking Clarke's value of the polar radius as 3949.830 miles, the compression c (taken in the sense $c = \frac{a-b}{b}$, in which a is the equatorial and b the polar radius), will be $\frac{13.412}{3949.830} = \frac{1}{294.5}$. From an exhaustive discussion of all measured arcs of meridian, Clarke has obtained $\frac{1}{294.0}$ as the value of the compression. This is certainly a very close agreement with the result derived by means of my method, for it represents a difference of only 158 feet in the value of the equatorial radii determined by the two different methods. The determination of the compression, by means of the pendulum, differs considerably from that derived from arcs of meridian, the value of c so obtained being $\frac{1}{288.5}$. Pendulum observations have been made in great numbers and very carefully, so that the probability of any material difference being due to observational error is small; the discrepancy has, therefore, been attributed principally to the effect of local attraction upon the motion of the pendulum, but I purpose showing, further on, that it is due, not to errors of observation, or those attributable to local attraction, although both probably exist, but to another cause simple in itself, but very essential to a proper determination of the figure of the earth from pendulum vibrations. I will here anticipate a little, and say that when this cause is taken into account, the pendulum value of the compression becomes $\frac{1}{293.5}$, a quantity *practically* the same as the two already obtained. What we have to consider now is simply the effect of rotation upon the sun and upon the planets above mentioned. Taking the best known values of the respective radii, rotational velocities, and the motions of the bodies revolving around the sun and the planets aforesaid, together with the distances of these bodies from the respective centres of gravity around which they revolve, I have obtained the results tabulated below:

	Sun.	Earth.	Mars.	Jupiter.	Saturn.	Uranus.
Polar radius (miles)..	426,441	3949.83	2,180	39,736	32,064	15,414
Computed value of p,	9	13.41	1	2,687	3,004	1,210
Resulting equatorial radius....................	426,450	3963.24	2,181	42,423	35,068	16,624
Computed compression, taken, $c = \frac{a-b}{a}$	$\frac{1}{49738}$	$\frac{1}{295.5}$	$\frac{1}{2181}$	$\frac{1}{15.8}$	$\frac{1}{11.7}$	$\frac{1}{13.7}$
Observed compression,	....	$\left\{\frac{1}{295.0}, \frac{1}{294.5}\right\}$	.....	$\frac{1}{16.7}$	$\frac{1}{9.4}$	......

It is obvious that all bodies rotating upon an axis are subject to the action of "centrifugal force," which tends to increase the equatorial diameter of a fluid body. The sun is such a body, and it must, therefore, have an equatorial diameter longer than its polar, but thousands of carefully made observations have disclosed no difference between the diameters. The results for the sun tabulated above show why this is so, for the value of the compression derived by my method is only $\frac{1}{49738}$, and this gives as the difference of the diameters, in angular measure, only 0″.04, a quantity so small that instrumental measures cannot well detect it.

In the case of the earth, we see that the theoretical compression is $\frac{1}{295.5}$ while the observed values are $\frac{1}{295.0}$ and $\frac{1}{294.5}$, the first of these values being that derived from arcs of meridian, and the second that obtained from pendulum vibrations. The last is, as stated, a corrected result, and the reasons for making the correction will be shown further on.

The difference between my theoretical value and that derived from the arcs is only 128 feet, and the difference between it and the pendulum result (corrected) is only 234 feet in the value of the equatorial radius. In the case of Mars the observations are not at all concordant, some observers claiming the existence of an appreciable difference between the diameters, others seeing none at all, while still other few assert that the polar radius is the longer. The determination by my method gives $\frac{1}{2181}$ as the value of the compression. If we consider the value $\frac{1}{60}$, which has been assigned by some, we find that it amounts to only 0″.10 between the angular diameters. It is a quantity too small to be observed with any certainty. Therefore I think that the theoretical value which I have found is more likely to be the true one. I have used in the computation both Phobos and Deimos, and both processes give the same result, viz., a difference of one mile between the radii.

The difference between the theoretical and the observed values of the diameters in the case of Jupiter amounts to only 0″.12, the greater part of which discrepancy may, I think, be justly attributed to errors of observation.

In the case of Saturn the difference between theory and observation amounts to 0″.36. A portion of this may be properly attributed to observational error, but I think that a large part of it is due to another cause. Paradoxical as the statement may seem, if there were not a real difference between the theoretical and the observed value, the theory would be at fault; this can be made evident by a consideration of equation (1). We see that p, or the measure of the compression varies inversely as k^2, but k is determined from the motion and the mean distance of the first satellite which revolves outside the *rings* of Saturn; therefore the value of k which I have used involves the mass, not only of the ball of Saturn, but of the innumerable satellites which constitute the rings as well, while the value of k which should be used is that which involves the mass of the ball only. For the particles whose orbits are to be computed constitute the ball, and the action of the matter of the rings upon them will be only a perturbative one. It is apparent that the former value of k is greater than the latter, and that therefore p, or the theoretical compression, should be less than the observed, just as I have found it to be. If there were no error of observation this difference would furnish a measure of the mass of the rings.

In the case of Uranus, there is, so far as I know, no instrumental determination of the value of the compression, and, furthermore, the rotational velocity is only approximately known. Using the velocity assigned, I find a theoretical compression whose value is $\frac{1}{13.7}$; this gives as the angular difference between the diameters only $0''.28$. If the position of the axis were well known, and a great number of measurements very carefully made, I think that a compression approximating the above would be disclosed, but the total amount is so small that a very accurate determination is impossible. Since Mercury and Venus have no known satellites, the above method cannot be used in its entirety for the determination of the compression of these planets; but since their respective masses are known approximately a modified method, viz., one of comparison with the earth's compression can be used for this purpose. Let the earth's mass, radius and rotational period be each equal to unity, and the corresponding quantities for Mercury and Venus be expressed in terms of the former quantities, by m, a and b. A consideration of equation (1) will show that the value of the compression c may be obtained from the following equation:

$$c = \frac{13.412a^4}{mb^2r} \quad (6)$$

In this equation r represents the radius of the planet, expressed in miles. From (6) I have obtained for the compression of Mercury $\frac{1}{338}$, and for Venus $\frac{1}{291}$; the first quantity represents a difference between the angular diameters of Mercury of only $0.''02$, and the latter a difference of only $0.''06$ between the diameters of Venus, quantities too small to be accurately observed.

It is obvious that, by means of my method, an accurate knowledge of the figure of the earth can be derived from linear measurements of arcs of *longitude* either on the equator or reduced to it. Such arcs would furnish a value of the equatorial radius, and this in connection with the velocity v, and k, would give a value of the compression closely approximating the true one. This again will give a near approximation to the value of the *polar* radius from which a more accurate value of the compression can be determined. Three approximations will suffice to give a true value of the last named quantity.

(To be Continued.)

DEARBORN OBSERVATORY.

H. A. JOHNSON, M. D.*

The Chicago Astronomical Society, after mature consideration, decided to commit to the Northwestern University the care and use of the Dearborn Observatory. The arrangements by which the location of the Observatory and the incorporation of it as a part of the university has been accomplished are mutually satisfactory. As a result of these arrangements we have met to-day to lay the corner-stone of a building which we hope and believe will become known wherever science is cultivated, and especially wherever the heavens are studied. There is not time, nor perhaps is this the fitting place to enter upon a historical statement of the great telescope. It is sufficient to say that at the time it was secured for the Observatory it was the largest in existence; that is, the largest refracting telescope. Although there are now a few instruments with larger object glasses than this, this one still remains among the very best, among the most reliable and most powerful in existence. It has been in use since it was first mounted, and the contributions which have been made to our knowledge of celestial phenomena through its revelations have been recognized by all interested in this department of science. I may mention especially the studies of the varying condition of the surface of the planet Jupiter, carried on through a series of years. These have been published in the reports of the society, and are a lasting monument to the skill and industry of the director, Professor Hough.

The relations of the society to the university do not relieve us of responsibility, nor diminish our interest in the future of the observatory. We trust that the liberality

* Address delivered by the president of the Chicago Astronomical Society at the laying of the corner stone of the new building for Dearborn Observatory at Evanston, Ill., Thursday, June 24, 1888.

that has secured for the instrument a suitable building and mounting, and the conveniences for profitable use here will be exercised to meet the increased needs that shall be developed. These needs will come. They will always be growing. It is only by relegating the instrument to the list of unused things that its wants can remain stationary. We trust that some liberal-minded friend of a wider and more liberal education will provide for the astronomical department an endowment which shall make this institution as permanent as are some of the older observatories of this and other countries. This requires money, but money put into this fund will pay more than it now commands in the business markets of the world.

We congratulate the Northwestern University upon this addition to the means of culture and influence which it is creating here upon the borders of this beautiful lake. It is within my memory that these grounds were transferred from the domain of wild nature to classic shades, academic groves. I once stood upon yonder bluff and looked out upon the quiet lake. There a little way down the country road was a farm house, and that was all there was of the city of Evanston, and all that there promised to be at that time. I had come to make a professional visit to a poor woman, the farmer's wife, and strayed out among the trees and gazed upon the lake while thinking what I might do for my patient. No one then thought of a future city amid these groves. Chicago itself had barely 30,000 inhabitants, and a prophet who should have foretold the realities of to-day would have been regarded as—well, as a very pronounced "Chicago man"—that is a little "cranky." I believe that my old teacher, the venerable Dr. John Evans, was among the most enthusiastic believers in the greatness of Chicago. It was the outcome of his enthusiasm, his far-seeing wisdom, that these magnificent grounds were consecrated for all coming time to the noble uses of a higher education. His monument is not alone in the name which this city bears. It is in these clustered halls, these temples of literature, of science, of art, of religion, and in the wider, more powerful, and vastly better influence which, in the persons of the alumni of this institution, permeates all of this broad land.

The occasion which has called us together is of peculiar interest. Why have we determined to build here among these classic shades and in connection with these seats of learning, a temple to the stars, perhaps I might say to Jupiter? What is the significance in these days of practical things of this addition to the university? Is there any use to which it may be put? Will it in any way help the student in his work of preparation for the duties of life? These are questions that will naturally occur to those who look upon every kind of learning from the standpoint of utilitarianism. If we were to admit that all learning should be judged by the help which it brings to the material interests of life, there would still be found a sufficient answer to these interrogatories. It is not, however, in this narrow sense that a university should be judged. It has a wider range, a broader field, a richer harvest of truth and usefulness than simple food, shelter and raiment, than a provision for the machinery of business, and we trust that this institution will serve this wider purpose. It is possible, nevertheless, to show that the studies of the astronomer, the use of instruments of precision in the observation of the celestial bodies, and the abstruse mathematical calculations by which these observations are translated into the language of common life, that these are all helpful in the affairs of time and sense. Perhaps we are hardly aware of the very great importance of accuracy as to time in many of the business transactions of civilized communities. In fact this precision is one of the indications of intellectual and social progress. It enters into all of the industrial pursuits. It constitutes an important factor in all our commercial transactions; and especially in these days of eager, anxious haste, it furnishes the condition of safety, in fact the only substantial condition of safety. The astronomer in his dome, the world shut out, with his telescope pointed away from earth, while all the heavenly hosts in rapid succession march across his field of vision, determines the timetable of the skies, the place and hour when and where suns and planets shall meet and pass a thousand years to come.

These studies furnish the data, and the only data, upon which the dispatcher of terrestrial trains conducts with comparative safety the millions of human beings to and fro, from sea to sea, and over and through this interminable network of railways and steamships, a network which has been drawn closely around all whom we love, all who love us, and all who in any way are concerned in the welfare of the human race. It is accuracy, precision, certainty, the conviction that the clock in the railway office, the time-keeper in the business exchange, the watch of the conductor and engineer and the chronometer of the master of the great steamship, that all these markers of duration are in accord, that they are all right, that gives a sense of security, of restfulness which nothing else could give. Accuracy in time is the foundation of accuracy in every other matter. It is promotive of truthfulness in every other respect. In some sense, then, the Observatory is a moral institution, an ally of the biblical institute. The great telescope is a detective, a sure witness, a trustful, unchanging, unambiguous revealer of the secrets of nature. Its creed never changes. It has no favorites, and no enemies. It cannot be bribed. No threats intimidate it. Its revelations of the past are not myths, but veritable history. Its prophecies will surely be fulfilled. All this precision, all this certainty, all these helps in the affairs of practical life, are the outcome of astronomical work, and would be impossible without it.

It would be trite, perhaps, to refer to the studies connected with such institutions as a means of enlarging the scope of mental action and giving it a wider range of intellectual vision. Perhaps even such a view of the influence of astronomical investigation would by some be considered an objection to this class of studies for all except the very few whose lives are to be devoted to the especial work of time keeping. Such a view is in accord with the tendency of the age, which, as it seems to me, is to narrowness. It is true, this very fact gives a high degree of skill in a given pursuit, but it nevertheless dwarfs the powers of the individual in every other respect. The division of labor carried to the extreme, the tendency to an exaggerated specialism in the professions, the narrow line of studies pursued in some of our educational institutions where studies are selected with special reference to the work of the coming years, and before any general foundation has been laid down upon which such special studies ought to rest, all these may lead to great intensity.

Like the diamond drill, they may push on a narrow line to the very front of knowledge along that line, while all that lies parallel to it, and perhaps very near to it, remains unknown but connected with it. I confess I see with some regret this tendency, and I hail with satisfaction all these scientific additions to the university as in some sense corrective of the narrowness which the desire to make of every man a specialized machine seemes to necessitate.

The bearing of these studies upon the moral and religious elements of our being is only good. One who during his life has looked longingly and lovingly into the heavens exclaimed: "the undevout astronomer is mad." The contemplation of the divine wonders of the celestial vault leads the thought away from the small things of time and sense, and opens the eternal volume which must always be a companion to that written upon the rocks of Sinai. The nice balance of the universe, the order that comes out of apparent disorder, the infinite depths of space, the vast whirl of mighty suns to which our sun in its warmth and glory is but a spark, the far-off nebulæ, the star-dust that like the lights of a distant city gleam upon the very confines of the visible universe, these are all so many sources of inspiration. No wonder that old Chaldean shepherds, gazing into the heavens, were wise beyond their fellows; that they were "seers." All these sublime chambers of the infinite open before us we become, like the stars themselves, silent with awe. The words of the poet feebly give voice to our struggling thought:

"What though in solemn silence all
Move round this dark terrestrial ball;
What though no real voice nor sound
Amid those radiant orbs be found;
In Reason's ear they all rejoice,
And utter forth a glorious voice,
Forever singing as they shine,
The hand that made us is divine."

Opposition of Mars for 1888. L. Niesten, of the Royal Observatory of Brussels, has published a brief paper on the physical aspects of the planet Mars at opposition for 1888. Two plates accompany the paper.

THE EXISTENCE OF ALL-PERVADING ETHER PROVED BY EXPERIMENT.*

And now I want to spend a short time in explaining to you how the question has been decided. An illustrative example may make the question itself clearer, and so lead you to understand the answer better. In colloquial language we say that balloons, hot air, etc., rise because they are light. In old times this was stated more explicitly, and therefore much more clearly. It was said that they possessed a quality called "levity." "Levity" was opposed to "heaviness." Heaviness made things tend downwards, levity made things tend upwards. It was a sort of action at a distance. At least it would have required such an hypothesis if it had survived until it was known that heaviness was due to the action of the earth. I expect levity would have been attributed to the direct action of heaven. It was comparatively recently in the history of mankind that the rising of hot air, flames, etc., was attributed to the air. Everybody knew that there was air, but it was not supposed that the upward motion of flames was due to it. We now know that this and the rising of balloons are due to the difference of pressure at different levels in the air. In a similar way we have long known that there is an ether, an all-prevading medium, occupying all known space. Its existence is a necessary consequence of the undulatory theory of light. People who think a little, but not much, sometimes ask me, "Why do you believe in the ether? What's the good of it?" I ask them, "What becomes of light for the eight minutes after it has left the sun and before it reaches the earth?" When they consider that, they observe how necessary the ether is. If light took no time to come from the sun, there would be no need of the ether. That is a vibratory phenomenon, that is affected by matter it acts through—these could be explained by action at a distance very well. The phenomenon of interference would, however, require such complicated and curious laws of action at a distance as practically to put such an hypothesis out of court; or else be purely

* An extract from the Address of Professor G. P. Fitzgerald, M. A., F. R. S., President of the Section of Mathematics and Physical Science of the British Association, at its annual meeting in Bath for 1888.

mathematical expressions for wave propagation. In fact, anything except propagation in time is explicable by action at a distance. It is the same in the case of electro-magnetic actions. There were two hypotheses as to the causes of electro-magnetic actions. One attributed electric attraction to a property of a thing called electricity to attract at a distance, the other attributed it to a pull exerted by means of the ether, somewhat in the way that air pushes balloons up. We do not know what the structure of the ether is by means of which it can pull, but neither do we know what the structure of a piece of india-rubber is by means of which it can pull; and we might as well ignore the india-rubber, though we know a lot about the laws of its action, because we do not know its structure, as to ignore the ether because we do not know its structure. Anyway what was wanted was an experiment to decide between the hypothesis of direct action at a distance and of action by means of a medium. At the time that Clerk Maxwell delivered his address no experiment was known that could decide between the two hypotheses. Specific inductive capacity, the action of intervening matter, the delay in telegraphing, the time propagation of electro-magnetic actions by means of conducting material—these were known, but he knew that they could be explained by means of action at a distance, and had been so explained. Waves in a conductor do not necessarily postulate action through a medium such as ether. When we are dealing with a conductor and a thing called electricity running over its surface, we are, of course, postulating a medium on or in the conductor, but not outside of it, which is the special point at issue. Clerk Maxwell *believed* that just as the same air that transmits sound is able by differences of pressure—*i. e.* by means of its energy per unit volume—to move bodies immersed in it, so the same ether that transmits light causes electrified bodies to move by means of its energy per unit volume. He believed this, but there was no experiment known then to decide between this hypothesis and that of direct action at a distance. As I have endeavored to impress upon you, no *experimentum crucis* between the hypotheses is possible except an experiment proving propagation in time, either directly, or indirectly by an experiment exhibiting phenomena like those of the interference of light. A theorist may speak of propagation of actions in time without talking of a medium. This is all very well in mathematical formulæ, but, as in the case of light we must consider what becomes of it after it has left the sun and before it reaches the earth, so every hypothesis assuming action in time really postulates a medium whether we talk about it or not. There are some difficulties surrounding the complete interpretation of some of Hertz's experiments. The conditions are complicated, but I confidently expect that they will lead to a decision on most of the outstanding questions on the theory of electro-magnetic action. However, there is no doubt that he has observed the interference of electro-magnetic waves quite analogous to those of light, and that he has proved that electro-magnetic actions are propagated in air with the velocity of light. By a beautiful device Hertz has produced rapidly alternating currents of such frequency that their wave length is only obout 2 metres. I may pause for a minute to call your attention to what that means. These waves are propagated 300,000 kilometers in a second. If they vibrated 300,000 times a second, the waves would be each a kilometer long. This rate of vibration is much higher than the highest audible note, and yet the waves are much too long to be manageable. We want a vibration about a thousand times as fast again with waves about a metre long. Hertz produced such vibrations vibrating more than 100,000,000 times a second. That is, there are as many vibrations in one second as there are seconds—in a day? No, far more. In a week? No, more even than that. The pendulum of a clock ticking seconds would have to vibrate for four months before it would vibrate as often as one of Hertz's vibrators vibrates in one second. And how did he detect the vibrations and their interference? He could not see them; they are much too slow for that; they should go about a million times as fast again to be visible. He could not hear them; they are much too quick for that. If they went a million times more slowly they would be well heard. He made use of the principle of resonance. You all understand how, by a succession of well-timed small impulses a large vibration may be set up. It explains many things from speech to spectrum analysis. It is related that a former Marquess of Waterford used the principle to over-turn lamp-posts—his ambition soared above knocker-wrenching. So that it is a principle known to others besides scientific men. Hertz constructed a circuit whose period of vibration for electric currents was the same as that of his generating vibrator, and he was able to see sparks, due to the induced vibration, leaping across a small air space in the resonant circuit. The well-timed electrical impulses broke down the air resistance just as those of my Lord of Waterford broke down the lamp-post. The combination of a vibrating generating circuit with a resonant receiving circuit is one that I spoke of at the meeting of the British Association at Southport as one by which this very question might be studied. At the time I did not see any feasible way of detecting the induced resonance: I did not anticipate that it could produce sparks. By its means, however, Hertz has been able to observe the interference between waves incident on a wall and the reflected waves. He placed his generating vibrator several wave-lengths away from a wall, and placed the receiving resonant circuit between the generator and the wall, and in this air-space he was able to observe that at some points there were hardly any induced sparks, but at other and greater distances from his generator they reappeared, to disappear again in regular succession at equal intervals between his generator and the wall. It is exactly the same phenomenon as what are known as Lloyd's bands in optics, which are due to the interference between a direct and a reflected wave. It follows hence that, just as Young's and Fresnel's researches on the interference of light prove the undulatory theory of optics, so Hertz's experiment proves the ethereal theory of electro-magnetism. It is a splendid result. Henceforth I hope no learner will fail to be impressed with the theory—hypothesis no longer—that electro-magnetic actions are due to a medium pervading all known space, and that it is the same medium as the one by which light is propagated, that non-conductors can, and probably always do, as Professor Poynting has taught us, transmit electro-magnetic energy. By means of variable currents energy *is* propagated into space with the velocity of light. The rotation of the earth is being slowly stopped by the diurnal rotation of its magnetic poles. This seems a hopeful direction in which to look for an explanation of the secular precession of terrestrial magnetism. It is quite different from Edlund's curious hypothesis that free space is a perfect conductor. If this were true there would be a pair of great anti-poles outside the air, and terrestrial magnetism would not be much like what it is, and I think the earth would have stopped rotating long ago. With alternating currents we *do* propagate energy through non-conductors. It seems almost as if our future telegraph cables would be pipes. Just as the long sound waves in speaking tubes go round corners, so these electro-magnetic waves go round corners if they are not too sharp. Professor Lodge will probably have something to tell us on this point in connection with lightning conductors. The silvered glass bars used by surgeons to conduct light are exactly what I am describing. They are a glass, a non-conducting, and therefore transparent, bar surrounded by a conducting, and therefore opaque silver sheath, and they transmit the rapidly alternating currents we call light. There would not be the same difficulty in utilizing the energy of these electro-magnetic waves as in utilizing radiant heat. Having all the vibrations of the same period we might utilize Hertz's resonating circuits, and in any case the second law of thermodynamics would not trouble us when we could practically attain the absolute zero of these, as compared with heat long-period vibrations.

We seem to be approaching a theory as to the structure of the ether. There are difficulties from diffusion in the simple theory that it is fluid full of motion, a sort of vortex sponge. There were similar difficulties in the wave theory of light owing to wave propagation round corners, and there is as great a difficulty in the jelly theory of the ether arising from the freedom of motion of matter through it. It may be found that there is diffusion, or it may be found that there are polarized distributions of fluid kinetic energy which are not unstable when the surfaces are fixed: more than one such is known. Osborne Reynolds has pointed out another, though in my opinion less hopeful, direction in which to look for a theory of the ether. Hard particles are abominations. Perhaps the impenetrability of a vortex would suffice. Oliver Lodge speaks confidently of a sort of chemical union of two opposite kinds of elements forming the ether. The opposite sides of a vortex ring might perchance suit, or maybe the ether, after all, is but an atmosphere of some infra-hydrogen element; these two latter hypotheses may both come to the same thing. Anyway we are learning daily what sort of properties the ether must have. It must be the means of propagation of light; it must be the means by which electric and magnetic forces exist; it should explain chemical actions, and if possible gravity.

On the vortex-sponge theory of the ether there is no real difficulty by reason of complexity why it should not explain chemical actions. In fact, there is every reason to expect very much more complex actions would take place at distances comparable with the size of the vortices than at the distances at which we study the simple phenomena of electro magnetism. Indeed, if vortices can make a small piece of a strong elastic solid, we can make watches and build steam-engines and any amount of complex machinery, so that complexity can be no essential difficulty. Similarly the instantaneous propagation of gravity, if it exists, is not an essential difficulty, for vortices each occupy all space, and they act on one another simultaneously everywhere. The theory that material atoms are simple vortex-rings in a perfect liquid otherwise unmoving is insufficient, but with the innumerable possibilities of fluid motion it seems almost impossible but that an explanation of the properties of the universe will be found in this conception. Anything purporting to be an explanation founded on such ideas as "an inherent property of matter to attract," or building up big elastic solids out of little ones, is not of the nature of an ultimate explanation at all; it can only be a temporary stopping-place. There are metaphysical grounds, too, for reducing matter to motion and potential to kinetic energy.

MR. J. A. BRASHEAR'S EUROPEAN TRIP.*

At London I visited the rooms of the Royal Society and here I had a *royal* time with Professor Dewar who, with

* On Mr. Brashear's return from Europe, we asked him to tell us something about his trip, in informal way, for we knew he would be exceedingly busy after vacation absence. His reply contains so many things of interest that we share it with our readers, though not especially prepared for publication.

Professor Liveing, is carrying on some most interesting researches on the spectra of the gases, and particularly the spectrum of water vapor in high vacuo, in perhaps the largest vessels that have ever been used for the purpose. Some remarkable discharges were witnessed, or rather one would call them streams of electric energy having all the appearances of comets when nearing the sun, and Professor Dewar seems to think that these experiments may have an important bearing in the solution of cometic phenomena.

At the Royal Institute I had the privilege of an examination of many of the treasures of the museum, where are stored the models and apparatus of Sir Humphrey Davy, Faraday and Cavendish.

While in London I had the pleasure of visiting Dr. Huggins at his Observatory on Upper Tulse Hill. Here we found the good Doctor and his charming wife (Mrs. B. said she came very near to her idea of an angel) ready to show us his grand equipment for celestial spectroscopy that is perhaps not excelled anywhere. The Doctor has two telescopes mounted on the same stand after Grubb's plan, and there are so many accessories to his outfit that it would take a large volume to describe them. Mrs. Huggins handles these instruments with perfect ease, and her interest in the work has certainly been a large factor in the wonderful results that have been achieved by the Director of the "Upper Tulse Hill Observatory." We had the pleasure of meeting Mr. E. B. Knobel, the secretary of the Royal Astronomical Society, at Dr. Huggins', and the delightful "tea" we sat down to in that charming "library" will not soon be forgotten. At Cambridge Professor Liveing gave us every facility to see what they are doing. A new chemical laboratory is about completed at St. John's College, in which is to be placed a concave grating spectroscope. This grating (which was 21 feet radius) I had the pleasure of carrying over with me. You have no idea how much pleasure I had here in examining one of the largest of the reflecting telescopes made by Sir Isaac Newton and kept in a good state of preservation. I was allowed the rare privilege of taking out the speculum and measuring its constants, examining the character of the metal, its polish, etc. The polish is still quite good and would show bright objects fairly well.

At Cambridge we met the venerable Professor Adams and his good wife, and renewed a most pleasant acquaintance formed at Philadelphia in 1884. Professor Adams is still in the harness, and is one of those grand men whom the world will miss when they have "finished their course."

But I must hasten over to Paris where I had a "glorious" time with "glorious" men, and I cannot refrain from saying that the courteous secretary of the Paris Observatory, Mr. Fraissinet, did everything in his power to make my stay pleasant. A day was spent with Dr. J. Janssen and his delightful family at the great "Observatory" of Meudon, where at present no less than *three* large new observatories are being completed. The old chateau of the first Prince Napoleon is now being changed into a great Observatory, the dimensions of which will be but a few feet less than the Lick. The great new refractor is to be placed in this. In one of the other observatories a reflecting telescope of one meter aperture and three meters focal length is to be placed, for use in photographing the nebulæ, comets, and other celestial objects requiring large apertures, and in the third, one of the standard thirteen-inch photographic refractors is to be set up. All these instruments are under way—the optical parts being made by the Henry Brothers, and the mechanical parts by M. Gautier.

Of course every one will know I was particularly interested in the Brothers Henry and their work. Here a most hearty welcome awaited us, and to say that we enjoyed it hugely is to put it very mildly.

These two devotees of science work by themselves with some help from their father, whom they hold in the highest reverence, and he is a grand old man, and I confess I never left a place more reluctantly than I did the home of these whole-souled men.

At the time of our visit they were working a 13-inch photographic objective by their usual method of paper polishing of which they seem to be complete masters. They were so totally unselfish that they showed me the entire *modus operandi.* They are doing some large work, for, besides the photographic and other large objectives, they are engaged on several large instruments known as the Equatorial Coudé, one of which is to be 23 inches clear aperture. I saw in their shops a 40-inch plane mirror, 7 inches thick, a beautiful piece of work, and I had the pleasure of examining a number of their optical surfaces with them. All I fear of these grand fellows is, that they are *working beyond their limit*, for not only is every hour of the day spent at their optical work, but every night with a clear sky finds them at their post at the Observatory carrying out their part of the photographic chart of the heavens, and we all know how well this part of their work has been done. I could fill a dozen sheets with what I saw here, but I must desist. I had received a very cordial invitation from Dr. Loewy to make some observations with the Equatorial Coudé, and of course availed myself of the privilege, as this was one of my desires in going to Paris. When I called the doctor was making some studies of the constants of refraction by his new method, which is well known to astronomers, and notwithstanding the fact that here was an additional pair of mirrors added to the telescope, the image of the stars in the field was all that could be desired. It is understood, however, that the reflected image of each star comes from three mirrors, and not from four. I had every facility afforded me to study the construction of these instruments, both at the Observatory and at the works of M. Gautier, who was kind enough to show me all the drawings and the work under way.

While in Paris I visited the optical glass works of M. Mantois, successor to Feil. M. Mantois has reconstructed the works, and he has now everything arranged so systematically that it is a genuine pleasure to go into his warehouse or his works. Every kind of glass has its department and is so arranged that if you desire first, second or third grade, of any density or index, it can be at once pointed out to you. I had the pleasure of examining many discs from 6 inches to 30 inches diameter, as well as a huge mass that M. Mantois is preparing for the Paris exhibition next year. I have not the least doubt in my mind that the mantle of Feil and his predecessors has fallen upon M. Mantois, who will not only wear it with honor to himself, but will make it all the more valuable by the work he will do in the future. But I must close this already too lengthy letter, and leave the subsequent part of my pleasant experience for another letter. I cannot forget the kindness of Dr. Janssen, Professor Deslandres, M. Admiral Mouchez, M. Fraissinet, MM. Paul and Prosper Henry, M. Loewy, M. Gautier and others who made my stay in Paris so pleasant and profitable, and I trust the genuine spirit of unselfishness that I found in these lovers of the good and beautiful, will always be emulated by their brethren on this side of the Atlantic.

MEAN PARALLAX OF FIRST MAGNITUDE STARS.*

Since my last report the series of observations on the parallaxes of the ten stars of the first magnitude in the Northern Hemisphere has been brought to a close. It may seem worth while to mention in brief here the results arrived at, in advance of their detailed publication in our Transactions. They are as follows:

Star.	Parallax.	Prob. Error.	No of Comp. stars.	No. of obs.	Proper Motion.
α Tauri,	+0″.116	±0″.029	6	64	0″.202
α Aurigæ,	+0 .107	0 .047	2	16	0 .442
α Orionis,	—0 .009	0 .049	2	16	0 .022
α Canis Minoris,	+0 .266	0 .047	2	16	1 .257
β Geminorum,	+0 .068	0 .047	2	16	0 .628
α Leonis,	+0 .093	0 .048	4	15	0 .255
α Boötis,	+0 .018	0 .022	10	89	2 .287
α Lyræ,	+0 .034	0 .045	2	30	0 .344
α Aquilæ,	+0 .199	0 .047	4	16	0 .647
α Cygni,	—0 .042	0 .047	4	16	0 .010

The probable errors here given include an estimation of the probable *systematic* error of the measures, derived from the agreement of the independent results from the several pairs of comparison stars where more than one such has been employed. They are therefore considerably larger than those generally assigned to such results, which, as a rule, only take into account the mere *casual* error of observation.

It will be seen on inspection of the table that of the ten stars six may be said to give indications of a measurable parallax, but in only two cases are the values in any degree

* Report of W. L. Elkin, Astronomer in charge of the Heliometer, at the Observatory of Yale University, New Haven, Ct.

remarkable. These are those for α Canis Minoris and α Aquilæ, and it is worth while to note that they confirm closely results of former investigators, namely those of Auwers and Wagner on Procyon, which gave +0″.240 ±0″.029 and +0″.299 ±0″.038 respectively, and that of W. Struve at Dorpat on Altair, which gave +0″.181 ±0″.094. On the other hand my next two largest results, those for Aldebaran and Capella do not confirm the larger values found by O. Struve at Pulkowa, which were +0″.516 ±0″.057 and +0″.305 ±0″.043. In the case of the former star I am, however, in close agreement with Hall at Washington, who found +0″.102 ±0″.030, and there seems to be but little doubt that the Pulkowa value is largely in error. There have been no results of any importance derived hitherto for Pollux and Regulus, the remaining two of the six stars where the effect of parallax is at all sensible.

Of the four stars where the parallactic displacement has been inappreciable, Arcturus, with its large proper motion of over 2″, second only to that of α Centauri in all of the 200 brightest stars down to the fourth magnitude, is especially noteworthy. The minuteness of the parallax is beyond doubt, depending as it does on five pairs of comparison stars, all in reasonable agreement, and it cannot be considered as seriously at variance with results previously obtained by Peters and Johnson, +0″.127 ±0″.073 and +0″.138 ±0″.052 respectively, when their liability to systematic error is duly taken into account. For α Orionis and α Cygni, in view of their extremely small proper motions, the insensibility of their parallaxes is not surprising. The Yale result for α Lyræ, however, does not fall in well with those which have been hitherto deduced for this star. If we commence at the epoch of W. Struve and neglect the earlier attempts to find the absolute parallax, we have the following list of values:

W. Struve at Dorpat, 1837–40,	+0″.261	±0″.025
Peters at Pulkowa, 1842,	0 .103	0 .053
O. Struve at Pulkowa, 1851–53,	0 .147	0 .009
Johnson at Oxford, 1854–55,	0 .154	0 .046
Brunnow at Dublin, 1868–69,	0 .212	0 .010
Brunnow at Dublin, 1870,	0 .188	0 .033
Hall at Washington, 1880–81,	0 .134	0 .0055

from which a parallax of about +0″.17 would seem well assured. The pair of comparison stars used here is very symmetrical and so large a value would seem incompatible with Heliometer measures: I hope, however, to be able to trace the discordance to its source.

In planning this work the object in view was the determination of the average or mean parallax of the stars of the first magnitude, and in pursuance of this I may state that the mean of the 10 values above given is

$$+0''.085 \qquad \pm 0''.015,$$

to which should probably be added $+0''.004$ as the probable parallax of the comparison stars which are in the mean of about the eighth magnitude, giving

$$+0''.0890 \qquad \pm 0''.015$$

for the result sought for. I do not, however, in view of the wide range of distance implied by the values of the above table, feel at all certain that this result may be taken as a measure of the average distance of the stars in question, and at all events it must be considered only as provisional and partial until it can be combined with the results for the first magnitude stars of the Southern Hemisphere, now in course of determination by Dr. Gill. At the same time I might draw attention to its near coincidence with the values derived by Gyldén ($0''.084$) and Peters ($0''.102$)— without, however, wishing to lay too much stress on this agreement.

FORMATION OF SUNSPOTS.

JOHN R. HOOPER.

The following table is derived from a careful examination of 422 diagrams made at the eye-piece and extending from Jan. 1st, 1882, to Oct. 31st, 1885, thus embracing the time of greatest sunspot activity.

Large groups, evidently proceeding from the same centers of causation, have been considered as single spots and care was taken to avoid counting spots twice. No attempt is made to identify spots which may have made a second appearance, but the scrutiny is confined to the behavior of all spots as they presented themselves upon the disk of the sun.

Whatever the cause, or perhaps, wherefore the coincidence, the fact is shown, that a large majority of the sunspots come into view from the farther side of the sun, fully formed.

The few spots originating on the near side of the sun were mostly of inferior importance. A tendency to stop enlargement and even to lessen size, was also apparent while the spots continued on this side of the sun. The claim is not made that our earth can thus influence the place of origin, or modify developement and subsidence, of solar commotions; the table results from an attempt to answer a question of a fellow sunspot observer. "Why do all sunspots of any importance always come around the corner?"

A study of the records of the past thirty years, and preferably photographs, might yield some useful information.

The record of the present minimum is to be reduced later on, and an attempt will be made to study the next maximum from this standpoint very exhaustively.

This paper is put forth, hoping others who have kept drawings may make a similar examination.

TABLE.

	Spots.	
Originated on Disk, and increased	5	
" " " remained same	8	
" " " diminished	9	
		— 22
On the Disk after 4 to 6 days cloudy weather and increased	0	
On the Disk after 4 to 6 days, remained same	10	
" " " " " " " " diminished	3	
		— 13
Came in on limb and increased	41	
" " " " " remained same	125	
" " " " " diminished	55	
		—221
Total		256

METROLOGY AT THE NORTHWESTERN UNIVERSITY.

The Northwestern University of Evanston, Ill., has recently organized a Beaureau of Metrology, etc., with Dr. M. D. Ewell as director. The instrumental equipment of this Bureau comprises, among other things, two dividing engines, by Professor W. A. Rogers, one small and non-automatic, and the other the very perfect machine upon which Professor Rogers has hitherto executed his superior rulings. This machine has two precision screws, one ½ meter long with a pitch of $\frac{1}{20}$ inch, and the other about six inches long with a pitch of $\frac{1}{50}$ inch. Both these screws are fine specimens of workmanship and the smaller one is very nearly perfect. The large machine is entirely automatic when executing rulings finer than $\frac{1}{1000}$ inch. The Bureau also has two comparators both by Professor Rogers, one small and the other large and capable of comparing standards up to 114 centimeters in length. Both are constructed with adjustable stops, the standards to be compared being compared with the constant distance between the stops, from which their relation to each other is ascertained. The larger comparator has co-efficient of expansion, end-measure and ruling attachments and is practically a perfect instrument. Among the standards are a Sir Joseph Whitworth yard and its subdivisions, a yard and meter line-measure upon a steel surface by Clark, a ½ yard and ½ meter on aluminum bronze and other short standards, all ruled and investigated by Professor W. A. Rogers.

For thermometric standards there are among others four Kew Standards, two by Baudin, six by Geissler and two very perfect standards by H. J. Green of New York. The last standards by Green are exceptionally fine, the calibration of one being perfect the whole length of the scale, and the other having only one error and that so small as to be almost, if not quite, within the error of observation. With these are boiling-point and freezing-point apparatus and a water comparator devised by Dr. Ewell for the comparison of thermometers.

The work of the Bureau will consist principally in the preparation and investigation of standard micrometers and larger scales, and in the comparison of thermometers. Some little time longer will be occupied in the investigation of the long screw, as the systems of correction change every time the machine is dismounted, after which some special line of investigation will be adopted, which will be duly announced.

The Examination of the Eclipsed Moon is the title of a valuable paper recently read by George F: Burder before the Bristol Naturalists' Society May 3, 1888.

CURRENT INTERESTING CELESTIAL PHENOMENA.

THE PLANETS.

Mercury will be at greatest elongation west from the sun, 19°34', Nov. 16, when it will rise an hour and three-quarters before the sun. The declination of the planet, however, is so far south that it will not reach a sufficient altitude to be well seen in northern latitudes. Mercury will be in conjunction with the moon, 3°34' south, on Dec. 2 at 2:45 A.M. central time.

Venus is coming into better position for observation especially in the southern hemisphere. Her altitude will be pretty low for northern observers. She is "evening star," and will be easily recognized in the southwest between Jupiter and Mars, and brighter than either of them. It will be seen from the tables that Venus sets from two to three hours later than the sun during the month Nov. 15 to Dec. 15.

Mars continues in about the same position with reference to the sun, the change being slightly to the better for observation, but its distance from the earth has increased to about three times that of the planet's opposition in April, so that but little detail may be expected to be visible upon its surface. The October number of *L'Astronomie* contains four more drawings of Mars, made in May and June, 1888, by M. Perrotin with the 30-inch refractor at Nice, each showing some of the "canals," and especially one new one extending several hundred miles in a meridional direction, from the north polar *cap*, parallel to a previously known canal. M. Perrotin also speaks of the marked changes which he has noticed in the detail of Mars' surface during the long continued observations of a single night; affecting especially the dark spots of the surface. In the same number of *L'Astronomie* there are two attempted geological explanations of the canals: the one by Dr. Eug. Penard, of Geneva, that they are immense fissures, produced by the contraction of the planetary mass, through which the waters of the oceans flow; the other by "a Subscriber," whose name is not given, that the canals are wrinkles on the crust of the planet, or mountain ranges.

It may be of interest here to reproduce a drawing of the planet Mars made by the writer (H. C. Wilson) in 1886 with the 11 inch equatorial of Cincinnati Observatory. The drawing was made at 12*h* 30*m* March 6, 1886, a night when the seeing was the most exquisite ever experienced during the six years spent at that observatory. The observer was not then at all familiar with the configuration of Mars' surface and drew what he could see without effort. At least three of Schiaparelli's canals are shown. The north polar ice cap was very white and sharply defined.

MARS, March 6, 1886, at 12*h* 30*m*, as seen with 11-in. refractor, power 450.

In copying the drawing the outline of the disk was constructed by mistake from data pertaining to Mercury instead of Mars. The mistake was not noticed until after the cut had been engraved. The disk should be almost circular as the drawing was made within one day of opposition.

Jupiter will come to conjunction with the sun on Dec. 8, and is now so near the latter (apparently) that no observations of value can be made.

Saturn is in good position at midnight now and in December may be observed after 10 P. M. He will be in quadrature with the sun November 11, and stationary in his apparent course among the stars November 30. It will be noticed from the tables that the motion during the whole month, November 15 to December 15, is less than a minute in right ascension and 10′ in declination. In Monthly Notices of the R. A. S. for June, 1888, Mr. T. G. Elger gives a resumé of his observations made with an 8½ inch silver-on-glass reflector by Calver during the first four months of the year. Several interesting points are noted, among which are, the varying color of the planet and rings, due probably to atmospheric causes; Encke's division frequently seen as a faint, delicate dark line; Cassini's division not perfectly black or well defined except at the inner edge; the outer edge being sometimes "fuzzy" and without any definite limit; irregularities in the brightness of different segments of the middle ring; a dark line traced part of the way round between the middle and inner rings; inner edge of inner or dusky ring irregular and sometimes deeply notched; marked change in the belts since 1887; distorted appearance of the shadow of the planet upon the rings. Speaking of the abnormal features noted Mr. Elger says: "It is perhaps noteworthy that those with sufficient optical means, who do *not* see them, are more or less desultory observers of the planet, while those just mentioned [Messrs. Trouvelot, Terby and others] examined it on every available opportunity. Continuous observation night after night doubtless tends to educate the eye, so that it soon becomes so familiar with the object scrutinized that delicate features, which are either only doubtfully glimpsed or not seen at all by the occasional gazer, are readily detected whenever definition permits.

"No telescope of the largest type has of late, so far as I know, been brought to bear upon the rings of Saturn. It is to be hoped that this will be done before they become too unfavorably placed for the detection of abnormal details."

Uranus may be seen in the morning. He will be found about 3° almost exactly north of Spica.

Neptune will be in opposition to the sun November 22, and is therefore in very favorable position for observation. It will be difficult to find this planet without an equatorial telescope provided with circles. It is about 5° south and as far east of the Pleiades.

MERCURY.

	R. A.	Decl.	Rises.	Transits.	Sets.
	h m		h m	h m	h m
Nov. 15	14 12.2	−10°47′	5 11 A. M.	10 31.4 A. M.	3 53 P. M.
25	14 58.3	−15 06	5 36 "	10 38.2 "	3 40 "
Dec. 5	15 57.9	−19 53	6 18 "	10 58.3 "	3 39 "
15	17 03.0	−23 22	7 00 "	11 23.8 "	3 47 "

VENUS.

	R. A.	Decl.	Rises.	Transits.	Sets.
Nov. 15	17 44.6	−24 59	9 48 A. M.	2 03.4 P. M.	6 19 P. M.
25	18 38.8	−25 01	10 03 "	2 17.9 "	6 33 "
Dec. 5	19 32.1	−23 49	10 10 "	2 31.8 "	6 53 "
15	20 23.7	−21 28	10 11 "	2 43.9 "	7 17 "

MARS.

	R. A.	Decl.	Rises.	Transits.	Sets.
Nov. 15	19 17.0	−23°46′	11 14 A. M.	3 35.6 P. M.	7 57 P. M.
25	19 49.9	−22 31	11 01 "	3 28.9 "	7 57 "
Dec. 5	20 21.9	−20 51	10 46 "	3 21.9 "	7 58 "
15	20 53.7	−18 47	10 29 "	3 14.4 "	8 00 "

JUPITER.

	R. A. h m	Decl.	Rises. h m	Transits. h m	Sets. h m
Nov. 15	16 43.0	−21 48	8 30 A. M.	1 01.7 P. M.	5 33 P. M.
25	16 52.5	−22 06	8 02 "	0 31.8 "	5 02 "
Dec. 5	17 02.2	−22 22	7 38 "	0 02.2 "	4 30 "
15	17 12.0	−22 35	7 05 "	11 32.7 A. M.	4 00 "

SATURN.

	R. A.	Decl.	Rises.	Transits.	Sets.
Nov. 15	9 31.6	+15 38	10 40 P. M.	5 47.5 A. M.	12 55 P. M.
25	9 32.2	+15 37	10 02 "	5 08.9 "	12 16 "
Dec. 5	9 32.2	+15 39	9 22 P. M.	4 29.6 "	11 37 "
15	9 31.5	+15 45	8 42 "	3 49.6 "	10 57 "

URANUS.

	R. A.	Decl.	Rises.	Transits.	Sets.
Nov. 15	13 14.2	− 7 12	4 01 A. M.	9 36.2 A. M.	3 11 P. M.
25	13 16.0	− 7 23	3 23 "	8 57.0 "	2 31 "
Dec. 5	13 17.8	− 7 35	2 46 "	8 19.0 "	1 52 "
15	13 19.3	− 7 42	2 09 "	7 41.5 "	1 14 "

NEPTUNE.

	R. A.	Decl.	Rises.	Transits.	Sets.
Nov. 15	3 57.3	+18 42	4 53 P. M.	12 14.3 A. M.	7 36 A. M.
25	3 56.1	+18 38	4 13 "	11 33.8 P. M.	6 55 "
Dec. 5	3 55.0	+18 35	3 33 "	10 53.3 "	6 14 "
15	3 53.9	+18 32	2 52 "	10 12.9 "	5 34 "

THE SUN.

	R. A.	Decl.	Rises.	Transits.	Sets.
Nov. 10	15 05.4	−17 26	6 52 A. M.	11 44.1 A. M.	4 36 P. M.
15	15 25.9	−18 45	6 59 "	11 44.9 "	4 30 "
20	15 46.7	−19 56	7 06 "	11 46.0 "	4 26 "
25	16 07.8	−20 57	7 12 "	11 47.4 "	4 23 "
30	16 29.3	−21 49	7 18 "	11 49.2 "	4 21 "
Dec. 5	16 51.0	−22 30	7 23 "	11 51.2 "	4 19 "
10	17 13.0	−23 01	7 28 "	11 53.4 "	4 19 "
15	17 35.1	−23 20	7 32 "	11 55.8 "	4 19 "

Ephemeris of Variable Stars of the Algol Type.

[*Approximate Central Time of Minima ; from Astronomical Journal, No. 182.*]

d	h	Star
Nov. 10	9 P. M.	λ Tauri.
11	1 A. M.	Algol.
12	9 P. M.	Y Cygni.
13	10 P. M.	Algol.
14	6 P. M.	λ Tauri.
14	7 P. M.	U Cephei.
15	5 P. M.	R Canis Maj.
15	9 P. M.	Y Cygni.
16	7 P. M.	Algol.
16	8 P. M.	R Canis Maj.
17	5 P. M.	S Cancri.
17	11 P. M.	R Canis Maj.
18	5 P. M.	λ Tauri,
18	9 P. M.	Y Cygni.
19	2 A. M.	R Canis Maj.
19	3 P. M.	Algol.
19	7 P. M.	U Cephei.
21	8 P. M.	Y Cygni.
24	7 P. M.	U Cephei.
24	7 P. M.	R Canis Maj.
24	8 P. M.	Y Cygni.
25	10 P. M.	R Canis Maj.
27	1 A. M.	R Canis Maj.
Nov. 27	8 P. M.	Y Cygni.
29	6 P. M.	U Cephei.
30	8 P. M.	Y Cygni.
Dec. 1	2 A. M.	Algol.
2	6 P. M.	R Canis Maj.
3	8 P. M.	Y Cygni.
3	9 P. M.	R Canis Maj.
3	11 P. M.	Algol.
4	6 P. M.	U Cephei.
5	12 A. M.	R Canis Maj.
6	4 A. M.	R Canis Maj.
6	4 P. M.	S Cancri.
6	8 P. M.	Algol.
6	8 P. M.	Y Cygni.
9	5 P. M.	Algol.
9	6 P. M	U Cephei.
9	8 P. M.	Y Cygni.
10	5 P. M.	R Canis Maj.
11	8 P. M.	R Canis Maj.
12	8 P. M.	Y Cygni.
12	11 P. M.	R. Canis Maj.
14	5 P. M.	U Cephei.

Occultations Visible at Washington.

Date.		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
Nov.	7	ν^1 Sagittarii	5	5 37	124	6 33	324	0 56
	7	ν^2 Sagittarii	5	6 03	113	7 05	234	1 02
	9	20 Capricorni	6½	9 00	33	9 53	286	0 53
	18	δ^2 Tauri	5½	17 00	101	18 05	243	1 05
	23	35 Cancri	6½	12 57	82	14 20	290	1 22
	23	ε Cancri	6½	17 02	17	Star 0.9′ N. of moon's limb.		
	25	37 Leonis	5½	12 05	102	13 09	283	1 04
Dec.	9	ψ^2 Aquarii	4	8 20	329	Star 9.0′ N. of moon's limb.		
	9	ψ^3 Aquarii	4½	7 45	81	8 56	219	1 11
	10	30 Piscium	4½	3 50	130	4 21	173	0 31
	13	ξ^2 Ceti	4½	10 51	154	Star 6.1′ S. of moon's limb.		

Phases of the Moon. Central Time.

		d	h	m	
New Moon	Nov.	3	6	02	P. M.
First Quarter	"	10	10	16	A. M.
Full Moon	"	18	9	16	"
Last Quarter	"	26	11	20	"
New Moon	Dec.	3	4	6	"

Ephemeris of Comet c 1888 (Brooks). The following ephemeris of Comet *c* is from the *Astronomische Nachrichten*, No. 2860, elements by Dr. Krueger. The ephemeris was computed by J. Möller, for 12*h* Berlin mean time.

1888.	α	δ	log. *r*	log. Δ	L.
	h m s	° ′			
Nov. 2	16 56 26	−1 42.0			
4	17 0 33	2 23.2	0.2633	0.4034	0.10
6	4 36	3 2.7			
8	8 35	3 40.6	0.2753	0.4172	0.09
10	12 30	4 17.0			
12	17 16 21	−4 51.8	0.2870	0.4306	0.08

We are sorry not to be able to present an ephemeris of Barnard's comet, though it is so bright that any one knowing its locality will doubtless easily pick it up when the moon is out of the way. The ephemeris will be in hand a few days later, and will be sent to any observer in need of it.

Comet e, 1888 (Barnard), was seen by Mr. J. M. Parkhurst, Marengo, Ill., October 9, 10, 14. It was very faint.

Last Observation of Comets. It is especially requested that observations of any of the comets of this year, near the time of disappearance, be sent us that the records of all may be as complete as possible.

EDITORIAL NOTES.

The Old and New Astronomy. The readers of this important new book will be gratified to learn that its publishers, Messrs. Longmans, Green & Co., will carry out the original plan of its publication as heretofore announced. This is possible because Mr. Proctor had nearly completed the copy for the work before his sudden death.

Definitive Determination of Comet 1887 IV. Mr. Frank Muller, of the Leander McCormick Observatory, University of Virginia, has completed and published a Definitive Determination of Comet 1887 IV. This work was presented to the Faculty of the University of Virginia on applying for the degree of Doctor of Science.

Catalogue of Variable Stars by Chandler. Those interested in the study of variable stars will find S. C. Chandler's catalogue of variable stars (*Astronomical Journal*, No. 179–80) the latest and the most complete work of its kind anywhere in print so far as we know.

New Nebulæ, Catalogue No. 7, Warner Observatory. Dr. Swift has published in *A. N.*, No. 2859, Catalogue No. 7, containing 100 new nebulæ which have been found at Warner Observatory since the publication of Dr. Dreyer's New General Catalogue. In this catalogue he calls attention to the fact that an inspection of all the lists of new nebulæ will show an extraordinary number in Draco where formerly but few were known. Preceding October 13 Dr. Swift had discovered forty-three more new nebulæ, a large beginning for the eighth catalogue.

Comet e, 1888. There seems to be a little discrepancy in *Science* Circular, No. 82, as to the dates of Mr. Barnard's discovery, and the independent discovery by Mr. Brooks, of Geneva, N. Y. Mr. Barnard found the comet Monday morning, Sept. 3, and Mr. Brooks on Tuesday morning, Sept. 4, civil reckoning. The astronomical dates would, of course, be respectively Sept. 2 and 3. The two discoveries were separated by one day and not two.

Bessel's Log. B for Great Elevations.

Bar. inches.	Log. B.	Diff.	Bar. inches.	Log. B.	Diff.
20.0	—0.17021	+216	23.8	0.09467	+182
.1	0.16805	+216	.9	0.09285	+182
.2	0.16589	+214	24.0	—0.09103	+180
.3	0.16375	+214	.1	0.08923	+180
.4	0.16161	+212	.2	0.08743	+179
.5	0.15949	+211	.3	0.08564	+179
.6	0.15738	+211	.4	0.08385	+177
.7	0.15527	+209	.5	0.08208	+177
.8	0.15318	+208	.6	0.08031	+176
.9	0.15110	+208	.7	0.07855	+176
21.0	—0.14902	+206	.8	0.07679	+175
.1	0.14696	+206	.9	0.07504	+174
.2	0.14490	+204	25.0	—0.07330	+173
.3	0.14286	+203	.1	0.07157	+173
.4	0.14083	+203	.2	0.06984	+172
.5	0.13880	+201	.3	0.06812	+171
.6	0.13679	+201	.4	0.06641	+171
.7	0.13478	+199	.5	0.06470	+170
.8	0.13279	+199	.6	0.06300	+169
.9	0.13080	+198	.7	0.06131	+169
22.0	—0.12882	+197	.8	0.05962	+168
.1	0.12685	+196	.9	0.05794	+167
.2	0.12489	+195	26.0	—0.05627	+167
.3	0.12294	+194	.1	0.05460	+166
.4	0.12100	+194	.2	0.05294	+165
.5	0.11906	+192	.3	0.05129	+165
.6	0.11714	+192	.4	0.04964	+164
.7	0.11522	+191	.5	0.04800	+164
.8	0.11331	+190	.6	0.04636	+163
.9	0.11141	+189	.7	0.04473	+162
23.0	—0.10952	+189	.8	0.04311	+162
.1	0.10763	+187	.9	0.04149	+161
.2	0.10576	+187	27.0	—0.03988	+161
.3	0.10389	+186	.1	0.03827	+160
.4	0.10203	+185	.2	0.03667	+159
.5	0.10018	+185	.3	0.03508	+159
.6	0.09833	+183	.4	0.03349	
.7	0.09650				

Some years ago I computed Bessel's log. B from barometer = 27.4 inches down to barometer = 15.0 inches, and as I have never seen any similar table, it has occurred to me that astronomers who may have occasion to make astronomical observations at great elevations might find them of some value, and I therefore venture to send such a table of log. B between the limits of 20.0 inches and 27.4 inches to THE SIDEREAL MESSENGER. Professor Harkness is of opinion that for altitudes above 4,000 feet the value of log. B may be too large. (See *Astronomical Journal*. No. 182.)

Washington, Oct. 13, 1888. H. P. TUTTLE.

Heliometer Work at Yale Observatory. Dr. W. L. Elkin, in his last report, gives a glance at the work going on in the observatory by the aid of his fine heliometer. He says it "is now being employed in a triangulation of the stars in the vicinity of the North Pole. Early in the year Professor Pickering, of Harvard, applied to us to determine the relative places of a few stars to serve as fundamentals for a catalogue of stars within one degree of the Pole, by photographic methods. I have concluded to enlarge the plan originally laid out for this purpose, and am now observing 24 stars within 100′ of the Pole, nearly all that are measurable with the heliometer in the area. The work is well under way, but as a considerable portion of the months of October, November and December are to be devoted to the joint observation with Dr. Gill of the extremely favorable opposition of Iris for a determination of the solar parallax it may not be completed before next year.

Mr. Hall has been steadily occupied with the reduction of his measures of Titan, which is now approaching completion. In this connection he has made an extensive series of measures on the division errors of the parts of the scale in use therefor. He has also taken up for investigation of their parallaxes the stars 6 B Cygni and 18115-22 Lalande, both of which present special interest.

The series of measures of the sun's diameter has been continued, a special research having been undertaken on the influence of different apertures upon the same, and upon the scale value. We have also made some measures of the diameter of Mars at its late opposition and of various double stars."

The Horizon at Lick Observatory. The dip of the horizon at Lick Observatory, Mt. Hamilton, California, as far as it is merely geometrical, can easily be computed from the altitude of the Observatory, which is 4,209 feet above sea level. The distance of the sea horizon (which is in view) is eighty-seven miles. The actual horizon is bounded by mountains of various heights all around except on the west in a few places. It would seem then the dip of the horizon to the west ought to be approximately 62′. It is still an interesting query to ascertain what the effect of refraction is at low altitudes at Mt. Hamilton. By kindness of Professor Holden we have the exact distances given above.

New Meridian Circle for Cincinnati Observatory. We have received a photograph of the new meridian circle just completed by Messrs. Fauth & Co., Washington, D. C., for the Cincinnati Observatory. In appearance the instrument is a beautiful one, and we have no doubt but that it is as good as it looks. At our request Messrs. Fauth & Co., are to furnish us a full page cut of this new instrument for the next MESSENGER, and Professor Porter, Director of the Cincinnati Observatory, has already prepared a description of it for publication. This is the largest and the finest instrument we believe that Messrs. Fauth & Co. have made up to this time. Its circles were divided on their large, new dividing engine, which is, we suppose, the best machine of its kind in this country, if not equal to the best in the world. A detailed cut of it was given in this journal not long ago.

Professor C. Piazzi Smyth, late Astronomer Royal and Professor of Practical Astronomy in the University of Edinburgh, favors us with a report of the Observatory, bearing date August 25, 1888. It is matter of very great regret that so able an astronomer as Professor Smyth should find it necessary to resign his place. His account of the causes leading to it will provoke surprise and shame in the minds of all lovers of astronomy the world over. When will the time come that government officials charged with the guardianship of the useful sciences, will either know enough, or care enough about their welfare not to desert them, say nothing about actual starvation. We indulge the hope that Professor Smyth will soon be recalled to his old position, with the Observatory refitted in such a way as it should be for a government astronomical observatory to be used in modern times.

Leander McCormick Observatory. The last report of Professor Stone, Director of the Leander McCormick Observatory, University of Virginia, shows for the year ending June 1, 1888, that 154 southern nebulæ have been observed at least twice, and 96 others once; that the motion of Hyperion, the seventh satellite of Saturn is nearly commensurate with that of Titan, the sixth satellite, whose mass is much larger than that of either of the other satellites of Saturn. These satellites approach very near to each other at conjunction; as a result the ordinary methods for determining the motion of Hyperion are inapplicable. From a discussion of the problem Professor Stone finds that the mass of Titan is much larger than had hitherto been supposed, and his result has been confirmed by Mr. G. W. Hill who used an entirely different method.

Bibliography of Astronomy for 1887. William C. Winlock, assistant astronomer at the United States Naval Observatory, has compiled a subject-index of astronomy for the year 1887, which forms an interesting general review of the progress of astronomy during that year. The sources of information have been scientific journals, the transactions of societies and more elaborate publications that have come to the compiler's notice. This is 664 of the Smithsonian Miscellaneous Collections, and the pamphlet contains 63 pages and 364 titles arranged in alphabetical order, the titles being printed neatly in heavy faced type.

Professor Comstock's Article of last month on "The Value of a Revolution of a Micrometer Screw," has one error in the formula on page 345, which was discovered by him too late to correct in the copy. The equation

$$\Delta\delta = \Delta x + \tfrac{1}{2}\Delta x\,(\sin \Delta y \tan \delta)^2$$ should read

$$\Delta\delta = \Delta x + \tfrac{1}{8}\Delta x\,(\sin \Delta y \tan \delta)^2.$$

Astronomical Photography. The following circular will interest many of our readers, and therefore we print it in full:

In accordance with the wish expressed by the Astro-photographic Congress, held at Paris last year, we are now occupied with the constitution of a Committee to study the best methods of working and to collect results obtained in celestial photography, other than the photographic chart of the heavens (which is in the hands of the Committee of the Congress).

If you wish to take part in this work, we should be glad if you would send to either of us your adhesion.

Next year, when scientific congresses will be held in Paris, we intend to call together those who have thus expressed their adhesion in order to constitute a Committee, and examine the questions that we shall have to consider. We would further ask you to let us know if you would be disposed to take a part in this meeting to be held in Paris at a time to be hereafter notified.

J. JANSSEN,
(*President de l'Academie des Sciences; Directeur de l'Observatoire d'Astronomie Physique de Paris*), *Meudon*, (*Seine et Oise*), *Paris*.

A. A. COMMON, F. R. S.,
Eaton Rise, Ealing, London.

1888, September 15th.

Question sixth of the October number asks for a table of the most accurately measured distances of the stars.

Guillemin in his "Heavens," page 292, gives a table of the distances of eight stars expressed in astronomical units:

	Radii of earth's orbit.		Radii of earth's orbit.
α Centauri	211,330	ε Ursa Majoris	1,500,800
61 Cygni	550,920	Arcturus	1,622,800
Vega	1,330,700	Polaris	3,078,600
Sirius	1,375,000	Capella	4,484,000

The astronomical units may be converted into miles by multiplying by 92,500,000. I have made the multiplication by logarithms.

	Miles.		Miles.
α Centauri	19,548,025,000,000	ε Ursæ Maj	143,449,000,000,000
61 Cygni	50,960,100,000,000	Arcturus	150,109,000,000,000
Vega	123,089,750,000,000	Polaris	284,760,500,000,000
Sirius	127,187,500,000,000	Capella	404,770,000,000,000

3979 Iowa Ave., St. Louis, Mo. MARTIN S. BRENNAN.

Queries. 8. There is an object in approximate R. A. 19*h* 25*m* and N. Decl. 9°5 that has the appearance of a comet in my 8½-inch reflector. There are two stars in same field, which form a right angle with the unknown object nearly. The stars are 14 or 15 magnitude. W. K.

In Dr. Dreyer's new general catalogue of nebulæ and star clusters there are two objects answering to the above position roughly; a planetary nebula, and more closely a faint star cluster marked *c*B, S, *i*R, *rrr*, meaning "considerably bright, small, irregularly round, well resolved, clearly consisting of stars." We have not had opportunity to verify the object at the telescope, but think that the last object was the one seen. Our querist has probably mistaken the magnitude of the stars near, as 14th magnitude stars of the ordinary scale would be barely visible in a 10-inch glass.

9. Why do astronomers in their tables of elements of orbits of comets give the perihelion distance, *q*, by its logarithm, and the longitude of perihelion, longitude of node, and inclination by their natural numbers? A. B. C.

This is all very natural. Computers use formulæ that are made up chiefly of symbols like these referred to. Mathematicians are so familiar with all such terms that they incline to use them from choice, doubtless to the inconvenience of the popular reader who may have interest in such work. One familiar with the use of logarithms will not consult his tables once in ten times to know the natural number represented. He reads that approximately from the logarithm. We have known of one computer who rarely ever went to his tables for a four-place logarithm. He carried the tables in his mind to that extent. The reason that longitude of perihelion, longitude of node and inclination are given in natural numbers (so-called), is because logarithms of arcs or angles are scarcely ever used in computations of this kind. Work is done by logarithms on trigonometric functions, and tables give the angles that belong to the functions found.

For the benefit of readers troubled by these symbols we will gladly give the plainer statement of the elements of comets in the future.

10. On page 354 it is said that the table (elements) shows that the comet is receding from the earth. How does it show that? A. B. C.

That statement was made when we intended to print an ephemeris. Later that was thought undesirable, but inadvertantly the last line, which did not belong to the elements, but did apply to the ephemeris, was not withdrawn as it should have been.

Doubtless some of our readers would like to share in answering queries sent to the MESSENGER. Here are a few that came just as we are ready to go to press, and we can only give room for them without answer, which will appear later:

11. Why do almanacs in giving the times of the moon's rising say "morning", instead of giving the time, as, for instance, on Oct. 13 of the present year? Between the preceding two and the following two days there is a difference betwen her risings of about an hour, whereas between the 12th and 14th there is but about an hour difference. She must certainly rise at the same time on the 13th and why not give the time instead of saying "morn?" A. B. C.

12. Why do nearly all text-books on astronomy fail to state that there is such a thing as precession in declination? All devote a chapter to precession in right ascension, but scarcely an instance can be found where the former is dealt with, or even hinted at. A. B. C.

13. At certain times of the year, especially in November, why is there a difference of half an hour between the lengths of the forenoons and afternoons? A. B. C.

14. How is the oft repeated statement made by astronomers explained that the sun attracts a comet and at the same time repels it to form its tail? How can the sun simultaneously attract and repel? A. B. C.

15. If, at the equator, a ball be fired from an accurately zenith pointing rifle, to a height of fifty miles, will it at its descent strike the earth east or west of the gun? How would it fall if the experiment were tried at St. Petersburg? A. B. C.

16 Is the orbit of the earth, so called, the path of the center of the earth's mass? P. M.

17. What is a dialytic telescope? E. W. A.

Next time we shall speak of the progress of Professor H. A. Howe in planning and building the new observatory for the University of Denver.

We have received a lengthy and interesting paper on the velocity of sound. It claims to prove that physicists are wrong in accounting for the difference between theoretical and observed velocities of sound waves or pulsations on the ground of the agency of heat. The theoretical and the observed volumes of these pulses should agree, and do agree when rightly computed, without considering the development of heat at all.

American Telescopes. Professor David P. Todd, Amherst College, prepared the paper on American Telescopes and telescopic work done in the United States which is found in the appendix to vol. xxiii, Encyclopedia Britannica, American reprint. This article speaks of the telescope in use as early as 1830, and the one projected and built in 1838 by E. P. Mason and H. L. Smith (now Professor Smith of Hobart College); of the beginning of Celestial photography, in 1850, by Professor Bond of Cambridge who tried Vega and the double star Castor, and the work of Bartlett of West Point in 1854 and Campbell of New York; of the results of L. M. Rutherford of New York with an 11¼-inch objective figured by himself; of Dr. Henry Draper's success in the same time by the aid of a still larger telescope which is still in use in the researches of the Henry Draper memorial at Harvard College Observatory; of the marked success of the Professors Pickering at the last named Observatory, and, in general, the large promise that belongs to this new branch of astronomy. Considerable space is rightly given in this review of current astronomical work in America, to the makers of astronomical instruments, in which the following names appear: Spencer of Canastota, N. Y., Clacy of Boston, Lyman of Lennox, Mass., Professor Hastings of Yale Scientific School, Clark Brothers of Cambridgeport, Mass., Young of Philadelphia, Messrs. Fauth & Co., Washington, and Brashear of Allegheny City, Pa. This interesting paper closes with a brief description of the discoveries that have been made by American astronomers, which will signify the kind of work done, as well as the progress of the science on this side of the Atlantic.

A planet of the 13th magnitude or fainter was discovered by Palisa Oct. 25.2486, Greenwich mean time, in R. A. 0^h 53^m 36.4^s; Decl. $+2° 54' 58''$.

Readers of mathematics will find food for thought in Mr. Corrigan's article, the leader of this issue. In our next this paper will be concluded, showing some surprising results.

Dr. B. A. Gould, editor of the *Astronomical Journal*, Cambridge, Mass., who has been abroad for several months, is expected to return about the first of November. S. C. Chandler has edited the *Journal* in Dr. Gould's absence.

Important Papers from Harvard College Observatory have been received bearing the following titles: Total Eclipse of the Moon, Jan. 28, 1888; Photometric Observations of Asteroids, by Henry M. Parkhurst; and Total Eclipse of the Sun, Aug. 29, 1886, by William H. Pickering. These papers deserve more than a mere mention by title. We would give full notice of them now but for lack of space. Some parts of them show excellent results in photography. Abstracts may be presented later.

BOOK NOTICES.

Planetary and Stellar Studies, or Short Papers on the Planets, Stars and Nebulæ, by John Ellard Gore, F. R. A. S., etc. London: Messrs. Roper & Drowley, 29 Ludgate Hill, E. C., 1888, pp. 264. Price 7*s* 6*d*.

For many years past Mr. Gore's writings on astronomical themes have been favorably known to those acquainted with the science, and this book is largely a reprint of papers previously published by him. Some of them have been re-written and brought down to date, and those on the planet Mercury, the Minor Planets, Uranus and Neptune, and the Distances of the Fixed Stars are entirely new. As a whole the book is an interesting brief review of Planetary Astronomy and Sidereal Astronomy. The characteristics of each of the planets are noticed and a statement of authority made, giving, as far as we know, late and reliable information. While enough is said about the supposed satellite of Venus, no mention is made of the supposed Vulcan or other intra-Mercurial planets. The six lithographic plates of Mars' surface, as observed in 1877, when at last nearest approach to the earth, give considerable surface detail, but show scarcely anything that looks like the parallel canals of Schiaparelli. This is not surprising, because, so far, the best American telescopes have not done much better. Pertaining to the stars are interesting articles on the double stars, variable stars, the distances of the fixed stars, the Milky Way, the Great Pyramid and the precession of the equinoxes, new stars, the masses and distances of the binary stars, the absolute dimensions of a star cluster, stellar photography, the zodiacal light and the infinity of space. The publishers have done their part of the work handsomely.

College Algebra, for the Use of the Academies, Colleges and Scientific Schools. With numerous examples.

Academic Algebra, for the Use of Common and High Schools and Academies. With numerous examples. Both by Edward A. Bowser, L.L. D., Professor of Mathematics and Engineering in Rutgers College. New York: D. Van Nostrand, publisher, 23 Murray and 27 Warren streets, 1888. College Algebra, pp. 540. Academic Algebra, pp. 352.

The College Algebra is a book complete in itself, as it starts with the beginning of algebra, using the first eighteen pages for definitions and the enunciation of first principles. The next one hundred and forty pages are devoted to the fundamental operations, factoring, divisors, multiples and fractions, with abundant examples for practice under each theme. To the equation of one and more unknown quantities are given about fifty pages, the methods of elimination being only the usual three.

After involution and evolution come the study of the theory of exponents and the radical quantity, including the binomial surd. The examples under these topics are well chosen and considerable in number.

Chapter XVIII. gives a new and convenient name to the proofs used in establishing certain propositions. It is called Mathematical Induction. The discussion of the imaginary quantity is considered next to the intermediate equation. The geometric meaning of the imaginary unit is helpful. The book closes with a short chapter on the theory of equations and Cardan's solution of the cubic equation. We are a little disappointed not to see the subject of infinitesimal analysis touched upon at all in this book, which is certainly very thorough in its treatment of all themes presented. The elements of this important branch ought to be in every college algebra, if necessary at the expense of several less useful topics ordinarily given.

The Academic Algebra is a book of 352 pages arranged on the same general plan as that already given. The subjects of quadratics, rates, proportion, progression and the binomial theorem are the last and most difficult ones given in this lower book.

We are sure that the teacher with beginning classes will find this a model book for the class-room. Mr. Van Nostrand's publishing house knows how to make a mathematical text-book that will afford constant pleasure in its use so far as the mechanical part of the work is concerned.

Our Celestial Home, An Astronomer's View of Heaven. J. G. Porter, A.M., Director of the Cincinnati Observatory. New York: Messrs. Anson, D. F. Randolph & Company, 38 West Twenty-third street; pp. 116.

This little book contains six articles titled as follows: Heaven a material locality, Heaven a part of the Universe, Habitablity of the celestial worlds, Stability of the Universe as to motion, Stability of the Universe as to force, Conclusion.

The author was led to this writing from the often expressed views that "the material universe is inevitably destined to decay and death, and therefore not fitted for an eternal dwelling place of the redeemed." Suppose that man were permitted to live on, here, in some form, the earth is gradually losing its energy of rotation on its axis, as well as that of revolution around the sun; the sun is losing his energy; the planets are growing old like the moon; the solar system must decay in time, and what happens to our system doubtless belongs alike to all stars, for our sun is but an inferior one of the great starry hosts of heaven, so that if these all are finite, they are doomed to utter dissolution. Although there is sublimity and grandeur in this visible universe of ours, its garment is not an immortal one. "We must look elsewhere if we would be clothed with immortality as with a garment." Eternal life is not merely existence prolonged forever; nor has Professor Drummond probably all in mind that pertains to it, when he says, "it is to know God, to have communion with Him." Evidently there is a higher range of human being not at all dependent on our present material environment. The author gives an astronomer's view of this, one who has thought and read carefully, and in happily chosen phrase brings to bear on it from astronomical science latest facts as he thinks they may be interpreted reasonably in the light of the Bible. We most heartily commend the noble spirit of this little book, in view of the common attitude of scientists at the present time, of professing to know little of, and to care less about, the relations of God to his glorious works, than almost anything else.

Books Received.

Wentworth's College Algebra, Messrs. Ginn & Co., publishers.

Bowser's Analytic Mechanic's; Bowser's Analytic Geometry; Bowser's Hydro-mechanics; all published by D. Van Nostrand.

Numbers Symbolized in Elementary Algebra, Messrs. D. Appleton & Co., publishers.

Goodsoe's Manual of Mechanics; Elementary Lessons in Mechanics; Elementary Lessons in Mechanics, second stage; all published by Messrs. Longman's, Green & Co.

Poetry and Prose by T. and T. H. Higginson.

THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE,

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

VOL. 7, NO. 10. DECEMBER, 1888. WHOLE NO. 70.

THE FIRST COLLEGE OBSERVATORY IN THE UNITED STATES.

JAMES L. LOVE.*

FOR THE SIDEREAL MESSENGER.

An Astronomical Observatory begun at the University of North Carolina in 1831 and completed in 1832 has, for some reason, remained unnoticed by historians of astronomy. Professor Loomis, in his "Progress of Astronomy," edition of 1850, gives to Yale College the credit of the first purchase of a telescope, in 1828; and to Williams College the honor of erecting the first Observatory in 1836. But the University of North Carolina bought instruments before Yale, and built an Observatory before Williams. Yale College ordered her telescope in 1828, received it in 1830, and placed it in the steeple of one of the buildings, where low windows interfered with its use. Professor Albert Hopkins went to Europe in 1834 to select instruments for Williams College; and his Observatory was ready for use in June, 1838. President Joseph Caldwell went to Europe in 1824 to buy books and apparatus for the University of North Carolina. He laid out $3,234.74 for books and $3,361.35 for apparatus, of which a large part was for astronomical instruments. These were received in 1825-26, and were at first set up in Dr. Caldwell's lecture room; and used in determining, among other things, the first approximate values of the latitude and longitude of Chapel Hill. The foundations of the Observatory were laid in April, 1831; but work was stopped until March, 1832, when it was resumed and kept up until the completion of the building in August, 1832. It was a single-roomed building 15 by 23 feet and about 25 feet high. The first eight feet of the wall were of stone, plastered inside and out, and enclosing

* Associate Professor Mathematics, University of North Carolina.

a low basement slightly excavated. Above this the walls were of brick, terminating in a low parapet round the top. The first floor was several feet from the ground, and was reached by a flight of steps on the eastern face of the building. The roof was a nearly flat double floor, caulked and pitched. A steep stairway inside the building led up to this upper floor. Two pillars of masonry rose up through the interior, one of them terminating just above the first floor and bearing the transit instrument, and the other rising above the roof and bearing the altitude and azimuth instrument on its top. A low tower with doors in opposite faces was constructed to protect the altitude and azimuth instrument. This tower was placed on a railway and was moved back and forth by rope and windlasses. Its top was flat and was reached by a light ladder. To furnish a range for the transit, which was inside the building, a slit several inches wide was made across the roof and down into the north and south faces of the walls, in the plane of the meridian. Shutters were constructed to close up this slit when the transit was not in use.

The building was on a low hill just outside the campus. The trees had been cut away so that a sweep of the entire horizon could be made with the altitude and azimuth instrument. This was not a private Observatory. The entire cost of the building ($430), as well as of the instruments, was paid by the University.

The transit instrument was made by Simms of London. Its focal length was 44 inches and its aperture 3 inches. The altitude and azimuth instrument was also made by Simms. Its aperture was 2½ inches and focal length 33. Its horizontal and vertical circles were 20 and 24 inches in diameter, respectively, with two verniers and reading microscopes to each. These circles were graduated on platinum bands to 5 minutes of arc.

The telescope was a small portable one of 2½ inches aperture and 52 inches focal length. It was made by Dollond of London. The astronomical clock was made by Molyneux, with mercurial pendulum. The outfit contained also a reflecting circle made by Harris of London, a sextant, and a Hadley's quadrant.

Observations were made here by Dr. Caldwell and his two colleagues professors James Philips and Elisha Mitchell, but they were kept up for only a few years, but Dr. Caldwell was the moving spirit of the enterprise. His health begun to fail soon after the building was ready for use; and, after his death in 1835, there was no one here who had time and inclination to push the enterprise on to success. The times were not favorable here in North Carolina, nor any where else in this country, for the establishment of Observatories. Our national Observatory was not authorized by Congress for ten years after this; and even then, its name had to be disguised as that of a "Depot of Charts and Instruments." It was only when some individual enthusiast like Albert Hopkins or Joseph Caldwell, by his personal effort or influence had an Observatory erected, that anything at all was done. Had Dr. Caldwell been in the prime of life, or had there been any successor to his zeal and energy, something excellent would have grown out of this beginning. But Dr. Caldwell's successor in the Presidency of the University, D. L. Swain, was in no sense a scientific man. His studies were in history, law and politics. The Observatory was not fostered by him. The roof began to leak, and it proved so troublesome that the instruments were removed soon after Dr. Caldwell's death; and the wood-work of the building was burnt from some unknown cause about 1838. In a few years the bricks were hauled away and used in building a kitchen, which is in use still! The foundations of the Observatory can be easily traced yet, and there are several persons of the highest character, now living in Chapel Hill, who witnessed observations there in their childhood. All records of observations have been lost; whether during reconstruction days when the University was closed for some years and some of the dormitories turned into stables by negro troops, or before, no one knows.

All the instruments but the reflecting circle and the quadrant are still in the possession of the University; and all are unfit for use except the telescope and clock. The latter still marks time for Chapel Hill. It will be granted, I think, that Dr. Caldwell had a pretty fair nucleus of apparatus to begin his Observatory with. A telescope costing twelve or thirteen hundred dollars was in contemplation, but Dr.

Caldwell's death caused the failure of the whole enterprise before it could be bought.

Dr. Caldwell was a graduate of Princeton, and was called to the Professorship of Mathematics in the University of North Carolina soon after its establishment in 1795. He was afterwards made president. When he died in 1835, he had brought the University up to a position which compared very favorably with older and wealthier institutions. He brought back from Europe in 1824 nearly a thousand volumes of very carefully and intelligently selected books to start a good library with. The apparatus he bought was of the best. He brought to Chapel Hill some of the best talent in the country as members of his faculty. Among them were Professor James Phillips and Dr. Elisha Mitchell, who lost his life in the scientific exploration of the highest mountain east of the Mississippi, a peak of the Alleghany range in western North Carolina now called for him "Mitchell's Peak;" also Professor Ethan A. Andrews, who was called from here to a professorship of Latin in New Haven, Connecticut; and Denison Olmsted, who went from here to Yale.

Dr. Caldwell's efforts to promote science deserved a higher appreciation than they have yet received. Let us hope that he, and the institution he guided so intelligently, may be given the credit they merit for building the first College Observatory in the Union.

Chapel Hill, North Carolina, Oct. 31, 1888.

THE EFFECTS OF ROTATION UPON THE FLUID ENVELOPE OF A REVOLVING SPHERE.*

SEVERINUS J. CORRIGAN.

We can determine the effects of rotation upon any particle situated upon the augmented equatorial circumference or upon any augmented meridian circumference in the same manner and by means of the same equations used in the case above discussed.

The value of p, thus determined, will represent simply a force opposed to gravity and it is the one generally known

* Continued from page 381.

as "the centrifugal force." The equal force at a right angle to it represents an approximately tangential pressure in an eastward direction. It represents the force which, when called into action by the perturbing force of cosmical bodies, becomes, I claim, the prime cause of all the phenomena mentioned at the beginning of this article. The distance *ac* in Fig. 1, through which an unimpeded particle would fall to the "centre of gravity" *c*, may be regarded as representing the whole force of gravity acting upon the particle at *a*. This distance *ac* is the radius of the equatorial circle, and since *p*, or the radial force acting in opposition to gravity, is expressed in terms of this radius, the value of *p* computed from equation (1), by means of the augmented values of *v* and *r*, will represent the "centrifugal force," expressed, as it usually is, in terms of the whole "force of gravity." Performing the operation we find that $p = \frac{1}{291.5}$. As before, there will be an equal force having its origin at the focus *f*, or nearly seven miles below the surface, and directed at a right angle to the former force.

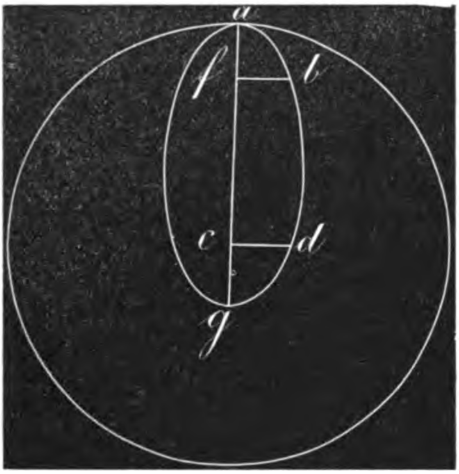


FIG. 1.

If we combine these two forces together, and then their resultant with the whole "force of gravity" by means of the well-known formulæ for the "composition and resolution of forces," we will find that the resultant or apparent gravity will be directed, not normally to the surface, but eastward at an angle *a*, whose value on the equator is 11′47.5″. This angle may also be computed from the equation $\sin a = \frac{p}{r}$; therefore the semi-parameter *p*, may be taken as the measure of this angle.

From equation (1) we see that *p*, and therefore the angle *a*, increase with the distance from the "centre of gravity."

The direction of gravity thus assumes the form of a curved line. All matter attracted to a centre and, at the same time, impressed with a velocity whose direction is not exactly toward the centre, will approach the latter in a curved line, as may be demonstrated by means of equation (1).

Of this action, there are, I think, examples in the "spiral nebulæ," whether these be gaseous or simply star clusters, and it is to it that the sun and the planets, formed by the condensation of nebulous matter toward a centre, owe the motion of rotation upon their respective axes. It thus bears testimony, to a certain extent, to the truth of the nebular hypothesis, taking the latter in a general sense. We see from the above that the "centrifugal force" which will now be designated by m, is $\frac{1}{291.5}$ of the whole "force of gravity." The value of m determined by the ordinary method is $\frac{1}{289.5}$. The small though very important difference between the results determined by the two different methods is due wholly and solely to the fact noted above, that the force acting at a right angle to the radius is *not* a tangential force, as it has been assumed to be in the ordinary method. As demonstrated above the force at a right angle to the radius has its origin, not on the surface, but at the focus, f, nearly seven miles below, and therefore its direction differs from that of a tangent to the surface by 11 47′ .5.

I have stated that the compression (taken in the sense $c = \frac{a-b}{b}$) deduced from pendulum vibrations is $\frac{1}{288.5}$, while that derived from arcs of meridian is $\frac{1}{294.0}$, and that the discrepancy has been attributed mainly to local causes affecting the motion of the pendulum. I have also *asserted* that the greater part of the discrepancy was due to a cause entirely different from that assigned. I now purpose to demonstrate the truth of my *assertion*. To do so I have recourse to Clairaut's well-known equation, which expresses the relation between the "centrifugal force" m, the compression e, and the difference between the "force of gravity" at the poles and at the equator, the polar gravity being denoted by g, and the equatorial by g'. This equation is as follows:

$$\frac{g-g'}{g} + e = \frac{5}{2} m.$$

If in this equation we use the value of m, determined by the usual method which does not take into account the inclination of the direction of gravity to the normal, the result for e will be, as stated, $\frac{1}{288.5}$, but if we use the value of m found by my method which does take into consideration this inclination, the result is $\frac{1}{293.5}$.

This can be seen at a glance from the above equation, for if we change m, as we do, by 2 units in the denominator, we change the denominator in the value of e by $\frac{5}{2}$ of the same amount, or by 5 units, so that instead of $\frac{1}{288.5}$ we have $\frac{1}{293.5}$. As has been stated, the value obtained from arcs of meridian is $\frac{1}{294.0}$. The difference between the two determinations represents only 106 feet in the length of the equatorial radius, certainly a remarkable agreement, and one demonstrating the fact of the eastward inclination. The existence of this tendency to eastward pressure can be shown in another manner. Let us consider the particle at *a* or the *apogee* of the orbit, shown in Fig. 1, and let the following figure show that portion of the orbit lying between the apogee and the end of the semi-parameter at *b*.

It is evident, from the laws of planetary motion, that the orbital velocity of the particle at *a* will be increased in passing from *a* to *b*; on the equator the direction of the velocity is parallel to the equatorial plane, or eastward, and, as has been shown already, the velocity not only decreases but it also changes its direction with the latitude; becoming at a right angle to the equator in latitude 90°. Therefore, if all the terrestrial particles were free to move, there would be tendency to an excess of angular velocity near the equator, and thus an eastward pressure. In a rigid mass there can be no actual motion, the effect being simply a strain, but in a tenuous fluid, such as the upper atmosphere of the earth, and in the surface matter of the sun, where the particles have comparative freedom, real motion would be the result, and thus differences of angular velocity would give rise to vortices in a manner too obvious to require a lengthy explanation, these vortices being comparable to the eddies of a stream caused by the different rates of motion in different portions of the current. The

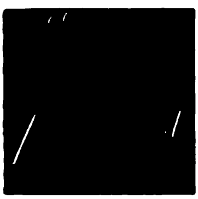


FIG. 3.

objection may be raised that when the earth or any other cosmical body has assumed its figure, equilibrium will exist, and that there will be no eastward pressure, no difference of angular velocity. This objection might be a valid one, were each cosmical body unaffected by any other, i. e., were there no perturbative action, but so long as the "law of gravity" is in force and neighboring bodies exist and pursue their courses, there can be no equilibrium in the strict sense of the word. Just as the orbits of the planets are affected by perturbation and the planetary velocities caused to vary periodically, so will perturbing bodies tend to cause the orbits and the velocities of the particles of solar, terrestrial or planetary matter to pass through cycles of change. The mode of action of the perturbing force cannot, of course, be explained in detail here, but in a general way. The effect is much the same as that which would be caused by adding to, or subtracting from, the mass of the central attracting body, whose particles are under consideration, the mass of the perturbing body.

Whether the latter mass will be additive or whether it will be subtractive, depends upon the position of the perturbing body, and also of the perturbed particle relative to the "centre of gravity" of the body to which the particle belongs. By relative position I mean not only angular but also linear distance. If we consider the mass of the central body to be, as it were, thus subject to variation, it follows that the value of k^2, used in equation (1), will be subject to variation and therefore, that p, derived from that equation will also vary. It is evident that, since the perturbing force varies in a manner dependent upon the position of the disturbing body relative to the disturbed, the variation of the value of p will be periodic, depending upon the periodic time of the perturbing body. Returning to the consideration of the effects of the difference of *angular* velocity, thus produced upon the particles of any cosmical body, it is obvious, as before stated, that this difference varying as it does with the latitude, will generate vortices in the fluid envelope of any revolving spheroid.

The vortices thus formed may be regarded as bodies distinct from the matter in which they are generated, and as such they will be acted upon by the eastward pressure in the same manner as is the infinitesimal particle, which has been considered. It is also possible that these vortices will tend to move in orbits around the "center of gravity" of the body upon which they are formed, just as the particle at *a* in Fig. 1 moves, the orbital motion being in the same general direction as is the motion of rotation. In the case of the sun, I have claimed that the sun-spots are such vortices; therefore they should have a *proper* motion in the direction of the sun's rotation, and also this proper motion should be greater the nearer to the solar equator the spots are located. The results obtained by eminent observers of the solar phenomena show that the spots have a *proper* motion such as my hypothesis demands. In the case of the earth, I have claimed that these vortices are the rotating storms, or the cyclones, (the word cyclone being used in this connection in its widest sense), therefore these storms should have a proper motion in the direction of the earth's rotation.

The *general* eastward march of all areas of low barometer, or the storm centres, is an indisputable fact of meteorology.

The periodic variation in the number of sun-spots has been observed to be, apparently, connected with the periodic times of Venus, the Earth, Mars and Jupiter. Since, according to my hypothesis, the sun-spots or vortices are due, mainly, to the perturbing action of the planets, and since the perturbing force varies with the periodic time of the perturbing body, it follows that the period of the vortices or sun-spots must be the same as that of the perturbing body. Since there are a number of these bodies, the result of the action of all may differ somewhat from that produced by any *one*, Jupiter being the largest as respects mass, his effect should be the most noticeable, but Venus being *nearer* the sun, although its mass is much less than that of Jupiter, should give a marked result. The same perturbative action is in force against the revolving particles of the earth. The moon and the sun are the bodies which exert the greatest force upon terrestrial particles, and since the same reasoning applies in the case of the earth as in the case of the sun, it follows that the varying positions of the moon and of the sun must produce variations in the *angular* velocities of the atmospheric particles, and that these variations will have a periodicity dependent upon the periodic time of those bodies.

The existence of some unknown connection between terrestrial storms and the varying positions of the moon and of the sun, has, for a long time, been surmised. If my hypothesis be true, what has been hitherto a mere surmise becomes an established fact; just as the perturbing planets act upon the solar particles, so do the moon and the sun act upon the atmospheric particles; these latter particles may be regarded as little planets whose orbital velocities the perturbing action of the moon and of the sun tends at certain times to increase, and at other times to retard, increase of velocity producing vortices, areas of low barometer or cyclones, while retardation of velocity causes a setting back and piling up of the atmospheric particles, thus producing areas of high barometer or anti-cyclones.

The sun apparently moves from aphelion to perihelion in six months, and the moon, which from its proximity to the earth produces the greater perturbative effect, moves from apogee to perigee in approximately two weeks. Atmospheric and seismic disturbances having periods corresponding, may therefore be inferred. Furthermore, the perturbative action depends upon the position of the moon and of the sun relative to each other. The two work together at the syzygies, and in opposition at the quadratures, therefore twice in each lunar revolution there should be a maximum effect, and twice in the same time, a minimum; thus it may be seen that atmospheric disturbances varying with the positions of the moon and of the sun, are necessary consequences of the action of the "force of gravity."

By the diurnal revolution of the earth, a terrestrial particle is carried around the globe in one sidereal day; the effect of this change of position relative to the positions of the perturbing bodies, is much the same as if the latter were to perform one revolution in the day; or we may regard the particle as making one orbital revolution in the same time, the perturbing bodies remaining stationary. The perturbative action may then be expressed by the following equation:

$$t = -\frac{k^2 m r}{\Delta^3} . \sin 2 \varphi \qquad (7)$$

Regarding the moon as the perturbing body, m, k^2, and r

have, in this equation, the same significance as before, Δ represents the distance of the moon and ψ the angle at the earth's centre, between r and Δ. The first member of this equation represents the tangential force, and as such it represents the force which operates to cause variations in the orbital velocity of any particle; hence variations in the production of vortices, areas of low barometer, or storms.

We see from equation (7) that the velocity will vary as $\sin 2\psi$; the action upon any one particle will, therefore, be 0 at the syzygies and at the quadratures, change sign at these points, and give two maxima and two minima half way between them. There should therefore be two maxima and two minima like those above mentioned but having a much shorter period; *i. e.* these effects should occur in one day, as well as in nearly twenty-seven days. I think that there is some evidence tending to show such action, for one of the best known phenomena of meteorology is the "diurnal oscillation of the barometric column," this oscillation having two maxima and two minima in one day. Furthermore, this phenomenon is most marked in the equatorial regions, just as my hypothesis demands that it should be.

The diurnal effect is, of course, very much less than the monthly, because the period is so much shorter, and the variation of the relative distance of the moon, much less. This brings us to the consideration of another question. It may be thought that the perturbing force is too small to produce the known effects; but, even admitting it to be small we must recognize the fact that the elements of time and of mass must be regarded as factors in the problem; a *small* force acting upon a *large* mass for a *long* time may produce momentous results, by virtue of inertia. Although the effect, produced in six hours, may be very small, that generated by continuous action for a week may be very great. It is also to be considered that, under my hypothesis the force exerts its greatest power upon the tenuous particles of the upper atmosphere; the rotary storms should, therefore, have their inception near the upper limit of the atmospheric envelope. The vortical motion may be small at the beginning, but the in-rush and up-rush of air, when the vortex has been formed, may generate *very* intense action. A very good illustration of this fact may be seen in what is often called the "cyclone" but which is more properly termed the "tornado." The beginning of the vortical motion of the "tornado" can frequently be distinctly seen through the medium of the clouds. The inception of the phenomenon is usually marked by the approach of two clouds toward each other high in the air. These clouds, indicating the movement of the air are seen to take up a rotary motion around a centre; the funnel is then formed, its apex dropping toward the earth. The *angular* velocity of the rotating column increases toward the apex, until it becomes terrific, and the column seems to become a solid mass, which moves in a *general* direction eastward.

The above facts are well known; I cite them only to show how, from a small beginning, intense action may be developed.

The "cyclones proper" or the great storms, probably act much in the same manner. It may be asked, are not variations of temperature, and the other facts of meteorology which have been assigned as the causes of storms sufficient? As to their adequacy I cannot say, but from what has been shown above, I think that the most rational view is that which regards them principally as concomitants, co-effects whose intimate relation to the phenomenon in question has led to their being regarded as causes; they may modify the action, and play a secondary part, but they cannot, I think, be regarded as prime motors.

In regard to the "seismic phenomena," I have claimed that they are due to the fact that a particle of the solid matter of the earth, being acted upon by the same force as is the fluid particle above considered, *tends* to move in an orbit with a varying angular velocity, the variation being due mainly to perturbation.

Since the particle of sold matter has not the freedom of the fluid particle, motion cannot usually result; but since the force, or the tendency to motion must exist, it takes the form of pressure or strain (probably torsional), the giving way of any part of the solid matter, under the stress, causing an "earthquake." It may be inferred that, according to my hypothesis, the "earthquakes" should have a periodicity depending upon the periods of the perturbing bodies, especially of the moon. Some eminent physicists have declared that a study of the records of a great number of earthquakes seems to indicate the existence of such periodicity, but since it is not to the strain alone, but to the *giving way* of the matter under the strain, that the phenomenon is probably due, we should not expect to find so marked a periodicity as in the case of sun spots or terrestrial storms; great strain may often exist without any shock.

Mallet has regarded the phenomenon as due to a tangential force or strain produced by the cooling of the earth's crust. According to my hypothesis it is due to an approximately tangential strain due, not to cooling of the terrestial matter, but to the force already referred to. It is worthy of remark that investigations of a number of earthquakes have disclosed the fact that the seismic force seems to have its focus or origin near the surface of the earth, the depth varying from three to twenty miles. If we now consider the fact that the pressure or force, represented by the semi-parameter *fb* in *Fig* 1, has its origin at the focus of the ellipse, which focus is at a depth of nearly seven miles below the earth's surface the inference that there may be some connection between the two facts, is not, I think, unreasonable. It has been shown that the orbit which a terrestial particle would describe if free, is an ellipse of great eccentricity, and we see from *Fig* 1, that the direction of the elliptic motion is tangential at the surface, but rapidly becomes directed toward the earth's center, so that whatever tendency there may be to eastward orbital motion or pressure it must be exerted near the surface precisely as the "seismic force" is found to act. If my hypothesis be true, a possible cause of *volcanic* phenomena becomes disclosed; for the compression due to the strain and the friction which must be a consequence of any rupture under the strain, cannot but result in the generation of intense heat in the superficial strata of the earth. The infiltration of the superincumbent water or its admission, through ruptures in the surface matter, upon the heated mass, would probably suffice to produce volcanic eruptions. If this view be true, Sir William Thomson's hypothesis of a "solid globe" becomes compatible with the observed volcanic phenomena.

(TO BE CONTINUED.)

THE DEVELOPMENT OF ASTRONOMY IN THE UNITED STATES.*

T. H. SAFFORD, PH. D.

About two hundred years ago Isaac Newton published his famous "Principia"; the English title is "The Mathematical Principles of Natural Philosophy." From that epoch dates modern astronomy; for the book laid down the law of universal gravitation, according to which the motions of the moon and planets are governed. The same law holds good to the remotest bounds of the universe; comets obey it in their journeys into far distant space, and double suns, in many solar systems, circle around each other in obedience to its formula.

From the discovery of this far-reaching law of nature, the most delicate and exact observations became necessary to test it; for from its very essence it must have an exact fulfillment. Observers must now carry their work to the last degree of delicacy; they must study the structure of the human eye to learn what is the highest precision attainable by the sense of sight, when aided by the best optical glasses.

Newton himself had a small observatory at Cambridge (in England), where he was a professor; but it was not to be expected that he himself should watch the heavens nightly. His mighty genius was too fully occupied with his great mathematical problems; among which is to be reckoned the invention, independently of Leibnitz, of the calculus.

Charles the Second, bad man as he was, possessed human sympathy enough to found an observatory, to preserve his sailors from shipwreck. Navigation was then extremely dangerous; there were no guides across the ocean. Such guides were to be found in a knowledge of the motions of sun, moon, and stars, to be gained by the patient labors of astronomers. So the Greenwich Observatory began; the first Astronomer Royal, a contemporary of Newton, was the Rev. John Flamsteed.

In 1705 Edmund Halley found that the great comet of 1862 was periodic, and would return in 1758; it did so

* A discourse read June 25, 1888, to commemorate the 50th anniversary of the dedication of the Hopkins Observatory at Williams College, Williamstown, Mass.

return, its orbit was again calculated by others, and its next appearance predicted for 1835. As we shall see, this last coming of Halley's comet was influential in the foundation of American observatories. Halley's calculations were made to test and exemplify his great master Newton's theory, of which they furnished a brilliant example. Who will not say, when this fine comet returns in 1910, that it furnishes a new proof of the law of gravitation? In fact Newton must be considered the best astronomer of all past ages.

At Flamsteed's death Halley succeeded him as Astronomer Royal; but he was then an old man, and added little to his former reputation. James Bradley, like Flamsteed a clergyman of the Established Church, was Halley's successor; it was he who first made Greenwich Observatory what it now is, the most prominent one, all things considered, in the world. About 1750 he obtained new instruments, and began the great work of his life,—a magnificent series of meridian observations, which is indispensable to all who wish to know anything about the stellar motions, or to follow sun, moon, and planets in their apparent courses. A most eminent living German astronomer has spent many years in recalculating Bradley's observations, and is now publishing his results.

Bradley was followed by Nathaniel Bliss, who was an indifferent observer; and in a few years by Nevil Maskelyne, who was Astronomer Royal for the half-century which began with our colonial troubles and ended with the war of 1812. Maskelyne possessed some eminent qualities as an observer, but lacked others. He discharged an assistant for noting time differently from himself; it was reserved for an abler man to find out that "personal equation" is a universal phenomenon among observers,—that no two observe times exactly alike. The poor fellow was really an excellent assistant. Maskelyne's great service was the establishment of the Nautical Almanac, the sailor's indispensable companion. The French had had something of the kind for many years, however; I have wondered whether John Paul Jones used his enemy's book in guiding his ships across the ocean, or that of our French friends, in a foreign language.

I have premised these few things about English astronomy as our own was naturally based upon it. We had not yet declared our scientific independence, were in fact thoroughly colonial in our methods of scientific teaching. Harvard received from an English benefactor, Thomas Hollis, the money for the foundation of her professorship of mathematics and natural philosophy; and English text-books were reprinted and used in some of our colleges till within the present century. The teachings of the colleges were probably traditional, and were not based upon independent research; but practical necessities soon required the employment of astronomical observers

If you look at a map of Massachusetts you will perhaps notice the extremely rough way in which the State is divided into counties and townships. Clarksburg, near us, is six miles long from east to west, by two in breadth; Hancock, fifteen long from north to south; Cheshire has twenty-two corners. The boundaries of our counties are extremely irregular lines, and even those of the State by no means plain and simple. All this confusion of landmarks grew out of old-world habits; we have even an "enclave" in Cohasset, which belongs to Norfolk County, although surrounded by part of Plymouth.

Boundary disputes came up everywhere in the colonies; the people of Bennington, New Hampshire grantees, fought the New Yorkers, who in their turn appear to have established an outpost on the Connecticut River. Many colonial grants had been based upon parallels of latitude and meridians of longitude; I was myself called in, fifteen years ago, to assist in determining a Canadian boundary line, which was a continuation of a meridian through Illinois.

In 1767 the proprietors of Maryland and Pennsylvania sent to England for two astronomers to settle the parallel of latitude between the two colonies. In Massachusetts a similar parallel had been wrongly run; to this mistake we owe the inclusion of the village of Williamstown in Massachusetts instead of Vermont. The astronomers who were called in to fix the Pennsylvania boundary were Charles Mason and Jeremiah Dixon; and these were, so far as I know, the first trained observers ever employed in the United States. Mason had been Bradley's assistant at Greenwich; and the German whom I have mentioned has discovered, by the handwriting in the original books, which observations were made by him, and which by Bradley and the others. He seems to have been an excellent observer. He had afterwards made many scientific journeys, and had done much by calculation to improve the lunar tables. Dixon was of course Mason's assistant, and is less known.

The work done by these two astronomers was the first piece of accurate measurement in this country, and perhaps it included the first parallel of latitude ever run out as a boundary.

It is not easy to cut one's way through the forest, to spend the nights in watching the stars and the days in moving on through the woods; to carry on horse- or mule-back the most delicate instruments, and watch (I can almost say), every step of the beast, to see if he gives the chronometers any jar; to make the most refined calculations under the most difficult conditions. It is easier to deal with mathematical formulæ by a warm fire in a pleasant room, or even to watch the stars in a well-appointed observatory. But practical astronomy of the kind brought here by Mason and Dixon is useful in all distant explorations, and is admirably adapted as a training for young observers. We have since had much of it in this country, and in our scientific development it has been of inestimable benefit.

About the same time an American astronomer, David Rittenhouse, was making a reputation. On the father's side Rittenhouse was Dutch; his family were paper-makers from Arnhem on the Rhine in Guelderland. He was self-educated; had read Newton's Principia and the other necessary mathematics, and taught himself the clockmaker's trade. Those were the days of the tall hand-made clocks, now so much prized as ornaments; and their construction was a matter requiring much skill. In 1767, Rittenhouse, born the same year as George Washington, was in the prime of life, and may have indulged hopes of making the boundary survey for his native State, Pennsylvania. But he was only a colonist; the proprietors employed him in some preliminary rough work, but sent "home" as the phrase is, for their astronomers. It should have been Mason and Rittenhouse, rather than Mason and Dixon; Mason indeed found America much to his taste, and returned and settled in this country.

In 1769 came the transit of Venus; that phenomenon which occurs twice in a century only, and to most parts of the world is visible but once during that time. Some of us remember it in 1882, when astronomers were sent all over the world; I visited the party sent from Germany to Hartford, Conn., and was much impressed with their less haste (but more speed) than is natural to the American observer. I had previously learned the same lesson from engineer officers in our army. But in 1769 the transit was the only good means of finding the earth's distance from the sun; a distance which has fluctuated between ninety-two and ninety-six millions of miles since my remembrance. It is now pretty well settled as between ninety-two and ninety-three millions, but a hundred and twenty years ago it was rather uncertain. Rittenhouse built a little observatory near his house at Norristown, Pa., and was of great help to others, who observed the transit in and near Philadelphia. The event caused much interest in astronomy, and added to the impulse which it received from Mason and Dixon's labors.

In later years Rittenhouse was much employed as a boundary commissioner; among other work of this kind our own West line along the ridge of the Taconics was settled by his efforts; it has lately been resurveyed and found as well done as was to be expected from his instruments.

He was also an early inventor of the "collimator," a device for obtaining a meridian mark without going far away;.it has lately come back from Germany, where it was re-invented, and is now employed in the Field Memorial Observatory.

In general science the two ablest colonial Americans were undoubtedly Benjamin Franklin and Benjamin Thompson. Franklin, as we all know, drew the lightning from heaven, and proved its identity with electricity. His services as a diplomatic agent in France were greatly helped by his scientific reputation; returning to America he was instrumental in founding the two early academies of science, the American Academy at Boston, and the American Philosophical Society at Philadelphia. Both these have done useful work recorded in their Memoirs and Proceedings. Thompson was so unfortunate as to be a Tory; not a bitter one, but yet enough to make him an exile, and a great loss to his country. He served in the English army, went afterwards to Bavaria, where he laid out the "English Garden," the fine park of Munich—it should have been called the "American Garden"—and then to France. In his peregrinations he was knighted as Sir Benjamin Thompson, and afterwards ennobled as "Count Rumford." In his old age he did not forget his native land, but left a part of his fortune for prizes to American investigators of light and heat, and another part for a Rumford Professorship at Harvard.

After the Revolution the first great astronomer of this country was Nathaniel Bowditch; born in 1773, and dying in 1838, he had the fortune to be brought up and to live in free America. He came of a family of shipmasters; had but few opportunities of education, but gave his whole leisure as a mechanic's apprentice, to learning. When a young man he went to sea as a supercargo, and continued his mathematical studies on long India voyages; he learned Latin and French for the sake of the sciences. When twenty-nine years old he went to the Cambridge commencement; his ship was then wind-bound in Boston Harbor, and he heard to his utter surprise that he was made a Master of Arts.

At that time he had edited for America John Hamilton Moore's Navigation; its errors were so many that he re-wrote the entire book, and published it as "Bowditch's American Practical Navigator." The work became famous, and brought him a modest fortune. By and by he was able to give up his seafaring life and enter on business at Salem, afterwards at Boston; meanwhile he continually corrected and improved the "Practical Navigator," so that it has long been the best book of its kind in the English language.

While successful in business, owing to strict method and sterling integrity, he was able to do much to further astronomical science. He observed eclipses, meteors, comets; calculated the orbits of these bodies, learned German in order to read the writings of Olbers and others on such subjects; and finally translated and published at his own expense the great treatise of Laplace on "Celestial Mechanics," with important additions from the works of the German astronomers. Meanwhile other French mathematical books of a more elementary character had been translated and published at Cambridge, as well as by the West Point professors. The military school was established early in the century, but received its chief development after 1817. During our Revolution we had employed continental engineers, Kosciuszko among them, and the French Revolution had brought others to this country, some of whom became instructors at West Point. The French mathematics thus supplanted the stiffer English text-books, including Euclid, both at West Point and some of the colleges; and John Farrar, professor at Cambridge, led his pupils pretty far along in these studies.

Among Farrar's students was a young friend of Bowditch's, Benjamin Peirce, who soon showed a profounder mathematical ability than Bowditch himself. Other Bostonians interested in astronomy were Robert Treat Paine, a very enthusiastic and careful observer, who went over sea and land to observe solar eclipses, and determined latitudes and longitudes in many places, especially in Massachusetts, with sextant and chronometers. Simeon Borden made, about half a century ago, a triangulation of the State, which with Paine's latitudes and longitudes, gave a measure of the earth, which is by no means seriously inaccurate, considering the smallness of the instruments, and the moderate size of the territory.

Meanwhile the United States had begun a general survey of its coasts. Early in the century there came hither a Swiss astronomer and geodetic surveyor, F. R. Hassler. He was for a time professor at West Point; he became known as a man of high scientific attainments and practical ability, and began the survey after furnishing a better detailed plan for it than any of his competitors. This work, however, soon lost favor with Congress, was interrupted for years, and begun again in 1832. He was successful in training up an able set of assistants, and was able to make a good beginning of the Survey. Meanwhile the West Point school had educated many promising pupils, and the engineers of the army began to be skilful in carrying on astronomical and other higher surveys, taking up the work of Rittenhouse and other civilians, and improving on the former methods.

One excellent astronomer among the army officers was James D. Graham, who had much the same characteristics as Paine, whom I have mentioned. Both were admirable sextant observers, and in general, could obtain very accurate results with very moderate instruments. Neither of them felt quite at home with the giant telescopes of modern times.

At Yale College a good telescope of moderate size was procured as early as 1832. In that year and the next occured the great November shower of meteors, which happens two or three times every thirty-three years. The teaching power of Professor Olmsted, the telescope of five inches' aperture, the meteoric shower, and later Halley's Comet, seem to have aroused a good deal of astronomical enthusiasm at New Haven, and for a few years a number of the students turned their attention to astronomy.

The telescope would have done better service had there been an observatory; but it was set up in the tower of a college building, and rolled upon casters over an unsteady floor; few accurate observations were made with it. Of the mathematicians and astronomers graduated in those days, Mason and Stanley died young, Loomis and Lyman are still aged professors at New Haven, but Chauvenet, on the whole the most eminent, never returned to the college. He went into the United States Service as Professor of Mathematics in the Navy, and was one of the most important men at the Naval Academy founded by Secretary Geo. Bancroft. He removed to St. Louis and became head of the Washington University of that city, where he died. Chauvenet was the son of a Frenchman who married in America, and combined in many ways the characteristics of the two nations. From his father he received a careful training in the French language, and his books exhibit much of the elegance of the writers of that nation. His "Spherical and Practical Astronomy" is probably the best book on the subject in any language; I see it quoted abroad as well as at home; it is an inexhaustible store of the best mathematics of the subject.

(TO BE CONTINUED.)

REPLY TO PROFESSOR CRAWLEY'S CRITICISM ON "A NEW THEORY OF SOLAR HEAT AND GRAVITATION."*

J. H. KEDZIE.

For THE MESSENGER.

My attention has just been called to a very candid, courteous and scholarly review, by Professor Crawley, of my book on Solar Heat, Gravitation and Sun Spots. There is no difference between us, and can be none, in regard to the fundamental facts and principles involved; nor can there be any essential difference between us as to the conclusions to be drawn from these facts and principles.

Still the Professor, as might be expected, finds several things to criticise, as some errors and inadvertencies are almost unavoidable.

If I can explain or answer all of these to his full satisfaction, I shall be doing a favor not only to him, but to all truth-loving readers.

I will first state the objections briefly, and then give my replies; indicating the substance of the objections by quotation marks, though not in the language of Professor Crawley.

1. "Spontaneous transformation of heat-bearing waves into world bearing waves or gravitation: Have we any instances of spontaneous transformations?"

I answer,—All transformations of energy are spontaneous, *i. e.* they all take place by virtue of nature's laws and forces, unaided by us, except in the arrangement of the circumstances. Take a supposable case: An insulated cubical rock might receive continuously on *one* side for many hours the intense radiations of a tropical sun. The heat would penetrate into and be distributed through the whole mass, and would ultimately be radiated from all the *six* sides of the rock in a "degraded" or modified form. So the heat waves from the suns must necessarily change in character by diffusion and storage in a constantly increasing number of particles.

2. "As the stars are by no means uniformly sown over the fields of space, the gravitation waves must be much more

* Professor Crawley's Criticism, to which this paper is a reply, was published in October MESSENGER, No. 68.

effective from some directions, the Milky Way, for example, than from the more sparsely populated regions."

I reply,—Do we find the diffused starlight on a moonless night any more intense from the direction of the Milky Way than from other parts of the heavens?

But the case is stronger in respect to the low-pitched waves of gravitation. It is well known, both from observation and mathematical calculations, that the mechanical pressure of the ether, estimated at a low figure as 500 tons to the square inch, though exerted in straight lines of radiation, is, and necessarily must be, equal in all directions. It is, therefore, quite immaterial whether or not the orbs which "people the profundities of space" be evenly or unevenly distributed.

3. "All bodies exposed to the same thermal influences receive heat in proportion to mass, but radiate in proportion to surface.

This is referred to in my book as one of the reasons why the earth has cooled more rapidly than the sun. But if the sun, as claimed in the book, receives his heat at his surface, does he not receive it in proportion to surface and in proportion to mass?"

I reply,—Certainly not. All bodies heated by radiations receive their heat at the surfaces exposed, and the farther progress of the heat inwards is by conduction. Two bodies of the same mass and similarly exposed to the same source of heat will, of course, absorb twice as much heat as one; that is, they will absorb heat in proportion to mass, but they will, of course, receive it in the first place at the surfaces exposed.

4. "In the book it is maintained that *another* reason why the earth has cooled off more rapidly than the sun is that a large portion of the waves of mechanical motion which attack the earth are utilized for the purposes of gravitation and therefore do not change to heat. The sun, being in the center of his system, has little or no gravitative motion relatively to the members of his own system, and therefore all of the waves reaching his surface must turn to heat. The Professor asks: 'Is Mr. Kedzie ready to deny the universal application of the law of gravitation?'"

I reply,—The reader of the book will notice that there, as here, I have carefully restricted this motionless condition of the sun as related to his own system, and that it has nothing to do with the motion of the sun accompanied by his system in space. There is not the slightest doubt but that our sun, with all of his attendant worlds, is moving grandly through space in obedience to tangential and gravitative forces.

But relatively to his own system, he is almost stationary, and all the waves of which he is the *center*, are and must be turned to heat, while a large portion of the similar waves striking on the outer surfaces of the planets, do not turn to heat, but continue as mechanical motion under the form of gravitation.

I cannot but express my gratification at the learned and forcible manner, far surpassing that of the author, in which Professor Crawley has approvingly outlined the main arguments of the book.

MR. KEDZIE'S THEORY OF SOLAR HEAT.

W. H. S. MONCK, DUBLIN, IRELAND.

FOR THE MESSENGER.

I think Mr. Crawley has done good service in calling attention to this theory, and that whatever becomes of Mr. Kedzie's views on gravitation or on the machinery by which the sun derives a supply of heat from the ether, there is room to construct a good working hypothesis from the residue of the theory. For this purpose I will approach it from a somewhat different point of view.

That there is something in space which absorbs or intercepts light is a theory as old as Olbers and W. Struve. The grounds of it I glanced at briefly in my *Note on the Distribution of the Stars*, which appeared in THE SIDEREAL MESSENGER for January, 1888. The amount of starlight which we actually receive is enormously less than what we would receive from a star system extending to infinity (or to a very great distance, such as, for instance, one million times the average distance of a star of the first magnitude), the average distribution resembling that of our nearer neighbors, and the medium being perfectly transparent. I therefore concluded (as others had previously done), that all the stars known to us form part of one great cluster, or else that there is a medium in space which intercepts light. In a paper which I read some years ago before the Royal Dublin Society I maintained that this medium, which absorbs or intercepts light, is the ether itself, a theory which I believe is likewise not new.

The reasoning is as applicable to heat as to light. There is, indeed, more uncertainty as to the total amount of star-heat which we receive than as to the total amount of star-light, and if the researches of Pouillet can be relied on, the total star-heat bears a much higher proportion to the sun-heat than the total star-light bears to the sun-light. But I think it must be admitted that the total heat which we receive from the stars is much less than what we would receive from an infinite star system or a finite star system of very large dimensions. We must therefore choose between a contracted star system and a loss of light and heat in transmission.

But if light and heat are lost in transmission, what becomes of them? For they can only pass into some different form of energy. Light may indeed be intercepted by opaque bodies, but in such cases it is either reflected or absorbed, and if absorbed is certain to reappear in the shape of non-luminous heat. The intervention of opaque bodies could make but very little difference in the total star heat since each of these opaque bodies would become a new center of radiant heat. A loss of star-heat therefore implies that the heat lost has passed into some other form of energy. Mr. Kedzie seems to me to have very little grounds for identifying this new form of energy with gravitation, but may not his hypothesis be rectified by speaking of it as simply a new and unknown form of energy?

Now we come to another point on which Mr. Kedzie and his critic seem to have laid sufficient stress. The sun and stars are giving out, and no doubt have been giving out for ages, much more heat than they receive back *as heat* from the ether. Notwithstanding this we have no reason to believe that they are cooling. Indeed geological evidence rather indicates that the sun has not become materially colder for several millions of years. But if they are not getting colder there must be something which maintains their heat. No satisfactory explanation has been given as to what this something is. Now we find that on the assumption of an infinite or very extensive universe they are surrounded by a medium which contains an immense amount of transformed heat, and if we suppose that the sun and stars possess the power of restoring this transformed heat to its original character, the mystery of The Fuel of the Sun is solved; (though, of course, the solution is only a partial one until we have ascertained the nature of the transformation and the means of restoration).

If the truth of such a hypothesis cannot be directly tested, it is nevertheless to a large extent susceptible of confirmation or refutation by observation, and this remark may be extended to Mr. Kedzie's views on gravitation. If gravitation is transmitted by the ether the obvious consequence seems to be that gravitation travels. The ether may have different rates for the transmission of different kinds of energy and gravitation may travel faster than light or heat; still it is probable that if it travels the effect produced on very distant bodies like Neptune or Halley's comet will show perceptible deviations from those computed on the usual assumption of instantaneous transmission. The problem is one worthy of the attention of mathematical astronomers, especially when we consider Professor Asaph Hall's dissatisfaction with the law of gravitation in the stellar regions. May not the cause of this dissatisfaction be that the action of gravity is not instantaneous?

Sunspots have been comparatively few during this year but during the month of November there have been two groups containing spots of considerable size. One was noticed near the east limb of the sun Nov. 5, and disappeared behind the west limb Nov. 17. The second group was noticed first Nov. 13, a little way from the east limb. Both of these groups changed rapidly and developed into large single spots. If they continue, the first should reappear on the east limb about Dec. 1, and the second about Dec. 9. A few photographs of the sun have been taken at Carleton College Observatory showing these spots and the granulation of the solar surface fairly well.

CURRENT INTERESTING CELESTIAL PHENOMENA.

THE PLANETS.

Mercury will be at superior conjunction with the sun Dec. 28, and so will not be in favorable position for observation before the middle of January, when he will be "evening star." He will be in conjunction with Jupiter, 1°08′ south, Dec. 16, and with the moon, 2°34′ south, Jan. 1 at 8*h* 12*m* P. M., central time.

Venus has no doubt been easily recognized by most of our readers during the past month, being so beautifully brilliant in the southwest in the evening twilight. The diameter of Venus' disk is now 14″ and is gradually increasing. Her phase is gibbous, about 0.8 of the disk being illuminated. Although the phase is decreasing the planet is approaching the earth rapidly, so that the increased size will more than compensate for the loss of illuminated area of the disk. The distance of Venus will be equal to the distance of the sun on Jan. 7, the diameter on that date being 17.2″ and the illuminated area of the disk 0.693. Venus will be in conjunction with Mars Jan. 2, 6:47 A. M., the latter being 40′ north of the former; in conjunction with the moon Jan. 4, 5:44 P. M., 1°28′ north. Her course among the stars will be toward the east and north for several months, the position becoming better and better for observation until April. Observers should look carefully and persistently for permanent markings of any kind, make careful drawings and note exact times of each for future study.

Mars continues to set a little later each night and is increasing in declination, so that he would be in more favorable position for observation were it not for his increasing distance, which, on January 15, will be twice that of the sun. He may be found among the faint stars of Capricorn, almost on a line between Altair and Fomalhaut. The conjunction with Venus has been spoken of. Mars will be in conjunction with the moon, 2°04′ north, Jan. 4 at 4 P. M.

Jupiter will be behind the sun so that he cannot be seen.

Saturn is in Leo, not far from Regulus, and may be easily recognized by his steady yellow light. The inclination of the plane of the rings to the line of sight is much less than it was last year, being now only 13°.5. The angle of inclination is now increasing slowly and will reach 16.6° in April, after which it will decrease rapidly for several months. The angle of the line joining the sun and the planet from the plane of the rings is about 15°, so that we are looking at the rings at about the same angle at which the sun is shining upon them. The major axis of the outer ring is about 44″ and the minor axis 10″. The diameter of the planet is 18″. We give this month the central times of the elongations and conjunctions of the two brightest of the satellites, Japetus and Titan, and the eastern elongations of Rhea, Dione and Tethys. The times of western elongation may be easily found by taking the middle time between two successive eastern elongations, and the intermediate positions of the satellites may be easily estimated. Hyperion is too faint and Enceladus and Mimas too near the planet to be seen except with telescopes of very high power.

Uranus is in Virgo about 3° north of Spica. He will be in quadrature with the sun Jan. 11.

Neptune is in Taurus about 5° south of the Pleiades. He will be in conjunction with the moon, 2° 26′ north, Dec. 15, 9:33 P. M., and again 2° 33′ north, Jan. 12, 3 A. M.

MERCURY.

	R. A. h m	Decl.	Rises. h m	Transits. h m	Sets. h m
Dec. 25	18 11.8	−24°56′	7 37 A. M.	11 53.1 A. M.	4 09 P. M.
Jan. 5	19 30.2	−23 56	8 07 "	12 28.1 P. M.	4 49 "
15	20 40.9	−20 19	8 20 "	12 59.1 "	5 38 "

VENUS.

	R. A.	Decl.	Rises.	Transits.	Sets.
Dec. 25	21 12.9	−18 09	10 05 A. M.	2 53.7 P. M.	7 42 P. M.
Jan. 5	22 03.8	−13 35	9 53 "	3 01.2 "	8 10 "
15	22 47.5	− 8 52	9 37 "	3 05.5 "	8 34 "

MARS.

	R. A.	Decl.	Rises.	Transits.	Sets.
Dec. 25	21 25.2	−16 24	10 10 A. M.	3 06.1 P. M.	8 02 P. M.
Jan. 5	21 58.6	−13 28	9 47 "	2 56.3 "	8 05 "
15	22 28.3	−10 36	9 25 "	2 46.5 "	8 08 "

JUPITER.

	R. A.	Decl.	Rises.	Transits.	Sets.
Dec. 25	17 21.5	−22 46	6 36 A. M.	11 03.0 A. M.	3 30 P. M.
Jan. 5	17 32.1	−22 55	6 04 "	10 30.3 "	2 56 "
15	17 41.4	−23 01	5 32 "	9 57.2 "	2 23 "

SATURN.

	R. A.	Decl.	Rises.	Transits.	Sets.
Dec. 25	9 30.0	+15 53	8 00 P. M.	3 08.8 A. M.	10 17 A. M.
Jan. 5	9 27.8	+16 06	7 14 "	2 23.3 "	9 33 "
15	9 25.1	+16 20	6 31 "	1 41.4 "	8 52 "

URANUS.

	R. A.	Decl.	Rises.	Transits.	Sets.
Dec. 25	13 20.6	− 7 49	1 31 A. M.	7 03.6 A. M.	12 36 P. M.
Jan. 5	13 21.5	− 7 55	12 48 "	6 20.3 "	11 52 A. M.
15	13 22.1	− 7 58	12 10 "	5 41.5 "	11 13 "

NEPTUNE.

	R. A.	Decl.	Rises.	Transits.	Sets.
	h m		h m	h m	h m
Dec. 25	3 52.9	+18°30′	2 12 P. M.	9 32.6 P. M.	4 53 A. M.
Jan. 5	3 52.0	+18 27	1 28 "	8 48.2 "	4 08 "
15	3 51.4	+18 26	12 48 "	8 08.5 "	3 29 "

THE SUN.

	R. A.	Decl.	Rises.	Transits.	Sets.
Dec. 20	17 57.2	−23 27	7 35 A. M.	11 58.2 A. M.	4 21 P. M.
25	18 19.4	−23 23	7 37 "	12 00.7 "	4 24 "
30	18 41.6	−23 06	7 38 "	12 03.2 "	4 28 "
Jan. 5	19 08.0	−22 32	7 38 "	12 05.9 "	4 34 "
10	19 29.9	−21 51	7 37 "	12 08.1 "	4 39 "
15	19 51.4	−20 59	7 34 "	12 09.9 "	4 45 "

Occultations Visible at Washington.

			IMMERSION.		EMERSION.		
Date.	Star's Name.	Magnitude.	Wash. Mean T.	Angle f'm N. P't.	Wash. Mean T.	Angle f'm N. P't.	Duration.
			h m	°	h m	°	h m
Dec. 16	ι Tauri	5½	12 26	345	Star 5.7′ N. of moon's limb.		
24	ν Virginis	4	12 59	46	13 26	1	0 27

No occultations will be visible at Washington during January except two or three very early in the evening twilight or late in the morning. A few will be visible in other parts of the United States but we have not time to make the calculations necessary in order to give the times. It is known, of course, to most students of astronomy that the time of an occultation varies with position of the observer upon the earth, because of the parallax of the moon. We give the Washington mean times of occultations at Washington. At other places the times will differ not only by the difference in longitude, or the difference in standard time used, but also by a certain interval of time, varying from 0*m* to 30*m* or more, depending upon the difference in latitude and longitude and upon the apparent distance of the star from the center of the moon's path.

Ephemeris of Variable Stars of the Algol Type.

[Approximate Central Times of Minima ; from Astronomical Journal, No. 182.]

d	h		d	h	
Dec. 15	8 P. M.	Y Cygni.	Dec. 24	7 P. M.	Y Cygni.
18	4 P. M.	R Canis Maj.	26	10 P. M.	Algol.
18	8 P. M.	Y Cygni.	27	6 P. M.	R Canis Maj.
19	5 P. M.	U Cephei.	27	7 P. M.	Y Cygni.
19	7 P. M.	R Canis Maj.	28	9 P. M.	R Canis Maj.
20	10 P. M.	R Canis Maj.	29	4 P. M.	U Cephei.
21	7 P. M.	Y Cygni.	29	7 P. M.	Algol.
22	1 A. M.	R Canis Maj.	29	12 midn.	R Canis Maj.
24	1 A. M.	Algol.	30	7 P. M.	Y Cygni.
24	5 P. M.	U Cephei.	31	3 A. M.	R Canis Maj.

Phases of the Moon.

		Central Time. d h m
First Quarter	Dec.	10 12 46 A. M.
Full Moon	"	18 4 41 "
Last Quarter	"	26 12 00 "
New Moon	Jan.	1 3 08 P. M.
First Quarter	"	8 6 41 "

Elongations and Conjunctions of Saturn's Satellites.

[*Central Time; E = Eastern elongation, W = Western elongation, S = Superior conjunction, I = Inferior conjunction.*]

JAPETUS.

d	d
Dec. 19, S	Jan. 9, E

TITAN.

d h	d h	d h
Dec. 16, 1 P. M. I	Dec. 28, 12 M. E	Jan. 8, 10 A. M. S
20, 1 P. M. W	Jan. 1, 11 A. M. I	12, 9 A. M. E
24, 1 P. M. S	5, 11 A. M. W	

RHEA.

d h	d h	d h
Dec. 15, 7.9 P. M. E	Dec. 29, 8.9 A. M. E	Jan. 11, 9.9 P. M. E
20, 8.2 A. M. E	Jan. 2, 9.2 P. M. E	
24, 8.5 P. M. E	7, 9.6 A. M. E	

DIONE.

d h	d h	d h
Dec. 17, 3.2 A. M. E	Dec. 28, 2.0 A. M. E	Jan. 8, 12.5 A. M. E
19, 8.9 P. M. E	30, 7.7 P. M. E	10, 6.1 P. M. E
22, 2.6 P. M. E	Jan. 2, 1.3 P. M. E	13, 11.7 A. M. E
25, 8.3 A. M. E	5, 6.9 A. M. E	

TETHYS.

d h	d h	d h
Dec. 15, 7.2 A. M. E	Dec. 26, 2.9 P. M. E	Jan. 6, 10.7 P. M. E
17, 4.5 A. M. E	28, 12.2 P. M. E	8, 8.0 P. M. E
19, 1.8 A. M. E	30, 9.5 A. M. E	10, 5.3 P. M. E
20, 11.1 P. M. E	Jan. 1 6.8 A. M. E	12, 2.6 P. M. E
22, 8.3 P. M. E	3 4.1 A. M. E	14, 11.9 A. M. E
24, 5.6 P. M. E	5 1.4 A. M. E	

Comet 1888 e, Barnard. Herr Berberich of Berlin has computed the following approximate ephemeris of this comet for the remainder of its apparition (*A. N.* 2862):

Date. Berlin Midnight.		α	δ	log δ	Light.
1888	Nov. 25	43°44′	− 4°58′	0.038	11.9
	Dec. 27	6 56	− 7 32	0.217	6.1
1889	Jan. 28	356 49	− 5 26	0.373	3.1
	March 1	354 28	− 2 53	0.449	2.0
	April 2	353 33	− 0 25	0.461	1.8
	May 4	350 47	+ 1 41	0.418	1.8
	June 5	341 46	+ 2 51	0.331	2.1
	July 7	320 15	+ 0 35	0.252	2.6
	August 8	292 37	− 4 48	0.300	1.7
	Sept. 9	277 20	− 8 45	0.446	0.7
	Oct. 11	273 12	−11 13	0.559	0.4

The unit of light is the brightness of the comet when discovered on Sept. 2, 1888. The theoretical brightness again becomes unity about Sept. 1, 1889, so that we may expect to observe this comet for at least a year. An ephemeris for the present month will be given later.

Recent Showers of Meteors.

Continued from Sidereal Messenger, December, 1887, page 356.

Epoch of Shower.	Night of Max.	Radiant Point. R. A. Dec.	No of Meteors.	Appearance.
1887.		° °		
November 14.	Nov. 14.	150+22	7	Swift, streaks, Perseids.
November 14–23.	Nov. 23.	132+31	5	Swift, streaks.
November 14–23.	Nov. 23.	194+67	7	Swift, streaks.
November 23.	Nov. 23.	157+49	5	Swift, streaks.
1888.				
July 8.	July 8.	3+49	6	Swift, streaks, Perseids.
July 8–12.	July 12.	310+79	5	Small, short, swift.
July 11–13.	July 12.	28+30	5	Swift, streaks.
July 11–13.	July 13.	319+22	6	Rather swift.
August 2.	Aug. 2.	35+54	14	Swift, streaks, Perseids.
August 5.	Aug. 5.	42+57	11	Swift, streaks, Perseids.
August 8.	Aug. 8.	42+57	20	Swift, streaks, Perseids.
August 13.	Aug. 13.	52+57	13	Swift, streaks, Perseids.
August 2–13.	Aug. 2.	312+15	5	Bright, swift.
Angust 13–14.	Aug. 13.	8+33	5	Swift, streaks.
August 8–13.	Aug. 13.	23+36	5	Swift, streaks.
August 5–13.	Aug. 13.	104+79	5	Very short, swift.
Aug. 29–Sept. 7.	Aug. 30.	313+65	6	Short, swift.
Aug. 29–Sept. 10.	Sept. 6.	354+67	6	Rather swift.
September 6–7.	Sept. 7.	48+63	5	Swift, streaks.
September 6–9.	Sept. 9.	33+54	5	Swift, streaks.

Though some of these radiant points were decidedly feeble and furnished only five or six shooting stars, I think they may be relied upon.

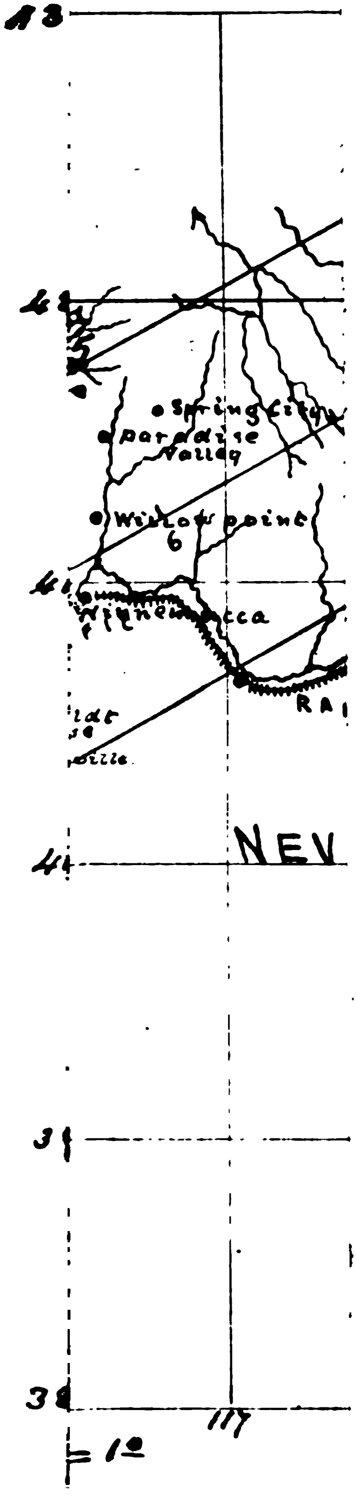
On July 8 I observed a very definite shower of streak-leaving meteors which I believe to have represented a very early display of the Perseids. Allowing for the displacement in the apparent radiant the centre at $3°+49°$ falls just where the shower might be expected on July 8 if visible so early as that. In 1885, July 11—14, I saw a shower of similar meteors from the point $11°+48°$ and there is no doubt that these radiants, situated during the first half of July near the head of Cassiopeia, are formed by meteors which are really the precursors of the great August display and are identical in their origin with that well known system.

At its return in 1888, the Perseid shower was not very conspicuous; its meteors were far less numerous than in some previous years. It furnished a brilliant fireball on the night of Aug. 13, 1888 11*h* 33*m* *G. M. T.* which gave a flash like vivid lightning, and left a streak for three minutes. It was well observed at Bristol and Leeds. This fine meteor appeared over the county of Yorkshire and fell from heights of 78 to 47 miles. Its streak was 18 miles long and situated at heights of 59 to 47 miles. W. F. DENNING.

Bristol, England, Oct 24, 1888.

Total Solar Eclipse of Jan. 1, 1889, will be observed by various parties from the United States and possibly some parties from foreign countries. We present herewith a map of a portion of the path of totality which probably will be of most interest to our readers. We are indebted to Engineer C. W. Irish, of Reno, Nevada, for the accompanying map and all points of local interest that we are able to give. The shadow of the moon will cross the west line of Nevada at the town of Verdi, and its width on the boundary will be 100 miles, the middle of the path being at a point 32 rods north of the 124th mile post of the Central Pacific railway line. The south edge of the shadow will pass about half way between Reno and the highest point of Peavine mountain. Thus Reno will be just outside the shadow. The center of the path will be about six miles north of Winnemucca and 29½ miles north of Tuscarora. The south edge of the path will pass north of Wadsworth and south of Pyramid, Lovelocks and Humboldt House. The north edge of the path will pass north of Buffalo Meadows, Willow Point, Paradise Valley, Spring City, Willow Creek, Cornucopia and White Rock, and will pass ten miles south of Ft. McDermitt.

In California, Susanville will be 14½ miles north of the center of the shadow and Quincy three miles north of it. Nevada City will be thirteen miles north of the south line of the path. All the towns named are inside the shadow path, as are Loyalton, Oneida, Long Valley, Milford, and all the settlements about Honey lake. All places in or near the center of the path will be in darkness two minutes of time. All those at the edges of the shadow will see the sun


43
42
Spring City
Paradise Valley
Willow point
6
41
Winnemucca
RA
NEV
40
39
38
117

momentarily eclipsed. The eclipse will begin at about 1:52 P. M. at Quincy, 1:53 at Honey Lake and 1:54 at Winnemucca. The shadow travels a northeast course across the state, leaving it at the northeast corner. Mr. Irish very kindly offers to furnish further information concerning localities in the path of the eclipse which observers may desire to know.

The points that may profitably receive observers' attention are:

1. Times of the four contacts and the direction of the line joining the cusps during the partial phases.
2. Search for intra-mercurial planets.
3. Observation of fringes which show themselves at the beginning of totality.
4. Photometric measurement of the intensity of light at different stages of the eclipse and during totality.
5. Telescopic observations of the details of the prominences and of the corona.
6. Spectroscopic observations of the lower atmosphere of the sun, prominences and the corona.
7. Observations with the polariscope upon the polarization of the light of the corona.
8. Photography both of the partial phases and of the corona.

The above points are those suggested by Professor Young in his new astronomy.

From recent letters we learn that Charles Burckhalter, of Chabot Observatory, will be at the head of a party of twenty amateur photographers who purpose to try their skill in getting pictures of the January eclipse phenomena. Mr. Burckhalter will use his 10½-inch Newtonian reflector.

New Minor Planets. No. 279 was discovered by Palisa Oct. 25, and noticed in last issue. No. 280 was found Oct. 29 by Palisa. No. 281 was found by same person Oct. 31. *The Astronomical Journal*, No. 184, gives the wrong number, we think, to the planet discovered Oct. 31. It should be 281 instead of 280. So says the *Tietjen* circular, No. 330.

EDITORIAL NOTES.

Volume VII of this publication is completed, and consequently a large number of subscriptions expire with this issue. In such cases a printed blank containing a request for renewal or discontinuance is enclosed in the current number.

It will save unpleasant irregularity if subscribers who receive enclosed printed blanks will promptly notify the publisher that the continuance or discontinuance of this journal is desired for the ensuing year, if this has not already been done.

Some persons having Vol. IV of this publication may find that the title page is wanting, as it was issued separately. Such wanting leaf will be mailed to any one on application.

Professor George Davidson, now of Buena Park, Los Angeles, California, has prepared a large ready blue print map showing the path of totality of the solar eclipse of Jan. 1, 1889, for California and Nevada, also a chart to exhibit the stars and planets to the 6th magnitude within ten or fifteen degrees of the sun. It is to be regretted that the duties of his position in Coast Survey work make it impossible for him to observe in the time of totality.

The Transparency of the Ether. In the first number of the "University Studies," published by the University of Nebraska, Professor D. B. Brace has an interesting article with the above title. Dr. Brace treats the subject mathematically and deduces the equations for the amplitude of luminous vibrations on three suppositions: 1. That the ether has viscosity; 2. That it has imperfect elasticity; and 3. That the diminution of the amplitude is of the character of that observed in solid bodies. The resulting equations are elegant and interesting. A discussion of them shows that, in any of the cases, the absorptive effect would be to give a relative predominance to the red end of the spectrum and that, consequently, if there is any absorption the more distant stars should be more reddish than the nearer, as the eye is quite sensitive to a small admixture of red in white and as it fails to recognize that the fainter stars are redder than the brighter ones, the author concludes that the absorption is inappreciable even for the most distant stars. His final conclusion is that "either the universe must be finite or, if infinite in extent, the average density of distribution of bodies outside our own system must be exceedingly small, as otherwise the sky would appear of a uniform brightness, approximating that of the sun." H.

Orbit and Ephemeris of Barnard's Comet (Oct. 1888) by J. M. Schaeberle, Astronomer of the Lick Observatory. [*Communicated by the Director*]. From Mr. Barnard's observations of Oct. 31, Nov. 2 and Nov. 4, I have computed the following orbit and ephemeris of this comet:

$$T = \text{Sept. } 9.4475$$

$$\left.\begin{array}{l} \omega = 267^\circ\ 9'.9 \\ \Omega = 137\ 52\ .0 \\ i = \ 45\ 52\ .6 \end{array}\right\} \text{Apparent Equinox.}$$

$$\log q = 0.04984$$

$$\text{Middle Place} \left\{ \begin{array}{r} o-c \\ \Delta\lambda \cos\beta = -0'.2 \\ \Delta\beta = +0'.2 \end{array}\right.$$

$$\begin{array}{l}\text{Heliocentric} \\ \text{Coördinates}\end{array} \left\{ \begin{array}{l} x = r[9.94271] \sin(144^\circ 57'.7 + v) \\ y = r[9.99009] \sin(\ 48^\circ\ 8'.5 + v) \\ z = r[9.72089] \sin(297^\circ 40'.5 + v) \end{array}\right.$$

Assuming that the above orbit is approximately correct, I find that at the time of perihelion passage the comet was in R. A. 10*h* 30*m*; Decl. $-21^\circ 44'$, and the light less than twice as bright as it was at the time of discovery. The comet will continue to decrease in brightness, although for several weeks to come its distance from the earth will keep on diminishing. On Dec. 5 and Dec. 25 the computed light will be 0.68 and 0.60 respectively; the light for Nov. 3.5 being unity.

The Photographic Chart of the Sky. The second fasciculus of the "Bulletin of the Permanent International Committee for the Photographic Execution of a Chart of the Sky" has recently come to hand and contains much interesting matter. In the opening chapter the president of the committee, Admiral Mouchez, reports that the seven instruments being made by Gautier will be finished by the beginning of next year, 1889, and the same will be true with regard to those being constructed by other makers. To the fourteen Observatories already known as certain to take part in the work, must be added the three English Observatories, Greenwich, Cape and New Zealand. Dr. Vogel, of Potsdam, has solved perfectly the question of the best form of a *reseau* or reticule to be used, and will make and verify them for 100 francs (about $25) each. M. Champigneulle is pursuing, with satisfactory results, his experiments with the vitrification of plates to make them unalterable with the time. The Messrs. Henry find the American "Seed" plates, sent them for experiment by Professor Pickering, to be remarkably superior, both in sensitiveness and uniformity of film, to any others which they have tried. These plates will reduce, by half, the time of exposure and consequently the time necessary for the execution of the chart. The president suggests that a reunion of the committee is necessary and that the World's Exposition of 1889 at Paris will afford a very favorable opportunity; that it would be well to place the date of the meeting very near to that of the Astronomische Gesellschaft at Bruxelles, in 1889. He also refers at some length to the project, proposed by Dr. Gill in the first number of the Bulletin, in regard to the creation of an International Bureau for the measurement of the plates, in order to construct a catalogue of stars down to the 11th magnitude; which project has met with considerable opposition on the part of certain astronomers, who maintain that the Congress did not sanction the construction of such a catalogue but only the taking of certain plates in such a manner that such a catalogue might be possible. Admiral Mouchez maintains that the Congress did vote the construction of the catalogue and that the method proposed by Dr. Gill is the most economical for carrying out the will of the Congress. In the next paper Dr. Vogel gives the results of his experiments on the form of reticule and the distortion of the film. He finds that the average distortion in a distance of 65*mm* or 1° amounts to about 0.006*mm* or 0.36″. If then the distance between the lines of the reticule be made only 5′, the errors resulting from distortion will be reduced to 0.03″, which is insignificant.

Dr. Capteyn discusses a method of measuring the plates parallactically so as to obtain the R. A. and Decl. of stars directly. Dr. Gill accepts Dr. Capteyn's method as a modification of his own and enters into a discussion of the details of the method and the reduction of the measures. Then follows Professor Pickering's report of photometric observations in progress at Harvard. A catalogue of 1,000 stars situated within 1° from the pole, is almost ready for printing. The discussion which accompanies it comprises the comparison of effects produced in taking photographs of stars by points or traces, in varying the aperture, the duration of exposure or the velocity with which the image is displaced upon the plate. All the stars of the Pleiades have been examined in various ways; also a list of 1,000 stars near the equator. He proposes to select groups of comparison stars at intervals of 5° in declination and 40*m* in right ascension, including stars from the 9th magnitude down to the limit of visibility, and to compare these by eye and by photography.

Several letters follow, discussing points of minor importance. The Messrs. Henry think that plates giving a field 3° square can be employed with accuracy. On the scale which was adopted by the Congress 3° would be 18 centimeters, or about 7 inches. Dr. Gill thinks that plates 2° square would be preferable, owing to the greater ease of reductions if the zones overlap 1° rather than 1½°.

Kepler's Problem. The following extract from the report of the meeting of the "Astronomische Gesellschaft," held at Strassburg, Sept. 22-24, 1881, published in *Copernicus*, Vol. I, p. 200, is worthy of reproduction for the benefit of students and all others engaged in the calculation of orbits:

"Professor Peters also showed how Kepler's equation

$$E = M + e \sin E$$

could be solved by the mere aid of ordinary logarithmic tables more rapidly than by using even the most extensive auxiliary tables. For a five-place computation $\log e$ in minutes of arc was written down; then with any approximate value of E (say $E = M$) $\log e \sin E$ was mentally computed, and $e \sin E$ added to M, thus giving a closer approximation to E. In practice one finger of the left hand is inverted in the table at $\log \sin E$, while another finger retains the place of $e \sin E$ in the logarithms of numbers."

JOHN TATLOCK, JR.

Last Observations of Comets. In compliance with your request that astronomers give you their last observations of comets, I send the following brief account of the supposed observation of Comet 1888 *a*, Sawerthal's. On the evening of Sept. 24th, as soon as twilight ended, it being an exceptionally fine night, I set my 16-inch on the place indicated by the ephemeris of the comet for that day. After closely scanning the field, I at length noticed a large and excessively faint nebulous object close to and a little north of six stars of about the 13th magnitude arranged in the form of two small right-angled triangles. Being so large I was in doubt, at the time, whether it was the comet or a nebula. I have had but two opportunities since to examine the spot, and on both occasions the seeing failed to equal that at the time of discovery (though one was nearly as good). I could detect nothing nebulous even with the most intense gaze, and so am inclined to think that the object seen was the comet.

Its approximate place was R. A. $23^h\ 53^m\ 40^s + 52°\ 18'\ 40''$.

I entered it in my note-book as follows: "e e e F., L., irregularly round, two little triangles close S." LEWIS SWIFT.

Warner Observatory, Nov. 16, 1888.

Harvard College Observatory will send out a party of observers to view the total eclipse of Jan. 1, 1889. From Professor E. C. Pickering, the Director, we have obtained the following facts:

The party will consist of W. H. Pickering, Chief. A. Lawrence Rotch, S. I. Bailey, E. S. King and Robert Black. Mr. Rotch has already more than a national reputation as a meteorologist and it will be in that line that his service will be rendered. The other three have been for some time past active assistants at the Observatory and are well practised in the manipulation of apparatus and familiar with the working methods of the institution.

The study of the eclipse will not include any direct visual observations, though a single telescope for visual purposes will be taken and may incidentally be serviceable. Photographic and photometric observations and those of the spectrum will be the chief aim. The principal instruments will be the 13-inch Boyden telescope, the 8-inch Boyden, the 8-inch Bache, a 5-inch telescope, a quadruplex spectroscope, a quadruplex photographing telescope, a spectroscope constructed with quartz lenses and prisms of the same material, and an instrument recently devised at the observatory known as the reversing-layer spectroscope.

The last-named instrument is designed to be put into service 10 seconds before totality, to continue during totality and for 10 seconds afterward. By this will be obtained a photograph by which the reversal of the rays of light, observed formerly by Professor Young, and other reported phenomena, may be determined in respect to their character.

The quadruplex spectroscope is so constructed that eight tracts or areas of the corona may be photographed at once, all these photographs dealing with the yellow and green regions of the spectrum. Another instrument photographs the blue regions, and the instrument provided with lenses and prisms of quartz will take the ultra-violet regions.

The two eight-inch telescopes will be employed in the photographic work of the outer details of the corona. One of these, the Bache instrument, has a rapid lens and the Boyden of the same aperture having a longer focus will operate more slowly, or, in other words, the negatives used will be given a longer exposure. As both are powerful instruments and operate upon the same region, which may be called the outskirts of the sun, one or the other might detect and record the inter-Mercurial planet, if, as some are disposed to think, such an one exists.

The five-inch telescope, having a focus of 7½ feet, will be employed in photographing the inner corona for measurements of light, which operation will comprise the brightness of the protuberances.

Many instruments of subordinate service are comprised in the equipment. Among these are a five-inch and a four-inch photographing camera of the ordinary kind. These worked with quick plates will be used for picturing the sky of the outer region of the corona and the sky at a distance from the sun. One of these will be operated at a considerable height above that of the observing station of the party. Each produces an image of ¼ inch diameter.

The other quadruplex instrument mentioned above is for measuring the brightness of the corona and is an ingenious piece of apparatus, a primary feature of which is a perforated plate having perhaps 1,000 minute apertures for the passage of separate shafts of light, any one of which may be used for the purpose of observation. An important part of the work will be photography of the spectrum, for which very complete apparatus is provided.

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18. On page 410, of the MESSENGER the distance of α Centauri is given as less than one-half that of 61 Cygni.

Have not later observations shown this to be wrong, and that the two are nearly the same distance?

The following table, taken from the proof sheets of Professor Young's new Astronomy, gives, doubtless, the best results concerning the parallaxes of the two stars:

Name.	Authority.	Date.	Method.	Parallax	Distance Light-Years.
				$''$	
a Centauri..........	Henderson........	1842	Mer. Circle...	0.913	3.60
	Maclear...........	1851	Mer. Circle...	0.919	3.50
(Probably best)..	Gill and Elkins..	1882	Heliometer...	0.750	4.35
61 Cygni............	Bessel...............	1838–40	Heliometer...	0.348	9.40
	Pogson............	1853	Heliometer...	0.384	8.50
	Johnson............	1854	Heliometer...	0.397	8.20
	O. Struve...........	1852–53	Micrometer..	0.505	6.50
	Auwers.............	1863	Micrometer..	0.564	5.80
	Ball..................	1878	Micrometer..	0.465	7.00
	Hall..................	1880–86	Micrometer..	0.270	12.10
	Pritchard..........	1887	Photography	0.433	7.55

By the term "light-year," at the head of the last column, will be understood the distance that light travels in one year at the rate of 186,000 miles per second, this being a better unit for the measure of the great distances of the stars than any other. The distance of a light-year is nearly 70,000 times the distance of the earth from the sun. Since a star with a parallax of 1″ is at a distance of 3.262 "light-years," by the following formula, $D = \frac{3.262}{p''}$, the distance of any star in "light-years," (D), may be easily found if the parallax is known, represented in the equation by p''.

The measures of the two stars given above are by good authority, and yet the results differ, in some instances, greatly, so that the uncertainty of true values is very great.

Note on the Orbit of the Comet Discovered at the Lick Observatory, on Sept. 2d, 1888, by E. E. Barnard. Late observations of this comet have permitted the calculation of orbits with close approximation to the true one. One of the best determined seems to be that of M. Berberich, given in the *Astronomiche Nachrichten*, No. 2862. His elements are:

$$T = 1889 \text{ Jan. } 31.14570 \text{ Berlin M. T.}$$

$$\left.\begin{array}{l} \omega = 340^\circ\ 35'\ 31''.8 \\ \Omega = 357\ \ 28\ \ 41\ .6 \\ i = 166\ \ 22\ \ \ 3\ .7 \end{array}\right\} \text{Mean Eq. 1888.0}$$

$\log q = 0.258382$ = (1,813 times the distance of the sun.)

The middle places are represented as follows:

	Sept. 17.5	Oct. 1.5
	$\Delta\lambda = -2''.8$	$+0''.7$
	$\Delta\beta = -4\ .3$	$-0\ .2$

M. Berberich points out the interesting fact that the theoretical brightness (H) will exceed the brightness at discovery for the best part of a year after the date of discovery. The comet will continue visible in the evening sky till the first part of March, 1889. From April to November, 1889, it will be observable in the morning, and later, the evening sky. On May 4, it rises about 2:30 A. M. It now has an almost stellar nucleus and a faint tail about half a degree long, and is an interesting object in the smallest telescope. It can easily be found by Professor Boss' ephemeris, printed in the *Astronomical Journal* (No. 184, p. 128), which for those who do not see the *Journal*, is reprinted here.

Greenwich M. T.	Appt. α	Appt. δ	log r	log Δ	Light.
	h m s	° '			
1888 Dec. 1.5	2 15 42	—6 18.7	0.29474	0.0575	11.6
2.5	2 9 35	—6 29.3	9.29367	0.0619	
3.5	2 3 36	—6 39.0	0.29261	0.0667	11.3
4.5	1 57 47	—6 47.9	0.29156	0.0717	
5.5	1 52 8	—6 56.0	0.29053	0.0769	
6.5	1 46 39	—7 3.3	0.28950	0.0824	
7.5	1 41 20	—7 9.8	0.28849	0.0881	10.4
8.5	1 36 12	—7 15.6	0.28749	0.0940	
9.5	1 31 14	—7 20.7	0.28651	0.1000	
10.5	1 26 26	—7 25.2	0.28554	0.1061	
11.5	1 21 49	—7 29.0	0.28459	0.1124	9.5
12.5	1 17 21	—7 32.2	0.28365	0.1188	
13.5	1 13 4	—7 34.9	0.28272	0.1253	
14.5	1 8 56	—7 37.1	0.28179	0.1318	
15.5	1 4 58	—7 38.7	0.28090	0.1383	8.5
16.5	1 1 9	—7 39.9	0.28003	0.1449	
17.5	0 57 29	—7 40.7	0.27815	0.1515	
18.5	0 53 58	—7 41.0	0.27730	0.1581	
19.5	0 50 36	—7 41.0	0.27746	0.1646	7.7

Formation of Comets' Tails. Answer to query 14, page 412 of the last SIDEREAL MESSENGER.

The statement, I believe, originated with Mr. Faye. He has only given it as his belief unsupported by any scientific facts, and it has, as far as I know, been unquestionably and generally accepted. Had he, for instance, stated that the anomaly was electrical, astronomers might have had a semblance of reason for accepting it; but as it was blindly received no other but its author could answer A. B. C.'s query.

There are several theories for the comet's tail. Tyndall says it is due to an actinic action of the solar rays on the sensitive cometic matter, decomposing it. This would suppose the comet to have only one axial revolution throughout its orbit somewhat like the moon, otherwise the actinic decomposition of the cometary atmosphere would be total if, like other bodies, it revolved on its axis faster than once, or a simultaneous re-composition of decomposed matter, an action inconsistent with known scientific facts and cometary observations.

Roche explains that radiation and gravity are sufficient to the formation of successive aureolas that are detached from the nuclei. This would suppose two ridges, one towards, the other away from the sun; observations do not confirm this. In a paper read by the writer before the A. M. A. in March last he attributed the tails of comets to the reflection of the solar rays by the highly rarified atmosphere or cometic matter surrounding the nucleus; that the solar rays are partly absorbed passing through the hemisphere nearest and partly reflected by the one farthest from the sun.

A. J. PIGEON.
No. 30 Richmond Square, Montreal, Canada.

Great Refractor for Los Angeles. By kindness of a friend in Los Angeles we learned, at the beginning of last month, of the purpose of the University at Los Angeles to erect an Astronomical Observatory which should have a telescope of 42-inches clear aperture. The instrument is to be mounted on Wilson's peak of the Sierra Madre mountains, which is 6,000 feet high, and about 25 miles from Los Angeles. The Trustees of the University now have in hand $50,000 which belong to the Observatory funds. Dr. M. M. Bovard, the President of the University, has already visited the East in the interest of this new enterprise. As the endowment of the University is already over $3,000,000 it is probable that California may yet boast of having two observatories with longer telescopes than elsewhere in the world.

We also learned from Professor Pickering recently that the 13-inch and 8-inch Boyden telescopes would be set up in January next for a short time, on Wilson's Peak, the site of the new observatory of the University of Southern California, and be operated there experimentally to try the site as a point for observation.

Comet f 1888 (Barnard). A comet was discovered by E. E. Barnard, Lick Observatory, Cal., October 31.0399 Gr. M. T., in right ascension $9h\ 43m\ 26.2s$; decl. $-15°\ 18'\ 52''$. Daily motion in right ascension is $1m\ 32s$; in declination, $+9'$. The physical appearance of the comet is as follows: Nebulosity slightly elongated, one minute of arc in diameter, 11th magnitude in brightness or fainter, strong central condensation. The cipher message conveying the above information, consisting of twelve words, was received Nov. 1, and three words were wrong, yet the entire message was made out correctly.

The following elements were computed by J. M. Schaeberle, astronomer at Lick Observatory, from observations Oct. 30, Nov. 1 and Nov. 3:

ELEMENTS.

$$
\begin{aligned}
T &= \text{Sept. } 9.45 \text{ Gr. M. T.} \\
\left.\begin{aligned} \omega &= 267°10' \\ \Omega &= 137\ 52 \\ i &= \ \ 45\ 53 \end{aligned}\right\} & \text{ Mean Eq. } 1880.0 \\
q &= 1.1216
\end{aligned}
$$

During the first part of last month the comet was in the constellation Hydra, being about 10° southwest of α on the 3d, and on the 15th 5° south of λ. It is a faint object, is diminishing in light, and moving slowly to the northeast. We have no ephemeris later than Nov. 15.

Charles H. Rockwell, of Tarrytown, New York, will observe the eclipse at some point in California.

The considerable space used for notices of the coming solar eclipse leaves us without space in this number for queries and answers.

George F. Davidson and Thomas Davidson, sons of Professor Davidson, of the United States Coast Survey, will use photographic apparatus in the path of the total eclipse at the high station of Winnemucca. They will employ a telescope of 4 inches aperture and 24 inches focus.

Meteors. Two bright meteors were seen at this Obseravtory on the evening of Nov. 6th. The first was observed by me at 6*h* 14*m* Haverford mean time. It appeared considerably brighter than Venus, was of a blue color, and moved in a direction from near Zeta Herculis to near Rho Serpentis.

The second was observed by my assistant, Mr. H. V. Gummere at 6*h* 51*m*. It was probably much brighter than the one first seen, and was of a green color. It curved slightly upward at first, and then went perfectly straight in a direction from Alpha Tauri to a point one-fourth the distance between Alpha and Beta Aurigæ. At the end it broke into three fragments which glowed for a while before disappearing.

F. P. LEAVENWORTH.

Haverford College, Nov. 9.

Zeta Herculis. In the Espin Circular, No. 22, under date Nov. 9, 1888, it is said that Zeta Herculis has increased in light. Mr. Gore confirms the observation.

The following important articles, as well as others, will appear in the next number: "Saturn and His Satellites," by Professor E. S. Holden; "The Canals of Mars" (illustrated), by Dr. H. C. Wilson; "Tracing Constellations, and the Constancy of Star-Maps" (illustrated), by Professor Wm. A. Rogers.

By recent letter from Florence we are pained to learn that Professor Tempel is again obliged to leave his Observatory on account of ill health.

BOOK NOTICES.

An Elementary Treatise on Analytic Mechanics, with Numerous Examples. by Edward A. Bowser, LL. D, Professor of Mathematics and Engineering in Rutgers College. New York: D. Van Norstrand, Publisher, 23 Murray and 27 Warren Street; pp. 511.

This text book, designed for scientific schools and colleges, is not new, though we have not before had the pleasure of examining it. It had already passed through its third edition in the first two years of its history.

The general divisions of the subject matter are those usually found in the best works of the kind, and their orderly arrangement is such as to make the progress of the student easy and natural. As might be expected the calculus is used from the first. But it is used in such a way as to encourage the student instead of discouraging him when he has, as yet, but little experience in the use of that branch as an instrument of mathematical investigation. This is noticeable in the first chapter, in getting the measure of acceleration and the integration that follows; in the second chapter, in the study of the conditions of equilibrium, and especially, in the fourth chapter, in the theme of the center of gravity whose investigations involve integration including the polar formulæ. The studies of attractive force are also instructive and might well receive extended notice. As in other works by the same author previously noticed, this contains numerous examples which will certainly serve to fix the principles well in mind, if faithfully solved by the student.

Theoretical Mechanics, by J. Edward Taylor, Head Master of the Central High School Grade and Science Schools, Sheffield. London: Messrs. Longmans, Green & Co., New York, 15 East Sixteenth Street, 1888; pp. 264.

This new elementary work is intended as an introduction to the study of theoretical mechanics, and to be helpful to those who are reading in the lines of science and art departments' syllabus for the elementary stage in the English schools. This text is said also to be sufficient for the requirements of the London University matriculation examination in this branch. The course of reading is simple and plain, and can be easily mastered by students having knowledge only of the elemental branches of mathematics. The examples under each head are numerous and make a prominent feature in the plan of the book. Teachers will be interested in examining this new book.

Books and Pamphlets Received.

Cape Meridian Observations, 1882 to 1884, under the direction of David Gill, LL. D., F. R. S., etc.

Greenwich Spectroscopic and Photographic Results, 1886–7.

Greenwich Astronomical Results, 1886.

Greenwich Magnetical and Meteorological Observations, 1886.

Annuaire de L' Observatoire Royal de Bruxelles, 1885, 1886, 1887 and 1888.

Annales de L' Observatoire Royal de Bruxelles. Tomes V and VI.

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