REPORTS OF OBSERVATORIES.

LICK OBSERVATORY, MOUNT HAMILTON, CALIFORNIA.

This report covers the period January 1, 1908, to July 1, 1909. It is intended that only the more important items of the activity of the observatory shall be considered, and these quite untechnically.

The total solar eclipse of January 3, 1908, was observed by means of an expedition dispatched from the observatory through the generosity of Honorable WILLIAM H. CROCKER, regent of the University of California. A popular account of the expedition and its work has already appeared in these *Publications*,[1] and its general features need not be repeated here. In spite of clouds which interfered with carrying out the program during the first third of the total phase, subsequent studies of the photographs showed that the expedition met with an unusual measure of success.

Dr. PERRINE completed his detailed examination of the sixteen photographs, obtained with eight cameras, covering the region 9° by 28° extending in the direction of the Sun's equator. These photographs had for their purpose the detection of any existing intermercurial planet or planets. In the sudden downpour of rain immediately preceding totality it was not possible to protect everything, and a little water got into these cameras. Some of the photographs are marked by narrow bands where the rain water ran across them. Until after our return to Mount Hamilton it was thought the photographs were damaged to such an extent that the value of the intermercurial search was seriously impaired, and our public announcement embodied this view. It is gratifying to state that these fears were groundless. There are images of more than five hundred stars on the photographs, down to about the ninth magnitude; and, surprising to relate, the rain-streaked areas contain the images of all the known stars we expected to find thereon. All the images have been identified as those of well-known stars. In our opinion, the work of the three Crocker Expeditions, to observe the eclipses of 1901, 1905, and 1908, brings the observational side of the intermercurial planet prob-

[1] **20**, 63, April, 1908.

lem—famous for half a century—definitely to a close. It is not contended that no planets will be found in the intermercurial region: it would not be especially surprising nor in contradiction to beliefs here expressed if small planets should be discovered at some future time; but it is confidently believed that their mass would be inadequate to account for the observed disturbances in the motion of *Mercury*.

The photographs of the solar corona obtained with cameras of 6′ and 40′ focal lengths are of great excellence. Opportunity has not been found to study these photographs as completely as we should like, and attention will be called to only one feature. A great number of coronal streamers appear to radiate from a common point near the eastern limb of the Sun (position angle 75°), as if thrown out by an explosion at the point, though it is not contended or even suggested that an explosion had actually occurred. The point of intersection of the streamers, obtained by prolonging them behind the Moon's disc, was estimated to be in position angle 75° and the distance from the Sun's center 13.′7 of arc. On comparing this position with the photographs of the hemisphere of the Sun turned toward us, as obtained by the Mount Wilson Solar Observatory on January 3d, 4th, and 5th, it was apparent that the vertex of the so-called disturbance was situated within the borders of a great group of sun-spots. It may be recalled that a similar cone of disturbance, as recorded on the Sumatra corona plates of 1901, appeared to have its vertex exactly over the large and only spot recorded on the photographs of the sun obtained on several days preceding and following the date of the eclipse; and that another radiating group of coronal streamers on the Spanish photographs had their estimated apex near, but apparently not in coincidence with, a prominent sun-spot. In view of these pieces of evidence, it is difficult to avoid the conclusion that the sun-spots and the coronal streamers referred to were closely related in origin.

Spectrograms of the corona obtained by Dr. LEWIS and Director CAMPBELL, using different instruments, recorded a large number of coronal bright lines, of which four observed by Dr. LEWIS and two by Mr. CAMPBELL are certainly new. The interpretation of the continuous spectrum of the corona is a difficult matter. The records are rendered very complex

by the diffusion of light of the solar prominences and of the brilliant inner corona over the whole area of the spectrum. The dark-line spectrum believed to be due to photospheric light scattered by minute particles in the corona is visible very faintly, and only in the region of the corona well out from the Sun's surface. By far the greater part of the light gives a strictly continuous spectrum, and seems to be due to radiation from the coronal particles perhaps rendered incandescent by the overpowering heat of the Sun. The position of maximum intensity of continuous spectrum is displaced slightly toward the red from that of the normal solar spectrum, signifying the lower temperature of the corona.

The changing spectrum of the Sun's edge, as the edge was gradually uncovered by the Moon, was recorded successfully on a continuously moving sensitive plate. More than a thousand bright lines, changing into the dark lines of the ordinary solar spectrum, were impressed on the plate in lengths and at times such that they indicate the thicknesses and locations of the gaseous and vapor strata giving rise to them in the Sun's atmosphere. Four such photographs, obtained at the eclipses of 1899, 1900, 1905, and 1908, respectively, may be said to constitute a unique basis for the study of chemical stratification of the solar atmosphere. The moving plate has a great advantage over the fixed plate in recording the spectrum of the Sun's edge, in that the former gives a continuous record of all changes occurring, whereas the latter gives an integrated record for the brief period of exposure only.

From photometric observations of the Flint Island corona, Dr. PERRINE has deduced the following results, the unit of brightness being the light from one square minute of arc of flame of a Hefner standard lamp:—

Total actinic light of portion of corona observed	222 units
Intrinsic actinic brilliancy of corona	2.02
Intrinsic actinic brilliancy of sky near corona..	.0027
Ratio of intrinsic actinic brilliancy of the brightest parts of sky	744 to 1
Total actinic light of full Moon	2602 units
Intrinsic actinic brilliancy of full Moon	2.58
Ratio of total coronal to full Moon light.....	0.111

A series of photographs for the study of polarization effects in the corona was obtained. The Rumford Committee of the

American Academy of Arts and Sciences has made a grant for the purchase of a photometer suitable for the measurement of these and other similar plates, and it is hoped that they may be subjected to quantitative analysis in the near future.

Dr. AITKEN has continued the double-star survey of the northern sky, according to the systematic plans described in my last report. It is expected that this survey, as carried on at Mount Hamilton, will extend to $-22°$ declination. About 90% of the survey has been completed; and given ordinary observing conditions in the following two winters and springs, the program should be completed. More than 3,300 close pairs of stars have been discovered as one result of this survey: 1,300 + by Professor HUSSEY and 2,000 + by Dr. AITKEN. The two components of each double are in fully 99% of the cases less than 5″ of arc apart.

It is scarcely necessary to say that the great value of this survey lies not in these discoveries themselves, but in the enormously increased opportunity which the discoveries will afford in the future study of double stars, in particular, and of the structure of the sidereal universe, in general. Holding the requirements of these studies in mind, the systematic qualities of the search are rigidly maintained; and at least two satisfactory micrometer measures of each pair are secured as promptly as practicable, before announcing the discovery. It is hoped, for example, that future computers of their orbits will have the great advantage of an accurate discovery position in each case.

About one hundred of the more important and more difficult of our well-known double stars are kept under observation by Dr. AITKEN, measures being made as often as they are needed. It has been found that the revolution period of 13 *Ceti* is only 7.4 years; next to that of *Delta Equulei* the shortest period known.

Astronomer TUCKER having been offered the superintendency of the Meridian Circle Station of the Carnegie Institution, in the Argentine Republic, the regents of the University were pleased to grant him leave of absence for the three academic years 1908-1911, in order that he might accept this highly honorable appointment. The remarkably large quantity of very accurate results secured by Mr. TUCKER during his fifteen

years' residence on Mount Hamilton had given rise to a widespread feeling among the specialists in his subject that he was the man for the place. It was largely in response to this opinion that the director recommended the loan of Mr. TUCKER'S services, involving as it did a serious interruption to our own program of observations. He left Mount Hamilton on May 1, 1908. His observations during the preceding four months, continuing his work of the preceding two years, related to the program for determining the extremely accurate positions of stars, based on fundamental methods as opposed to basing results upon a system of star positions already established with other instruments. The stars in his program are distributed nearly uniformly between 37° north and 37° south declination. Special stars are included for the purpose of determining the observer's personal errors as affected by his facing north or south while making the observations and by the direction of the apparent motion of the star through the field of view. Suitable stars for the investigation of atmospheric refraction were included, and likewise a list of stars to determine the effect of star magnitudes upon the personal equation. The reductions of the observations for the period of more than two years are well advanced, thanks to assistance afforded by the Carnegie Institution.

Much of Astronomer PERRINE'S time has been devoted for several years to devising methods of measuring and reducing the long series of *Eros* photographs taken in 1900 with the Crossley reflector, for the determination of the solar parallax; and to superintending this work. The measurements and computations, based upon 525 photographs, were made by Mrs. MOORE and Miss HOBE, Carnegie Assistants, beginning with December 1, 1905. The results of the measurement were brought together by Dr. PERRINE last winter, and a critical discussion led to the most probable value of the solar parallax, $8''.8067 \pm 0''.0025$. This result is in remarkably good agreement with the longer series of observations secured at other stations. The details of the measurements and discussions will be brought out in a volume to be published soon by the Carnegie Institution.

During the period covered by this report about one hundred and fifty photographs were made with the Crossley reflector,

chiefly by Dr. PERRINE and in part by Dr. ALBRECHT and others. The subjects included the faint satellites of *Jupiter,* nebulæ, star clusters, parallax objects, etc.

During the summers of 1907 and 1908 Mr. FATH made an extensive study of the zodiacal light with reference to polarization effects, the character of its spectrum, and its maximum extension northward from the ecliptic or Sun's equator. The spectrum observations are not yet ready for publication. The northern extension of the zodiacal light was observed satisfactorily, and there is left no doubt that it can be seen approximately 45° northward from the Sun, as viewed by a terrestrial observer.

Mr. FATH photographed the spectra of several spiral nebulæ and globular star clusters with a low dispersion instrument attached to the Crossley reflector. The text-books on astronomy ascribe in most cases a continuous spectrum to spiral nebulæ. Mr. FATH found that their spectra vary from those having principally bright lines, such as are found in the so-called gaseous nebulæ, to those containing only absorption lines of the solar type. No strictly continuous spectrum was observed. He confirmed in the strongest possible manner the earlier observations by SCHEINER and HUGGINS on the *Andromeda* nebula, removing any elements of doubt which may have attached to their results, to the effect that the spectrum of this object is of the solar type. The spectra of globular star clusters, including the great cluster in *Hercules,* are continuous, with a certain number of well-defined absorption lines. In general, stars of the so-called "F" type appear to predominate in the clusters. This type occupies a position about midway between the hydrogen stars and solar-type stars.

Micrometer observations of comets visible during the period have been obtained chiefly for the use of the Berkeley Astronomical Department in determining orbits. The spectrum of Comet Morehouse was studied by Messrs. CAMPBELL and ALBRECHT at Mount Hamilton, in the fall months of 1908, and by Astronomer CURTIS at the D. O. Mills Observatory in Chile, in the spring of 1909. The spectrum was essentially of a new type. The carbon and cyanogen bands usually visible in cometary spectra were relatively faint, and other sets of lines appearing in pairs were for the most part new and of remark-

able strength. Readers are referred to *Lick Observatory Bulletins* 145 and 147 for detailed particulars. It was suggested by one noted astronomer that the doubling of the lines was a Doppler effect, due to relative motions in the observer's line of sight. Not only did this hypothesis seem extremely improbable, but our observations in the two hemispheres showed that it could not be true, for the varying angles under which the comet was observed should have been accompanied by corresponding variations in the intervals between the lines of the pairs. These intervals remained, on the contrary, essentially constant.

Miss GLANCY, fellow in the Lick Observatory, secured a splendid series of photographs of Comet Morehouse. Her measurements and discussion of the plates and the reproductions of a large number of the photographs are in process of publication. Dr. CURTIS's photographs of the comet and its spectrum will be published in the course of a few months.

Mr. DUNCAN, fellow in the Lick Observatory, made a systematic investigation of the two variable stars, Y *Sagittarii* and RT *Aurigæ,* and discussed the possible causes of the type of stellar variation represented by these stars. The basis of his studies consisted of spectrograms obtained with the one-prism and three-prism Mills spectrographs attached to the 36-inch refractor. The causes of the variation appear to be exceedingly complex, and several in number. Tidal disturbance, motion in a resisting medium, and an atmosphere of variable absorptive powers were considered. No one of these is in itself sufficient to explain the variations of brightness observed, and it is not improbable that two or more of them, along with other causes, are acting. The studies of a dozen stars belonging to this type of variation, made chiefly by fellows of the Lick Observatory, have furnished a very considerable amount of valuable evidence bearing on the problem. The most significant fact established, by Dr. ALBRECHT, is that the maximum brilliancy in each case studied occurs when the star has its greatest velocity of approach toward the observer. There is little reason to doubt that an observer viewing the star from any point in our universe would in every case have maximum brilliancy when the star was approaching him. Studies of other stars of the same type are

extremely desirable, in order to make investigations of this type as a whole more effective.

The most extensive investigation under way is that of determining the radial velocities of the brighter stars by means of the Mills spectrograph attached to the 36-inch refractor, in the northern hemisphere, and by the D. O. Mills Expedition observing at Santiago, Chile, in accordance with a program determined upon by Mr. CAMPBELL in 1896. This program hopes to include all the stars whose visual magnitudes do not fall below 5.0 in the two hemispheres, using three-prism dispersion; with the addition of a considerable number of fainter stars in the southern hemisphere, using two-prism dispersion. The number of stars observed prior to June 1, 1909, at Mount Hamilton, is nearly 900, but approximately 200 of these have been temporarily rejected for observation with lower dispersion, because the lines in their spectra are too broad and ill-defined for accurate measurement. All the spectrograms secured prior to May, 1903, have been measured and reduced definitely; and about three fourths of those obtained between 1903 and 1909 have been similarly studied. In the southern hemisphere observations have been secured of 530 stars brighter than 5.0 and of about 150 stars fainter than 5.0 visual magnitude. The spectrograms of 148 stars observed by the D. O. Mills Expedition during its first period of work, in charge of Astronomer WRIGHT, have been completely measured and discussed, and both numerical results and accompanying text are entirely ready for the printer. Twenty-nine of the 148, or more than one in five, have been announced as spectroscopic binary stars. Of the spectrograms obtained during the second period of the expedition, in charge of Astronomer CURTIS, those made with three-prism dispersion have nearly all been measured and reduced; and those secured with two-prism dispersion have been submitted to approximate measurement and reduction.

Deducting stars observed in both hemispheres, the total number observed is 1,368.

The measurement and reduction of Mount Hamilton spectrograms have been invaluably assisted by grants from the Carnegie Institution.

In June, 1909, Dr. MOORE succeeded Dr. CURTIS as astronomer in charge of the D. O. Mills Expedition, the latter return-

ing to Mount Hamilton to take up the work of Astronomer PERRINE, resigned.

The orbits of a considerable number of spectroscopic binary stars have been determined by Messrs. CURTIS, MOORE, and PLUMMER.

The record of spectroscopic binary stars discovered, observed, and investigated is complete to date, and it is our purpose to publish a second catalogue of spectroscopic binary stars next winter.

Volume VIII of the *Publications of the Lick Observatory,* containing heliogravure, hand-press reproductions of seventy of Professor KEELER'S photographs of nebulæ, taken with the Crossley reflector, was issued in December, 1908. The arduous task of preparing the glass positives of just the right density to meet the engravers' requirements and of reading the proofs was borne by Dr. PERRINE. The preparation of the copper plates, coupled with much experimental work, extended through nearly four years. We struggled to reproduce the delicate details of the structure in both the bright and faint regions of the nebular subject and to preserve the natural dark sky backgrounds. As the engravers acquired experience and skill in dealing with our photographs, better and better results were secured; but we were forced to recognize that only the original negatives or copies on glass will suffice for the most exacting scientific requirements. We are hoping to place a set of positive copies on glass in each of half a dozen scientific centers of population, where they will be accessible to all qualified students of the subject. The expenses of the KEELER Memorial Volume were so heavy that the work could not have been carried through but for the generous help of many friends of the observatory.

It has been held in mind for several years that our most pressing duty relates to the publication of extensive results of observations as yet unpublished; and an ambitious program of publication was formulated for the biennial period just begun. With the approval and support of the regents of the university, the legislature which recently adjourned was asked to appropriate funds to carry out my program of publication. For reasons not connected with the observatory and therefore quite beyond my control, the increased appropriations were

not made. In fact, the actual appropriations for the biennial period are smaller than usual. Those available in the academic *year 1909-10 were consumed as soon as available* to meet deficits arising from printing for this and other departments of the university; and funds available for the year 1910-11 have been applied in good part to the same end. Efforts must be made to secure publication funds elsewhere. With the best of legislative intentions toward this observatory, we sometimes find it difficult to meet the expectations of other and distant astronomers in maintaining an international reputation on the basis of appropriations coming in meagerness from only one State of our own Nation—a generous State, whose finances were sorely tried by the catastrophe of April, 1906. The regents of the University of California, receiving their chief support from State funds, would gladly grant increased support to this department, I believe, if funds were available. The funds received from the university for the salaries of astronomers and astronomical assistants have been practically constant, since the beginning, in 1888, at $14,000 per annum. In the meantime the purchasing power of money has decreased fully one third.

Immediately following the completion of the KEELER Memorial Volume, we planned to begin with the reproduction of our long series of solar coronas, coronal spectra, etc., as illustrations for the proposed volume to contain the results of the Crocker Eclipse Expeditions to India, Georgia, Sumatra, Egypt, Spain, and Flint Island. It is hoped that efforts to secure funds for carrying on this work may soon be successful.

The number of *Lick Observatory Bulletins* issued to date is 160. This form of publication has been curtailed in the past three years to conform to *reduced* appropriations and greatly *increased* prices of printing. The special appropriation for the purpose has also borne the expense of printing and mailing brief *Bulletins* for the Berkeley Astronomical Department.

The half of a fire and earthquake-proof building, with several storage vaults to contain our invaluable collection of celestial photographs and rooms suitable for the development, enlargement, measurement, and study of the photographs, was erected late in the year 1907. The regents of the university recently appropriated funds to complete the building. The

construction is at present under way and the building should be complete in October, 1909.

During years of normal rainfall the water supply, depending in the dry summer and fall months upon the storage capacity available, has been sufficient to meet the needs of households, photography, etc.; but in years of short rainfall it has been necessary to curtail the consumption. A serious shortage occurred in the fall and winter of 1908. The regents of the university recently authorized the construction of a steel storage tank with capacity of 160,000 gallons. This tank is under construction and should be available for the storing of water during the rainy months of the winter, for consumption in the latter half of 1910.

A beginning has been made in the planting of trees immediately around the summit occupied by the main buildings. Assistance has been received from the U. S. Forestry Bureau. It is hoped that the afforestation near the summit of the mountain may proceed on a liberal basis from year to year.

At the request of the Navy Department of the United States Government, we determined the longitude of the Naval Observatory at Mare Island, California, with reference to the assumed longitude of the Lick Observatory.

The Lick Observatory has suffered great loss in the departure of Astronomer CHARLES D. PERRINE to assume the directorship of the National Observatory of the Argentine Republic. Coming to Mount Hamilton in the capacity of secretary in March, 1893, Mr. PERRINE'S ability, energy, and interest carried him rapidly forward in an astronomical career. He was appointed astronomer in the Lick Observatory in 1905. The results of his work are well known to the readers of these *Publications*. Suffice it to say that his services were of unusually great efficiency, and the many honors which have come to him were fully earned. He left Mount Hamilton with the personal goodwill of all his associates. The chief attraction of his new post of duty lies in the opportunity which the largely undeveloped state of astronomy in the southern hemisphere presents. It is confidently expected that he will give a good account of his stewardship.

W. W. CAMPBELL,
Director.

June 30, 1909.