lects nothing! To her the infinitely large and the infinitely small on the boundaries of which we live are alike finite among her infinities. Touch her at any point and your contact is with the eternal.

To contemplate the prolific labors of Professor Packard is to stand face to face with the attributes of genius. I do not wish to make an over-statement. True, there is an order of genius among the geniuses, but there is none in whose heart the sacred fire does not burn. There can be no holier joy than the joy of creative work, and yet it is a joy akin to terror. What is it which possesses a man even in early youth, which impels him despite all obstacles and restraint to strive evermore, intellectually alone, without approval, profitlessly after an unattainable ideal; whose spell grows more potent as his years ripen, as his toil increases, as the world grows caustic in its rebuke; and that leaves him only with death? Do not suppose that the poet or the sculptor or the martyr alone have it. It burns to-day with subdued passion but with all its pristine and unmitigated fierceness in the life of every true student of nature.

What is it that can sustain a man when every new avenue of thought discovered is but the approach to countless avenues beyond; when to finish, be it after years of labor, is only to be ready to begin; what encourages him when the unknown looms with greater vastness as the known is more profoundly mastered; when the very pinnacle of attainment is the sublime consciousness of ignorance, and when to be most renowned is to be most devoutly humble? It is the inspiration which illumined the life of our friend, our colleague, our teacher. Long may his ideals guide us at Brown!

Carl Barus.

Brown University.

THE ASTRONOMICAL AND ASTROPHYSICAL SOCIETY OF AMERICA.

The sixth meeting of the society was held December 27–30, 1904, at Philadelphia, Pa., during convocation week, in affiliation with the American Association for the Advancement of Science.

Three sessions of the society for the reading and discussion of papers and the transaction of business were held in room 106, College Hall, University of Pennsylvania, on Wednesday, Thursday and Friday afternoons. The number of members present at some time during the meeting was thirty-six and the average attendance was about fifty.

A pleasant social feature connected with the meeting was an informal dinner at the Hotel Walton, Thursday evening, at which twenty-six members and friends were present. Through the courtesy of Director Doolittle, a number of the members had the pleasure of examining the equipment of the Flower Observatory of the University of Pennsylvania at Upper Darby, and by the courtesy of Professor Snyder the extensive astronomical equipment of the Philadelphia Observatory was inspected by a considerable party.

During the meeting five new members were elected. The selection of a time and place for the next meeting was left open for future action by the council.

The officers elected were:

For 1905:
President—Simon Newcomb.
First Vice-President—George E. Hale.
Second Vice-President—W. W. Campbell.
Treasurer—C. L. Doolittle.
For 1905–6:
Councilors—W. S. Eichelberger, Ormond Stone.

On account of the contemplated absence from the country of G. C. Comstock for the greater part of the year 1905, W. S. Eichelberger was elected by the council as acting secretary.

W. S. Eichelberger and C. L. Doolittle represented the society in the council of the American Association for the Advancement of Science.

By request of a committee of the National Academy of Sciences appointed to secure international cooperation in solar research, a committee from this society was appointed by the president during the preceding summer to cooperate with the committee of the National Academy. The council has made this a standing committee of the society.

PAPERS PRESENTED.

C. L. DOOLITTLE: 'The Constant of Aberration.'

JOHN F. HAYFORD: 'A Test of The Transit Micrometer.'

ERIC DOOLITTLE: 'Remeasurement of the Hough Double Stars.'

D. P. TODD: 'Novel Design for Rotating Dome Track.'

EDWARD S. KING: 'A Study of the Driving Worms of Photographic Telescopes.'

C. L. DOOLITTLE: 'The Reflex Zenith Tube.'

ANNIE J. CANNON: 'Variations of the Bright Hydrogen Lines in Stellar Spectra.'

HENRIETTA S. LEAVITT: 'Variable Stars in Large Nebulous Regions.'

PERCIVAL LOWELL: 'Planetary Spectrograms, the Work of V. M. Slipher and C. O. Lampland.'

PERCIVAL LOWELL: 'The Canals of Mars: An Investigation of Their Objectivity.'

FRANK H. BIGELOW: 'Note on Three Solar Periods.'

JOHN A. PARKHURST: 'The Coordination of Visual and Photographic Star Magnitudes.'

HEBER D. CURTIS: 'The Quadruple System of Alpha Geminorum.'

HAROLD JACOBY: 'Use of the Method of Least Squares to decide between Conflicting Hypotheses.'

HAROLD JACOBY: 'Tables for the Reduction of Astronomical Photographs.'

EDWARD C. PICKERING: 'Recent Researches of the Henry Draper Memorial.'

ORMOND STONE: 'Calibration of a Photographic Photometer Wedge.'

J. G. HAGEN: 'Note on Two Variable Star Catalogues.

'Useful Work for a Small Equatorial.' A proposed discussion. To be opened by Edward C. Pickering.

ABSTRACTS OF PAPERS.

The Constant of Aberration: C. L. DOOLITTLE.

The systematic observation for variation of latitude was begun by the author December 1, 1889. This work has been kept up with some interruptions since that time. In 1896 was begun at the Flower Observatory a series which it was proposed to continue on a uniform plan for a period of seven years. This design was carried out with but little departure from the original program. Observation on this series was terminated December, 1906.

Work is now in progress on a more comprehensive plan, two instruments being employed, viz., the 5½-inch zenith telescope and the 8-inch Wharton reflex zenith tube.

The close of the former series seems to mark the proper time for bringing together the values of aberration constant which have been obtained, and for combining them to form a mean which may be considered final so far as may be shown by these observations.

The different values found are as follows:

SAYRE OBSERVATORY, SOUTH BETHLEHEM.

Date.	Aberration.	No. Pairs.	Wt.
1889 Dec. 1—1890 Dec. 13	20″.448±014	1479	0
1892 Oct. 10—1893 Dec. 27	20 .551±009	2900	1
1894 Jan. 19—1895 May 16	20 .537±014	1989	1
FLOWER OBSERVATORY, PHILADELPHIA.			
1896 Oct. 19—1898 Aug. 16	20″.580±008	2009	1
1898 Oct. 8—1899 Nov. 27	20 .540±010	1503	2
1900 May 5—1901 Aug. 30	20 .561±008	1994	2
1901 Oct. 3—1902 Dec. 1	20 .513±009	1935	2
1903 Jan. 22—1903 Dec. 7	20 .524±009	1554	2

The reasons which have led to assigning the wt. 0 to the first determination will be found fully set forth in connection with the published results of this series.* For various reasons which are fully explained elsewhere the first series at the Flower Observatory is not thought to be as reliable

* *Transactions of the American Philosophical Society*, Vol. XX., p. 318.

as the following ones. It has accordingly been assigned the wt. 1, the four remaining values being given the wt. 2. Combining according to these weights, we find for the mean,

$$20''.540 \pm .0055$$

I wish this to be regarded as the definitive value of this constant as derived from the zenith telescope observations extending from December, 1889, to December, 1903.

The Test of a Transit Micrometer: John F. Hayford.

When, in connection with an astronomical transit as used for time observations, a transit micrometer and chronograph are substituted for a system of fixed lines in the diaphragm, a telegraphic key and a chronograph, the observer is relieved of the necessity of operating the key at, or as soon as possible after, each of the several instants of transit of the star across the fixed lines. Instead, he is required simply to keep the star image bisected continuously by the movable micrometer line during its progress across the field of view. In the new process of thought the element of time enters only in an indirect manner. Hence, with a transit micrometer the personal equation becomes so nearly zero, and its variation so nearly zero, that it is difficult to prove that they are not both absolutely zero. The personal equation is one of the most serious sources of error in all time determinations and determinations of right ascension. The destiny of the transit micrometer is to produce a decided increase in accuracy in this class of observations without increase of effort or cost.

The observation of star transits by means of a movable transit line was first suggested in 1865 by Director Carl Braun of the Kalocsa Observatory. He believed that it was necessary to have the movable line driven by clockwork. He failed to construct a satisfactory apparatus.

Repsold, the well-known instrument-maker, was the first to suggest in print, in 1889, that no clockwork is required. He constructed a hand-driven transit micrometer with which excellent results were secured.

The Prussian Geodetic Institute put the Repsold hand-driven transit micrometer into use on portable instruments in making telegraphic longitude determinations in 1891, and has continued its use to the present time. In all, it has been used in ten longitude determinations.

Utilizing the published past experience with transit micrometers Mr. E. G. Fischer, chief of the Instrument Division, Coast and Geodetic Survey, designed and constructed in the winter of 1903–4 the transit micrometer which is before you, and which is adapted for use on the transits ordinarily used in longitude determinations.

It is a hand-driven transit micrometer. It is so well designed and constructed that in the extensive tests, to which I will refer in a moment, it never required the slightest change in adjustment, not even of the pressure of the contact spring, and not a single record was ever lost on account of any failure of the transit micrometer to operate properly.

A peculiar and important feature of this transit micrometer is an automatic switch which operates, without the slightest attention from the observer, in such a manner that a record is made on the chronograph for the middle four turns of the field, and for those turns only. This positively identifies those four turns, keeps the chronograph sheet clear, and enables the observer to practise following the star during the earlier part of its transit without affecting the chronograph sheet in any way.

In March, April and May, 1904, this instrument was tested by 75 time sets on 18 nights at the Coast and Geodetic Survey office. Sixteen observers took part in this test. The observers were purposely selected so as to include some with little or no experience in any kind of observation, some with long experience in astronomic observations and in handling various instruments of precision, and some of various grades between these two extremes. Two observers worked at the same time, observing alternate stars, and thus obtaining a determination of their relative personal equation. One of the sixteen observers was in the test continuously, became thoroughly accustomed to the instrument and method of observation, and served as an intermediary through which all the other observers could be compared with each other.

The tests show that for a practised observer with such a transit micrometer, the total error for a star, including errors which are constant for all the records as well as the accidental errors of bisection, is nearly the same for stars of all declinations if expressed in angular measurement. This is what should be expected if the errors concerned are of the same nature as if the object pointed upon were stationary instead of moving.

The accidental errors of bisection are nearly the same expressed in angular measure for stars of all declinations up to 59°, and are probably somewhat less for stars of greater declination. This is an indication that the accidental errors of bisection are of the same nature as if the image pointed upon were stationary, the indication being partly contradicted by the smaller errors for stars of declination greater than 58°.

Good observations can be secured at once with the transit micrometer without previous practise. Practise simply reduces the accidental errors by about 25 per cent. I feel that I may speak with assurance on this topic, for each of the sixteen observers was forced to begin observing on the first star that appeared in his field of view, with no previous experience whatever. This point is emphasized for the reason that I had been led to expect that long practise would be necessary before an observer could be sent to the field with a transit micrometer. The accidental error of a single record with the transit micrometer is about the same as that of a single record with a key.

During the first half of the tests the driving heads were geared to make one turn in $2^s.4$, when observing an equatorial star. During the last half of the tests the driving heads were geared to turn one half as fast, namely, one turn in $4^s.8$. This extreme change in speed produced surprisingly little effect on the accuracy of the result. With this instrument the speed of $4^s.8$ per turn, or possibly a slightly slower speed, is believed to be most favorable to accuracy.

The tests show that the relative personal equation between any two observers with the transit micrometer is so small as to be masked by the accidental errors of observation. This is equivalent to saying that it is probably less in every case than $^s.05$, and is, as a rule, much smaller than this. The relative personal equation with a transit micrometer is certainly not more than one tenth as large, upon an average, as with a key. This conclusion as to the relative personal equation applies to inexperienced as well as experienced observers.

The literature of the transit micrometer shows abundant corroboration of these conclusions as to the relative personal equation.

It is difficult to detect constant or systematic errors of any kind in transit micrometer observations. All the errors seem to belong to the accidental class.

This is far from being true of key observations.

The transit micrometer is about to be put into use in the regular longitude work of the Coast and Geodetic Survey.

I predict, basing my prediction upon the general experience with transit micrometers as well as on these particular tests, that with a transit micrometer three nights of observations without an exchange of observers will give as great accuracy as has been secured in the past from ten nights of observations with a key, including an exchange of observers. This is a prediction of which the truth or falsity can only be proved conclusively by field experience. I rely upon such experience to be gained within the next five years to verify the prediction.

I venture to predict also that the evidence in favor of the transit micrometer will accumulate to such an extent in the next ten years in fixed observatories, as well as with portable instruments, that the astronomer who uses a key in 1914 for accurate time determinations or determinations of right ascension will have difficulty in furnishing adequate explanation of his conduct.

An illustrated description of the Coast and Geodetic Survey transit micrometer, with a full report of the tests referred to above, and a brief résumé of a part of the literature of the transit micrometer, is now being printed as an appendix to the Coast and Geodetic Survey Report for 1904.

Remeasurement of the Hough Double Stars: ERIC DOOLITTLE.

The catalogues of new double stars published by Professor Hough comprise 622 pairs, of which 77 are closer than $\frac{1}{2}''$ and 143 closer than $1''$; in those pairs in which the distance is greater than $5''$ the companion is usually excessively faint; in fact, there are few of the stars which would not be difficult with a telescope of much less than 18 inches aperture.

The measurement of this fine series of doubles seems to have been strangely neglected. On a few of them, which are of the type of close pairs of equal magnitude, as 98, 260 and 296, there are a number of rather discordant measures, but the great majority have received no attention except from the discoverer himself. Thus there are but 87 pairs which have been measured in two different years, and on no less than 358 there is but a single prior measure.

The entire list was, therefore, added to the observing list for the 18-inch refractor of the Flower Observatory. Thus far, 360 pairs have been measured on three or more nights and many of the remaining 262 are partially measured; a single night's measure consists in each case of at least four measures of position angle and four of the double distance.

Change has been found in 16 of the close pairs, and among the wider ones there is in 33 instances indication of proper motion.

It is the intention, when the work is completed, to publish a catalogue of these stars, including about twenty new pairs which Professor Hough has discovered since his last list was issued.

A Study of the Driving-worms of Several Photographic Telescopes: EDWARD S. KING.

In following a star with a photographic telescope we must have for the period of the exposure a clock the hour hand of which will indicate the elapsed time on a scale graduated to seconds or less. We must have the equivalent of being able to determine the time by measuring the position of the hour hand with a micrometer. If any periodic error occurs in the train of the driving mechanism, causing the telescope to be first in advance of, and then behind, its proper position, the stellar images will be elongated into lines having a length dependent upon the amount of the oscillation. If the telescope follows the star only at one extremity of the oscillation, we shall have a series of images separated by trails, or, if the rate of the telescope is changed more, we shall have a trail with dark knots appearing at regular intervals. The number of the knots determines the frequency of the oscillation, and almost invariably indicates the driving-worm or endless screw as the offending member.

Such a periodic error, as shown by slide 1, is present in nearly all telescopes driven in this manner. This fact is not anything new, but has been recognized for years. The first example that I know of personally occurred in 1888 with the Boyden thirteen-inch telescope. In 1896 the director asked me to determine the periodic error of two of our photographic telescopes. Several series of measures were made of the eight-inch and the eleven-inch Draper telescopes. The method was to view a point of the tail-piece through a fixed microscope fitted with a micrometer. After each release of the detent by means of the signals given by hand, the position of the point was read and recorded. The reduction of these measures shows that the oscillation for the eight-inch Draper telescope was about 1 second, and for the eleven-inch Draper telescope about 0.2 second. These figures correspond to trails of less than 0.01 cm. on the plate. Within a few years Dr. Hartman has studied the periodic error of the Potsdam refractor and provided a very ingenious method of correction. A full account of his work will be found in the *Astronomische Nachrichten*, No. 3,769, page 2.

Nothing further was done here until the present year, when one of the small cameras was provided with a new mounting. The images proved to be lines lying in the direction of the clock's motion, and might, therefore, be affected by a periodic error. I proceeded to investigate the difficulty by a photographic method. The polar axis of the instrument was displaced in azimuth by a large amount. Such a displacement would cause equatorial stars, particularly when near the meridian, to move over the plate in declination. If an oscillation occurred, it would appear in the sinuous character of the trail. Slide 2, which is enlarged ten times from the original plate, shows the result, permitting no doubt as to the nature of the error. The numerous elongated objects are images of stars obtained on the same plate in the ordinary way. It is seen that the elongation of the images corresponds to the amplitude of the oscillation as exhibited by the vertical trail. The number of the oscillations was fifteen per hour, which fixes the responsibility upon the worm. A similar experiment made with a worm which had given satisfactory images is shown in slide 3. A slight irregularity is seen, but does not prove injurious. The same experiment made with the eleven-inch Draper telescope did not show anything definite, due probably to the smallness of the error. It is possible that it could be brought out by attaching an enlarging apparatus to the instrument and this will be tried soon.

The defective worm and several others were also tested visually. A telescope of about four feet focal length and having an eye-piece provided with a crosswire, was lashed to the camera and directed to a scale graduated to millimeters and placed at a distance. I was thus able to record the position of the telescope accurately. After every ten beats given by hand to the driving mechanism, the position was read for a period covering more than a revolution of the worm, which occurred in 240 seconds. The readings at the beginning and the end of the revolution determined the average rate from which were found the positions which the telescope should have occupied for the intermediate times. A comparison with the observed positions gave the periodic error. It was possible for the worm to be defective either in the thread itself or in the mounting. Rowland makes the remark that the correct mounting of a screw is more difficult than making the screw. It seemed to be so in the present case. If the screw was mounted eccentrically, we might expect a great improvement if it were allowed to engage only lightly with the R. A. wheel, being held in position by a strong spring. Slide 4 exhibits the resulting curves. It is seen that when the worm was adjusted to engage only lightly with the R. A. wheel, the oscillation extended through nearly eight seconds, but that, when brought into contact, the range was hardly two seconds. Thus the error of this particular worm was eccentricity.

A further test was made to determine if any intermediate adjustment of the worm with respect to the R. A. wheel would be advantageous. Slide 5 gives a set of curves for the various settings, beginning with the position in contact and ending with the worm very lightly engaged. Curve 1 is best and curve 3 is worst. That the position in contact is not always best is shown by slide 6, giving results for the worm that proved satisfactory. In this case the action was quite erratic when the worm was in contact.

A further test was made of the eleven-inch Draper telescope to determine the best adjustment of the worm with respect to the R. A. or sector wheel. Slide 1, which has already been seen, shows the appearance of the trails at what may be considered an average adjustment. In slide 8 we have the result when the worm is in contact, and in slide 9 when the position is adjusted to give the least error, found by trial. Probably in all instruments, one may, without any process of reconstruction, find by experiment where the periodic error is much decreased.

The foregoing has been in the nature of an abstract of an investigation in progress rather than a detailed account of work complete. It is possible that a careful study of curves representative of the action of the driving-worm will suggest an improvement in cutting the thread. As the experiments are easily made, I hope that other observers will test their instruments. A comparison of the results obtained with a greater variety of instruments would be of interest and might lead to a better understanding of the entire subject.

The Reflex Zenith Tube: C. L. Doolittle.

In 1851, or thereabout, the instrument having this designation was installed at Greenwich. The maker was Mr. Simons, the designer Mr. J. B. Airy. The immediate object in view was the observation of γ *Draconis,* a star which has been followed at Greenwich with some kind of zenith instrument since the time of Bradley.

The principle is briefly as follows: The telescope is fixed permanently, with its axis vertical as nearly as may be. Below the objective at a distance nearly half that of the focal length is placed a basin of mercury. The rays from a star at the zenith after passing through the objective, are reflected from the mercury surface and brought to a focus immediately in front of this objective. By means of a micrometer, the frame of which is firmly attached to the cell of the objective, with the plane of the reticule passing through the focus, the zenith distance of a star culminating within ten or fifteen minutes of the zenith may be measured. Finally a diagonal reflector brings the ray to the ocular, which is at right angles to the axis of the objective.

In practise the observation is made by bisecting the star, then quickly reversing by turning the objective with the micrometer attached through 180°, then making a second bisection. One half the difference of the micrometer readings will evidently be the measure of the star's zenith distance. Obviously both bisections can not be made with the star on the meridian. This makes necessary a small correction easily determined.

An instrument involving these principles has recently been installed at the Flower Observatory. So far as I am aware this is the second to be constructed. In detail, it differs in a number of particulars from the Greenwich instrument. The optical parts are by Brashear, and the instrumental parts by Warner and Swasey. The aperture of the objective is eight inches, the focal length one hundred inches. In the Greenwich instrument this cone of light after reflection passes a second time through the glass of the objective. In this case a hole one and one half inches in diameter is bored through the objective; through this hole a short tube passes, attached above to the micrometer box. When not in use this tube is closed by a shutter which presses up against its lower end, thus protecting the reticule from dust and moisture as completely as in the ordinary form of telescope. The construction may be likened to that of an ordinary telescope with the tube cut in two near the ocular, this end being passed through a hole through the middle of the objective.

Another matter of importance is this. It is evident that unless the plane of the reticule passes through one of the principal points of the objective, any change in the inclination of the apparatus will shift the zero point of the micrometer with respect to the vertical. This makes necessary a correction depending on the level readings—the very thing which we wish to avoid. For this purpose Dr. Hastings, who computed the curves of this objective, so designed it as to bring the first principal point in front of the upper surface, 0.155 inch. It was a simple matter to place the plane of the reticule at this same distance. These peculiarities introduced into the problem some technical and mechanical difficulties, all of which were successfully overcome, the optical performance being entirely satisfactory.

A solid cast-iron pillar, weighing several hundred pounds, formed the tube of the telescope. The focal adjustment is made by raising or lowering the mercury surface, this arrangement offering no difficulties.

As is usually the case with a new design, in part experimental, various unforeseen delays have occurred. All previous difficulties have apparently been overcome, and regular observations are now in progress. At present observations are carried on simultaneously with this instrument and the zenith telescope; four groups are employed as heretofore. In this program each group contains eight zenith stars to be observed with the reflex tube, and ten latitude pairs for the zenith telescope, with one wide pair for temperature investigation; the time required for these nineteen observations being on the average approximately two and one half hours. It is hoped that in the course of two or three years these observations may furnish data tending to throw light on a number of obscure problems.

The star γ *Cygni*, magnitude 2.5, culminates within less than one minute of the zenith of the instrument. Although at present it differs in right ascension from the sun by only $1^h\,30^m$, it is an easy object to observe. There will be no difficulty in following it during the greater part of the year. As an indication of the performance of the instrument the latitudes resulting from a preliminary reduction of the observations made on this star are here given.

1904, Dec.	6,	$\phi = 39°\ 58'\ 1''.83$
	7,	1.95
	8,	1.85
	9,	1.86
	13,	1.81
	14,	1.79
	16,	1.84
	18,	1.92
	31,	1.79
1905, Jan.	1,	2.00

Variations of the Bright Hydrogen Lines in Stellar Spectra: ANNIE J. CANNON.

Stars whose spectra are of the Orion type, having also one or more bright hydrogen lines, form a most interesting peculiar class whose position in the scheme of stellar evolution is enigmatical. The Harvard photographs show that the bright hydrogen lines are variables in the following six of these stars, *η Centauri, κ′ Apodis, υ Sagittarii, ε Capricorni,* J *Velorum* and 27 *Canis Majoris.* So far as known, no variation in the light of any of these stars has ever been observed, although the changes in their spectra point either to great atmospheric upheavals or to movements of two or more revolving bodies.

The most important changes in the spectrum of *η Centauri* may be summarized as follows: In 1897 all lines were dark and Hβ was nearly as intense as Hγ. In 1898 and 1899 Hβ was very faint and appeared as a dark line superposed on a faint bright band. In 1901 a most striking change had taken place, for Hβ had become a strong bright line, having considerable shift towards the violet when compared with the dark Hβ present in 1897. Hγ was dark with a bright band towards the violet. Photographs taken in 1902 recorded the reappearance of the dark line on the edge of greater wave-length of bright Hβ, and both lines were of moderate intensity. In 1903 the spectrum was similar to that of 1898. The period of these changes is probably several years in length.

The changes in the spectrum of *κ′ Apodis* are somewhat similar to those of *η Centauri.* It appears that both these stars are spectroscopic binaries, one component of each being a bright line star. The spectrum of *υ Sagittarii* presents another difficult spectroscopic problem, perhaps on the order of *β Lyræ.* The spectrum of *υ Sagittarii* always appears to be composite. The principal lines seem to be due to two bodies, one having a spectrum like *β Orionis* and the other like *ε Aurigæ.* The spectrum of *β Orionis* was strongly predominant on seven photographs, but frequently the two spectra seemed to be equally intermingled. Perhaps the most curious phenomenon is that on twenty-three photographs, on which the helium lines were very strong, those of hydrogen were unusually weak. Hβ was invisible, appearing neither as a line of emission nor of absorption, while line 4,922 was clearly seen. Hγ and Hδ were respectively much less intense than the adjacent helium lines at 4,387.8 and 4,120.5. It is possible that a third body, having bright hydrogen lines, might explain these appearances.

Eleven photographs of the spectrum of *ε Capricorni,* taken in 1903, showed Hβ to be a faint but distinct bright line lying on the edge of greater wave-length of an equally faint dark line. On earlier photographs, Hβ was dark and of varying intensity. Some faint lines, including several due to iron, are also subject to change in this spectrum.

It is possible that varying atmospheric conditions may account for the changes in the spectra of J *Velorum* and 27 *Canis Majoris.* On June 2, 1893, the dark Hβ and Hγ in J *Velorum* had a fine bright line superposed. In the spectrum of 27 *Canis Majoris,* bright hydrogen was present in March, 1890, April, 1895 and October, 1897. Numerous photographs of both these spectra on other dates showed all the lines to be wholly dark.

It is evident that a large field of investigation lies open to the spectroscopist among these bright-line stars.

Variable Stars in Large Nebulous Regions: HENRIETTA S. LEAVITT.

Since last March a special study of the distribution of groups of variable stars has been in progress at the Harvard College Observatory. As one result of this investigation, four hundred and fourteen new variables have been discovered and announced. Seventy-three of these are in Orion, one hundred and fifty-two in the Large Magellanic Cloud, fifty-seven in the Small Magellanic Cloud, one hundred and five in Scorpius, ten in Carina and seventeen in Sagittarius. The results of this study up to the present time may be summarized as follows:

First, as regards distribution, it has become evident that groups of variable stars are strongly localized. Of the ninety-nine confirmed variables at present known in the constellation of Orion, south of the equator, eighty-nine are within the limits of Bond's map of the region surrounding the Nebula of Orion, and of these all but four are found in less than half this area. The entire region thus finally limited is nebulous. The large number of variables discovered in the two Magellanic Clouds is in marked contrast with the small number found in the surrounding regions. The neighborhood of the Trifid Nebula in Sagittarius is noticeably poor in variable stars, and so also is the neighborhood of the nebula about η *Carinæ.* Yet these are two of the most densely crowded regions of the Milky Way. In Scorpius, after subtracting thirty-three variables which were found in the cluster Messier 4, there are still left more than four times as many variables as were found in an area in Sagittarius approximately equal in extent and far richer in stars.

Secondly, a certain order of brightness appears, on the whole, to prevail among the variable stars of each group, those in the central condensation of the Large Magellanic Cloud being the faintest, and those in Scorpius the brightest.

Finally, it is probable that different types of variability prevail in different regions. In both of the Magellanic Clouds, a large proportion of the variables appear to have very short periods, while in Scorpius the reverse may prove to be the case. Many of the variables in the Nebula of Orion remain faint during the greater part of the time, but occasionally show a striking increase of brightness. Whether these flashes of brilliancy occur regularly is not yet known.

The researches here described supplement the remarkable discovery by Professor Bailey, of large numbers of variable stars in clusters. They are similar to those carried on by Professor Wolf, of Heidelberg, who has announced lists of new variables in Orion, Aquila and Vulpecula. Evidently a further study of the distribution of groups of variable stars will be intensely interesting in its bearing upon the problems of stellar evolution.

Planetary Spectrograms: PERCIVAL LOWELL.

These spectrograms were made by Mr. V. M. Slipher and the lantern slides of them by Mr. C. O. Lampland, both of the Lowell Observatory staff, and were presented by the director, Professor Lowell.

1. Solar spectrum, photographed November 30, 1903—59 dark lines can easily be counted between G and Hγ.

2. Spectrum of ϵ *Pegasi,* photographed

September 20, 1904—exposure 2^h 15^m. Iron and chromium comparison spectrum. About 59 dark lines can be counted between G and Hγ.

3. Spectrum of Venus, photographed March 9, 1903. This is one of the set from which Mr. Slipher determined the rotation of the planet not to be of twenty-four hours or thereabouts, but very long—iron comparison spectrum.

4. Spectrum of Mars, photographed March 7, 1903—iron comparison spectrum. One of the plates of the set made on Mars by Mr. Slipher to test the measure of precision of the Venus set. The Mars plates gave 25^h 10^m $\pm$ for the planet's rotation. The true value is 24^h 37^m. As the precision possible on Mars is only half that possible for Venus the results speak for the decisiveness of the Venus set.

5. Spectrum of Jupiter, photographed November 21, 1903—iron comparison spectrum. The tilt of the lines shows a rotation in 9^h 50^m $\pm$, which is exactly the true rotation period as determined by Spots.

6. Spectrum of Saturn, ball and rings, photographed September 7, 1904, on a Cramer 'crown' plate—iron comparison spectrum. The tilt of the lines of the ball in one direction and that of the lines of the rings in the other are well shown, demonstrating that the rings are formed of discrete particles, as proved mathematically by Peirce in part and Clerk-Maxwell in whole and first shown spectroscopically by Keeler.

The spectroscope used in these researches was constructed by Brashear as powerful as possible, especially for the determination spectroscopically of the rotation period of Venus.

The Canals of Mars. An Investigation of Their Objectivity: Percival Lowell.

A new and striking proof of the objectivity of the double canals of Mars has recently come to me in a comparison of the width of the doubles obtained by Schiaparelli in 1888 and by me in 1903. The unintentional character of the corroboration is one of its strongest points. Not only at the time of my observations was his work not in my mind, but not even after the fact had I proposed to compare it.

The following table summarizes the results obtained in 1888 and in the May-June presentation of 1903.

CANALS DRAWN DOUBLE BY SCHIAPARELLI, 1888.

	Times Seen.	Width. °
Euphrates	4	5.1
Phison	4	3.9
Astaboras	3	2.9
Protonilus	4	2.2
Pierus	4	2.4

Canals drawn single by Schiaparelli: Astusapes, Python, Xenius, Rhysius, Apis, Typhon, Hiddekel, Callirrhoe, Deuteronilus.

Two canals, Arnon and Kison, were drawn convergent to the north.

CANALS DRAWN DOUBLE BY LOWELL, 1903.

	Times Seen.	Width. °
Euphrates	11	4 0
Phison	12	3.7
Astaboras	9	3.2
Protonilus	8	2.8
Pierus	2	2.1
Sitacus (faint)	12	3.6

Canals drawn single by Lowell: Astusapes, Python, Rhysius, Aroeris, Cadmus, Ægyptus. Hiddekel generally single, Callirrhoe generally a broad line.

Arnon sometimes convergent to the north, sometimes double. Kison suspicious of convergence to the north.

For both observers the direction of the canal had nothing to do with its single or double appearance.

The conspicuous doubles are the same in the drawings of both observers.

The conspicuous singles are the same in the drawings of both observers.

The Arnon and Kison are convergent in both and in the same direction.

Only the faint or very close doubles show differences at the two presentations.

The double canals, then, declare their own objectivity on three counts, each more compelling than the one before: (1) The fact of showing double, (2) the relative width of the double, (3) the absolute width of the double; and they do this precisely as a real object would, the certainty increasing with the ease of observation. The determination of the absolute width is very difficult, and here we find the probability for reality strong but not expressible; the relative width is easier to determine and the probability for reality is 24 to 1; lastly the determination of the fact of being double, the easiest observation of all, shows the probability that it is real to be 128 to 1.

Note on Three Solar Periods: FRANK H. BIGELOW.

The mean period of rotation of the solar photosphere at the equator is about 26.68 days, as determined by solar observations. There is a mean period of about 25.98 days indicated by terrestrial, magnetic and meteorological observations, which has been regarded as a period of solar rotation. The relative frequency of the solar prominences and the annual variations in the earth's atmosphere show that there is a short cycle of about 1,004 days. These are apparently related together by the equation,

$$\frac{1}{26.68}+\frac{1}{1004}=\frac{1}{25.98}\ \text{(approximately)}.$$

Some discussion is given of a possible physical cause for this condition, as found in the interior circulation of the sun's mass.

The Coordination of Visual and Photographic Star Magnitudes: JOHN A. PARKHURST.

The importance of stellar photometry among the departments of modern astronomy arises from the fact that the magnitude of a star bears immediately on the star's physical condition and changes. That this is of growing importance is witnessed, among other things, by the numerous discoveries of new variable stars, over three hundred in the present year; showing that variability must be reckoned with as a factor in stellar evolution to an extent that would not have been imagined a decade ago. The relation lately shown to exist between stellar variability and sunspot phenomena adds at once to the interest of the problem and the possibility of its solution.

The photometric catalogues published within the last few years by the Harvard and Potsdam observatories furnish a secure basis for visual photometry, their results agreeing reasonably well except the discordances arising from differences in the star colors. No such basis for photographic magnitudes now exists, therefore to be useful and intelligible, magnitudes must be reduced or reducible to the visual system. But the extension of photometric work demanded by the present needs of astronomy is possible only by photographic means; hence the pressing need of finding some method of harmonizing visual and photographic results for stars differing in type of spectrum and, therefore, in color. The usefulness of such a method will vary somewhat in proportion as it enables us to utilize the photographic magnitudes already obtained.

That the great accuracy of photographic methods applied to the astronomy of position has as yet no counterpart in the astronomy of magnitudes, is due to the one disturbing factor of star color. It is well known that a colored star will affect differently the eye and the photographic plate, but it is not so well appreciated that equal differences arise in the visual estimates of colored stars by different observers or by the use of telescopes of different apertures. The 'color correction' amounting to one or two magnitudes for a red star in the photograph, is no greater than the difference between the simultaneous Harvard and Rousdon visual estimates of the brightness of such stars. In fact, we find discrepancies of the same kind and similar in amount between different observers, different telescopes, visual and photographic results, and different brands of plates in photography. If the statement is made that no known relation exists between visual and photographic magnitudes, the retort can be made that a normal visual scale does not exist.

The advantages arising from the use of orthochromatic plates have long been recognized, but Scheiner dismisses them with the statement that they can never yield visual magnitudes. The suggestion was first (as far as I am aware) made by Schwarzschild that the difference between the magnitudes of a colored star on ordinary and orthochromatic plates can be taken as a measure of the star's color. If this difference is a function of the color it only remains to find the form of the function, and then complete allowance can be made for the effect of color and that troublesome factor can be eliminated, making possible the reduction of photographic magnitudes to visual, or *vice versa*. Two methods are available for finding the form of the function. First, by trial on known stars of different color (spectral type). To fix our ideas, suppose, for example, that a star of color 5 on Chandler's decimal scale was 7.0 magnitude visually, but photographed 8.0 magnitude on an orthochromatic plate and 9.0 magnitude on an ordinary plate. For such a star the orthochromatic plate gives half the color correction. It is evident that by such experiments with standard stars of known magnitude and color, the form of the function can be found. This work is being done by the writer, under a grant from the Carnegie Institution, using Cramer isochromatic plates in connection with ordinary plates, on the 24-inch reflecting telescope of the Yerkes Observatory. Provisional results thus far obtained are very promising. An independent method which will also be used for finding the form of the function, consists in comparing the intensity curves of the spectra of stars of different types with the intensity curves of the solar spectrum on the two kinds of plates used. It is evident that the photographic effect is the integral of the product of these two curves.

If the objection is urged that the difficulty of coordinating the results obtained with different brands of ordinary and orthochromatic plates, will be equal to the difficulty of harmonizing the visual and photographic systems, it may be met by the suggestion that any brands of plates used should be calibrated by observations of a carefully selected list of standard stars, including each spectral type.

No less important than the choice of plates is the kind of telescope to be used. It seems to the writer that the reflector is the only telescope suited for this work, since by it the rays of all wave-lengths are brought to the same focus.

Emphasis is needed on two further points in regard to the adaptability of the reflector to this work. When extreme ratios of aperture to focal length are avoided, first, the field is very nearly flat; second, the action is very rapid, so that the work can be extended to faint stars. This flatness of field has been denied, both from theoretical reasons and from so-called measures of reflector plates; but it should be stated that the theory is incomplete, not taking proper account of the distribution of light in the 'blurred' image; also that the measures published by Plummer and Poor were not made on the original negatives, and can not, therefore, be properly called measures. The only real measures so far published, to my knowledge, have been those of the Eros plates taken with the Crossley reflector, and measured at Columbia and Lick. A few of these measures discussed by Hinks showed distortions giving anomalous results near the edge of the plate, but these anomalies are matched on the plates taken at Algiers with the standard photographic refractor, and noticed on the following page of Hinks's paper. It should also be stated that the aperture ratio of the Crossley was large, about 1 to 6.

For this work a diaphragm twelve inches in diameter has been used on the 24-inch reflector, and as the focal length is 93 inches, the ratio is a little greater than 1 to 8. Allowing for the area cut out by the flat, the clear aperture of the mirror is equivalent to 10½ inches. The exposures have been timed to give good measurable images of all the stars on Hagen's charts which extend to twelfth or thirteenth magnitude; in good seeing this requires ten minutes with ordinary plates and fifteen minutes on the isochromatic plates. The magnitudes have been deduced by measurements of disk diameters, the increase per magnitude being nearly uniform and amounting to about 0.025 mm. As the diameters are measurable with a probable error of 0.001 mm., corresponding to 0.04 of a magnitude, the results are comparable with the best visual measures.

This work has some similarity to the spectral photometry of the Draper catalogue, each taking account of the intensity curve of the spectrum; but differs from it in two respects: It is not confined to the bright stars, but can reach to the faintest visible; also, taking account of the entire spectrum, its results will harmonize with visual magnitudes.

The Quadruple System of Alpha Geminorum: HEBER D. CURTIS.

The well-known binary star *α Geminorum* was pronounced by Sir John Herschel to be the largest and finest of the double stars in the northern portion of the sky. Measures, of a very rude character, were made of this pair as early as 1718 by Bradley and Pond, so that this system has been under observation for nearly two hundred years. In spite of this fact some of the elements of the orbit are still quite uncertain, particularly the eccentricity and the period. Values of the eccentricity have been derived, ranging from 0.32 to 0.80, with corresponding periods of 1,001 to 232 years. In recent years the distance between the two components has commenced to decrease, with the result that the elements have become rather more determinate, and Doberck (A. N., 3970) has recently expressed the hope that through this decrease in the distance it will be possible to fix the orbit with considerable accuracy within the next ten or twenty years.

Doberck has derived the following sets of elements, of which he regards the second as the most probable and most in agreement with recent measures.

Elements of Castor.

Ω	29° 29′	33° 56′	42° 34′
λ	84 44	82 26	118 11
i	73 3	63 37	61 56
e	0.7513	0.4409	0.2321
Period	268 years	347 years	502 years
T	1,936.65	1,969.82	1,963.30
a	7″.326	5″.756	6″.467

Retrograde.

In January, 1896, Belopolsky at Pulkova discovered that the fainter of the two stars forming this system is itself a rapid spectroscopic binary.* The period of this

* *Bull. Acad. St. Petersburg,* December, 1896. *Astrophysical Journal,* January, 1897. *Mem. Acad. St. Petersburg,* XI., 4, January, 1900.

component is very well determined, being close to 2.934 days. Belopolsky finds, however, certain irregularities in the observations of successive years which are best explained by the assumption that the line of apsides rotates in about 1,400 days.

Recent spectrograms taken with the remounted Mills spectrograph show that the brighter component is also a spectroscopic binary, and that the system of *α Geminorum* is in reality a quadruple one. Since the discovery of this interesting fact in November of this year a number of plates of both stars have been secured. At present fourteen plates are available for a rough preliminary determination of the period, which seems to be about 27 days. Two early plates of the bright component are rather poor, so that their value in determining the period is somewhat impaired and more plates will be necessary before a more accurate determination of the period can be derived.

Both stars are given in the Draper Catalogue as of type A, and in the later Harvard classification as type VIIIa. H *Gamma* is rather broad and has not been used in the measures. The line at λ 4,481 due to magnesium is very good and there are quite a number of other metallic lines, rather broad and quite faint in the spectrum of the brighter component, and somewhat easier of measurement in the fainter. Helium is apparently absent. There are a number of lines due to titanium and iron, most of the latter being enhanced lines; two lines seem to be due to chromium. With proper exposure (about sixteen minutes) from fifteen to twenty-five measurable lines are found. The total range in the radial velocity is about twenty-one kilometers, and the preliminary determination of the velocity of the center of mass of the system is approximately + 5 km. per second. The corresponding constant for the fainter component is given by Belopolsky in his latest paper as — 4.1 km. per second. It is well known that where the elements of the visual orbit of a binary and the relative radial velocities of its components are both known it is possible to derive an accurate value of its parallax. Assuming the relative radial velocity to be nine kilometers and using the period of 347 years and the corresponding elements which Doberck regards as the most probable, we find a parallax of 0″.03. Using the other orbits given above, however, we should get values differing widely from this. It is evident that such results are meaningless till the elements of the visual orbit are known more definitely.

In the star *α Geminorum* we have a well-established quadruple system, and it is hoped that the more detailed investigation which the writer has in progress will give a definite determination of the relative radial velocity of the two systems, so that with the improvement of the visual orbit we may in time have a relatively very exact knowledge of the distance, mass and orbital dimensions of this complex star.

Use of the Method of Least Squares to decide between Conflicting Hypotheses: Harold Jacoby.

In 1901 the writer published* a theorem concerning the application of least squares when it is necessary to choose between two different methods of reducing observations. The theorem was doubtless well known, but the writer was unable to find it in print. Since then, Mr. Midzuhara, of the Tokyo Astronomical Observatory, has written three interesting articles† in which, among other things, he gives a different proof of the writer's theorem, and also obtains another analogous one. The object of the present note is to point out a very important divergence between Mr. Midzu-

* *Astr. Jour.*, 514.

† *Astr. Jour.*, 521, 535, 568.

hara's conclusions and the writer's; and also to show how one of the former's most interesting results can be obtained in a manner different from that used by him.

The writer's theorem is: "Let there be given two series of observation equations as follows:

$$\left.\begin{aligned} a_1x + b_1y + c_1z + \dots + n_1 = 0, \\ a_2x + b_2y + c_2z + \dots + n_2 = 0, \end{aligned}\right\} (1)$$
$$\vdots \qquad \vdots$$
$$\left.\begin{aligned} a_1x + b_1y + c_1z + \dots + p_1w + \dots + n_1 = 0, \\ a_2x + b_2y + c_2z + \dots + p_2w + \dots + n_2 = 0, \end{aligned}\right\} (2)$$
$$\vdots \qquad \vdots$$

the equations being identical in the two series except for the addition of one or more new unknowns $w, \cdots$ in (2). Let each of these series of equations be solved by the method of least squares, and let: $[vv]_1$, be the sum of the squares of the residuals resulting from the solution of equations (1); $[vv]_2$, be the sum of the squares of the residuals resulting from the solution of equations (2); then, no matter what may be the law of the coefficients $p_1, p_2, \cdots$, and even if these coefficients are assigned at random, $[vv]_1$, is always larger than $[vv]_2$."

The conclusion drawn by the writer from this theorem is as follows:

"The method of least squares is used ordinarily to adjust series of observation equations so as to obtain the most probable values of the unknowns. But there is a subtler, and perhaps more important use of the method; when it is employed to decide which of two hypothetical theories has the greater probability of really being a law of nature; or to decide between two methods of reducing observations. In such cases, astronomers not infrequently give preference to the solution which brings out the smallest value of $[vv]$, the sum of the squared residuals. But in the light of the above theorem, it becomes clear that the mere diminution of $[vv]$ alone is insufficient to decide between two solutions, when one involves more unknowns than the other. To give preference to the second solution, it is necessary that the diminution of $[vv]$ be quite large, and that the additional unknowns possess a decided *a priori* probability of having a real existence."

In his paper in *Astr. Jour.*, 521, Mr. Midzuhara says: "This conclusion, perhaps, depends on the author's misapprehension of the principle of probability. For I believe that to compare the probabilities of the two solutions we must necessarily take

$$\frac{[vv]_1}{m-\mu_1} \text{ and } \frac{[vv]_2}{m-\mu_2}$$

where m expresses the number of observations, and μ_1 and μ_2 are the numbers of the unknown quantities in the first and second solutions, respectively."

In other words, Mr. Midzuhara takes as the criterion for deciding between the two solutions the quantity ordinarily called 'mean error of one equation,' instead of the sum of the squared residuals. When the number of unknowns in the two solutions is different, these two criteria may give opposite results; the one indicating the first solutions as the more probable, the other, the second solution.

It is evident that practise of astronomers varies in this matter. Mr. Midzuhara, for instance, and doubtless other astronomers, too, use $[vv]/m-\mu$ as the criterion. On the other hand, Bessel was in the habit of using $[vv]$. A good example is to be found in his classic paper on the parallax of 61 *Cygni*. He there* reduces his observations with parallax terms, and again without them. He decides in favor of the reality of his parallax terms solely on account of the diminution of $[vv]$; and not until after this is decided does he compute the mean error $\sqrt{[vv]/m-\mu}$. This quantity he calculates for the parallax solution only,

* *Astr. Nach.*, No. 366, p. 87.

not for both solutions. So far is he from using it as a criterion.

It would, indeed, appear that very simple reasoning indicates $[vv]$ as the right criterion. If we consider observation equations of the general form:

$$\phi(x, y, z, \ldots, n,) = 0,$$

the ordinary solution determines $x, y, z, \cdots$, so as to make $[vv]$ a minimum. If there exists a doubt as to whether the form of the function ϕ should be either ϕ_1 or ϕ_2, this fact simply transfers ϕ to the list of unknowns, and we must so determine $\phi, x, y, z, \cdots$, as to make $[vv]$ a minimum. We shall do this if we make two ordinary least squares solutions for ϕ_1 and ϕ_2, the only possible values of ϕ, and prefer that solution which gives the smaller $[vv]$. Since the other criterion may give an opposite result, that other criterion must be wrong.

It may be of interest to add to the above a remark concerning the attractive result obtained by Mr. Midzuhara in his equation (13).* This result is:

$$[vv]_1 - [vv]_2 = w^2 P_w, \qquad (13)$$

where w is the value of the new unknown, obtained in the solution of our equations (2) and P_w its weight from the same solution. Mr. Midzuhara gives a somewhat extended demonstration of this equation (13); it may, however, be obtained almost directly from a principle demonstrated by Gauss in 'Elementis Ellipticis Palladis.'† It is there shown that if μ be the number of unknowns, and if the normal equations are solved by the Gaussian method of elimination:

$$[vv] = [nn \cdot \mu],$$

where $[nn \cdot \mu]$ denotes the usual Gaussian auxiliary. In the present case, if there are μ unknowns in equations (1), and $\mu + 1$ in equations (2), we shall have, at the end of our Gaussian elimination:

$$\begin{array}{l} [pp \cdot \mu]w + [pn \cdot \mu] = 0, \\ \qquad\qquad\;\; [nn \cdot \mu] \\ \qquad\qquad\;\; [nn \cdot (\mu + 1)]. \end{array}$$

But, according to Gauss's principle:

$$[nn \cdot \mu] = [vv]_1,$$
$$[nn \cdot (\mu + 1)] = [vv]_2,$$

and, as usual:

$$[nn \cdot (\mu + 1)] = [nn \cdot \mu] - \frac{[pn \cdot \mu]^2}{[pp \cdot \mu]}.$$

Therefore:

$$[vv]_1 - [vv]_2 = \frac{[pn \cdot \mu]^2}{[pp \cdot \mu]}.$$

But:

$$w = -\frac{[pn \cdot \mu]}{[pp \cdot \mu]},$$

and:

$$[pp \cdot \mu] = P_w = \text{weight of } w,$$

so that:

$$[vv]_1 - [vv]_2 = w^2 P_w.$$

This is Mr. Midzuhara's equation (13).

* *Astr. Jour.*, 568.

† 'Werke,' Vol. 6, p. 22.

Tables for the Reduction of Astronomical Photographs: HAROLD JACOBY.

In 1895 the writer published a paper entitled 'On the Reduction of Stellar Photographs, with Special Reference to the Astro-Photographic Catalogue Plates.'* As indicated in the title, the method there described was intended primarily for the reduction of large series of plates made at the same declination. But ordinary stellar photographs intended for star-cluster catalogues, solar or stellar parallax, etc., usually involve so few plates of a single declination that it is not economical to prepare the kind of special tables suitable for a photographic catalogue of the whole heavens. Moreover, Contribution 10 of the Columbia Observatory has long been out of print, so that it is now impossible to supply copies to those asking for them.

*'Contrib. from the Obs. of Columbia Coll.' No. 10; and in French, *Bull. Com. Perm.*, Tome III.

For these reasons, the writer has prepared the present modification of his method, and has added tables suitable for the reduction of isolated groups of plates made at any declination distant more than 15° from the pole.

The tables will appear in a short time as one of the Columbia 'Contributions.'

Recent Researches of the Henry Draper Memorial: EDWARD C. PICKERING.

A photograph was shown of the spectrum of λ *Cephei,* which has a spectrum closely resembling that of ζ *Puppis* and contains the second series of lines probably due to hydrogen. A method of observing occultations photographically was explained and a printed enlargement of a photograph of the emersion of η *Virginis,* on December 28, 1904, was shown, which had been taken by Mr. Edward S. King. A rotary motion was given to the plate-holder so that the star gave a continuous trail, the time being indicated by a motion given to the plate at regular intervals. It appeared that the star increased in light during emersion for about a third of a second. The principal portion of the paper was devoted to the study of the distribution of the stars according to their spectra. The results were based upon an examination of the Draper plates by Mrs. Fleming. About 6,000 plates have been inspected, each showing on the average the spectra of a thousand stars, with small dispersion, and on these all that were peculiar were noted. Using a larger dispersion, about thirty thousand stars have been classified and catalogued. Visual counts of the number of stars in different parts of the sky have little value owing to the uncertainty of the magnitudes. The same might be said of a classification of photometric magnitudes of the stars taken as a whole. It was shown that stars of each class of spectrum should be considered by themselves, as the distribution differs widely. Thus, the Milky Way appears to consist wholly of stars of the first type. The helium or Orion stars have a different distribution, forming a Milky Way of their own, mainly in Orion and Argus. It was shown that the classification of the variable stars, proposed by the writer in 1880, was confirmed by their spectra, and that the latter formed a means of determining the class, in some cases, even better than the light curve.

Note on Two Variable Star Catalogues: J. G. HAGEN.

Father Hagen presented to the meeting some specimen pages of two Catalogues of Variable Stars, now in preparation, one by the Astronomische Gesellschaft and the other by Professor E. C. Pickering. Of the former catalogue seven pages had been printed for presentation at the astronomical congress in Lund, last September. A copy had been sent to Father Hagen in time for the Philadelphia meeting, but Dr. Mueller's report at Lund came, unfortunately, too late. For this reason only those features of the catalogue could be mentioned that presented themselves to the reader of these seven pages.

More definite explanations could be given on the other catalogue, since Professor Pickering was himself present, and had shown one specimen page previously to several friends. His catalogue will be a 'Bibliography of the Variable Stars,' with the lists of the known maxima and minima, and the sources from which they were taken. Father Hagen brought out the fact that the two catalogues will supplement one another. The catalogue of the Astronomische Gesellschaft will give exact positions and elements of light variations, with very condensed references to all accessible publications, on each variable star. Professor Pickering's 'Bibliography' will give fuller details of the spectra of the variables stars from the rich material at the Harvard College Observatory, and will put the lists of known maxima and minima in the convenient shape of tables. While the former catalogue will make a volume of about 500 pages (quarto size), the latter will only have one third of this bulk. Both catalogues will be a very valuable accession to our literature on this subject.

Useful Work for a Small Equatorial—A Proposed Discussion.

The discussion was opened by Professor Edward C. Pickering. He stated that measurements of wide double stars might be useful, but that the positions of stars much more than 5″ apart could be better determined by photography, while closer stars required a large telescope. The brightness of stars can now be readily and inexpensively determined with a wedge photometer, and the relative light of the components of close doubles by a polarizing photometer. The Herschel-Argelander method could be usefully applied to faint stars, especially to the components of coarse clusters, and to Durchmusterung zones, inserting all stars brighter than a fixed magnitude. Variable stars of long period can be usefully followed by inexperienced observers, since the range is large. Observations of suspected variables, of Algol, and other short period variables, are likely to be of little value, except when made by observers having long experience. But little useful work could be done with spectroscopes attached to small telescopes. A search for new stars in the Milky Way, and an examination of known nebulæ to see if they are gaseous, as was, perhaps, first done by Col. John Herschel, might prove of value. Observations of Jupiter's satellites, comets, sunspots and solar prominences were also mentioned as useful fields of work for instruments of this class.

Frank B. Littell,
For the Council.

SCIENTIFIC BOOKS.

Die Moore der Schweiz, mit Berücksichtigung der gesamten Moorfrage. Von Dr. J. Früh und Dr. C. Schröter. (Beiträge zur Geologie der Schweiz, herausgegeben von der geologischen Kommission der Schweiz, naturforschenden Gesellschaft, geotechnische Serie, III Lieferung.) Bern, 1904. 4°, pp. xviii + 751. 45 text-cuts, 4 plates and a map.

Probably every person seriously interested in peat-bogs (or, as we may better call them, peat-moors), whether it be from a geological, a phyto-ecological or an economic standpoint, has known that the present work was in preparation and has eagerly anticipated its appearance. The authors are well known as among the foremost authorities upon the subject, and their work now before us fully satisfies our high expectations. While primarily devoted to the study of the Swiss moors, the authors nevertheless discuss every question also from the general or world standpoint, so that the work as a whole is in reality a study of peat-moors based upon those of Switzerland as types. It is divided into two parts, a first devoted to Moor-questions in general (435 pages), and a second given to a systematic description of those of Switzerland (310 pages). Under the first part is discussed, the general nature and place of moors, peat-building plant-groups (a modern ecological study), peat and its nature, geology of moors, geographical distribution of moors, a geomorphological classification of the moors of the world, nomenclature in relation to physical features, agricultural conditions of the Swiss moors, post-glacial vegetation history and its reconstruction through moors. Every chapter is characterized by exhaustive but clear treatment, by copious citation of literature, including that of this country, and by appropriate illustration. Among the illustrations are many of those diagrammatic vegetation cuts now coming into vogue in ecological works, while the plates include two typical photographic moor-scenes, of which we could wish there were many more. It is impossible here to particularize farther, and it must suffice to say that this work is incomparably the