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PHOTOGRAPHIC ASTROMETRY WITH LONG FOCUS TELESCOPES.

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In choosing this subject for my address, I have placed myself between the upper and nether millstones. The astronomers present are no doubt already familiar with much that will be said. The amateurs, on the other hand, are—as such—more or less excluded from direct experience in the field of astrometry because of the specialized equipment required and especially in astrometry with long focus telescopes, because these are only available at established observatories. I trust the former will bear with me and that the latter—who are probably more interested in the results than in the methods of obtaining them—may gain some appreciation of the difficulties that beset precise astronomical measurement.

The emphasis in any science changes from time to time. In astronomy the pendulum has swung in the last generation away from the fundamental astronomy of position toward the physical and chemical aspects of the celestial bodies. More recently still it has moved in the direction of philosophical generalizations of the universe as a whole. It is well that this is so, as our horizons have been materially widened thereby. But the astrophysicist and the philosopher have been compelled to use astrometrical data in fashioning the bricks from which they construct their edifices. So, while astrometry may have yielded pride of place, its sun has by no means set.

In confining my remarks to astrometrical work with long focus telescopes, it is with a desire so to limit my subject as to keep within reasonable bounds. In passing, tribute must be paid to the long line of devoted astronomers who have paved the way for modern astrometry by means of fundamental work with the meridian circle and the heliometer, by the application of photography to astronomy, etc., in all of which the Cape Observatory has had a conspicuous and honourable part.

The first celestial photograph was taken by William C. Bond in 1850, when he was Director of the Harvard Observatory. This was an old-fashioned daguerrotype, whose usefulness was limited by its comparative insensitiveness. Later the wet collodion process provided the means of some advancement. But it was not until the invention of the dry plate that the era of photometric astrometry really began. The first application of photography to the cataloguing of the positions of stars was the Cape Photographic Durchmusterung, begun nearly fifty years ago. Later developments have been the Astrographic Catalogues and the Carte du Ciel. Recently, owing to the initiative of Dr. Schlesinger in experimenting with cameras of large field, repetitions of these projects are going forward at various observatories, the Cape Observatory again doing its share. This type of astrometric work is necessarily done with instruments of relatively short focus because of the necessity for covering large areas of the sky. The long focus telescope, with its restricted field, is perforce limited to other lines of investigation.

A celestial photograph is the projection upon the plate of a portion of the celestial sphere. The amount of light falling on the plate from a point source—such as a star—is proportional to the area of the lens which determines its light gathering power. The scale of the plate is determined by the focal length of the lens. The two are inter-related to some extent, as the difficulty of making a large lens which will give undistorted images over a wide field is very great. The familiar hand camera usually covers a field whose diagonal is roughly equal to the focal length of the lens. Granted that we could obtain the same angular field with our large telescopes, the plates would become unwieldy and the mounting of the instrument would tax our ingenuity. The long focus telescope therefore usually uses a plate whose diagonal is of the order of one-thirtieth to one-sixtieth of its focal length. This gives a very restricted field, usually of the order of one square degree or less. In such an area there are relatively few bright stars. On the average only half the plates taken at random over the sky would show a star as bright as the eighth photographic magnitude. Thus measures of the positions of objects on such plates yield only differential or relative positions. Absolute positions can be obtained only when the positions of at least three stars appearing on the plate are known. This is seldom the case with the degree of accuracy obtainable from the plate measures.

While dealing mainly with the refractor, most of the following remarks are applicable to the reflector as well. However, the latter instrument is not so well suited to astrometric work because of the coma which affects the estimation of the position of a star only a short distance from the axis of the instrument. The reflector possesses many advantages, such as great light-gathering power for a given weight, and freedom from chromatic aberration. But these find their greatest usefulness in other lines of investigation.

As already stated, the scale of the plate depends on the focal length of the lens. With three or four exposures on a plate the position of a star with respect to several nearby stars can be found with an accuracy of the order of one micron, *i.e.*, 0.001 millimeter. This linear distance on the plate corresponds to an angular separation of from 0.″01 to 0.″03 for telescopes of the type with which we are concerned. It might seem that the accuracy in seconds of arc obtainable should be directly proportional to the focal length of the lens. But this is not strictly true. The size of the smallest well-blackened images is also to some extent a function of the focal length, thus affecting the relative accuracy of the measures with the larger instruments. Various disturbances which have a given angular value are much more serious in the case of the longer telescopes.

Consider for instance a ray of light or a bundle of rays which pass through a portion of the lens which may be slightly imperfect. They are deviated from the normal cone of rays by a given angular amount. In a telescope of one meter focus this deviation might not be serious. In one ten times as long they would distort the image if they constituted any great percentage of the total light. Thus the position of a bright star might be shifted relative to a faint star owing to the anomalous rays being too weak to register in the latter. This has been tested by Dr. Knox-Shaw by taking two photographs of the same region, one with the telescope on each side of the pier. This reverses the effect in right ascension and a comparison of the measures of the plate reveals the quantitative amount.

Thus the first requirement for accurate astrometric work is a lens of the greatest possible perfection.

There are other causes operating to displace the rays of light which pass through the lens in whole or in part. One of these, which is beyond our control, is due to atmospheric disturbances. The light reaching the lens has passed through many miles of air, consisting of layers of different densities more or less in motion relative to the telescope. Within the atmosphere are also eddies and local condensations which affect the path of the light rays. They produce angular deviations from the mean position of the star, which are more serious in the case of the larger telescopes.

If these regions of inequality in the atmosphere are sufficiently small they may affect only a portion of the light reaching the lens, thus rendering it incapable of bringing all the rays to a focus at the same point. The image is no longer a point but an area of constantly changing size and position. This characteristic of the atmosphere is usually referred to as the "seeing." With a small lens the bundle of rays passing through it may be homogeneous and the seeing good, while with a large lens at the same location the inequalities become apparent and the seeing may appear much inferior.

When the atmospheric disturbances are such that all the rays reaching a large lens are disturbed together we may have a sharp image, which undergoes continual migrations about the mean position. This condition is referred to as the "steadiness." Again the long focus instrument is affected to a greater degree. The steadiness and seeing are closely related, but in exceptional cases one may be quite good and the other relatively poor.

Since we have no control over these atmospheric conditions, our only course is to choose for a large instrument that location which will provide the best average conditions. And, since the large telescope and its housing represent a large capital outlay, on which it is desired to obtain as many dividends as possible, the site is also to be chosen where the maximum number of clear night hours throughout the year are available. Other factors may affect this choice, such as the availability of water and electric power supply, but these are secondary.

It is on account of the climatic conditions outlined above that South Africa is becoming the Mecca for those wishing to establish large telescopes for observation of the southern skies.

But even though a perfect lens were placed in a perfect climate its performance might be adversely affected were the equatorial mounting necessary to counteract the rotation of the earth not such as to permit the accurate following of the stars during the exposure. Engineering ingenuity is taxed to its fullest to provide the necessary precision combined with the requisite rigidity without undue and unwieldy weight. No machinery is accurate enough to permit anything but instantaneous photographs with a long focus telescope without supplementary guiding. All large telescopes are provided with means by which the instrument may be shifted small angular amounts in each co-ordinate in order to keep the stars at rest relative to the photographic plate during exposure. But with the larger instruments even this does not suffice because of the small and rapid corrections required and the inertia of the large mounting.

This is usually overcome by a device originally suggested by Dr. Common. The plate holder and the guiding eyepiece, which views a star either in the field of the large lens, or an auxiliary lens of the same focal length placed alongside the larger one, are mounted on guiding ways at right angles to each other and movable by screws conveniently placed. This double slide arrangement not only permits the correction of the irregularities in the driving mechanism and the major long period fluctuations of the star images, but also to some extent, depending on the mobility of the parts and the skill of the observer, the neutralization of the more rapid fluctuations due to atmospheric disturbances.

Ritchey states that with the 40-inch Yerkes refractor, which, owing to its focal length of over 62 feet, renders small displacements visible, many hundreds of corrections per minute would be necessary to keep a star stationary relative to the plate. He states* that a skilled observer is able to introduce between one and two hundred corrections per minute when necessary. Such an instrument needs the best climatic conditions to realize its full possibilities.

Having considered the lens and its mounting, we come to the light-sensitive emulsion which records it. Plates are used because the glass on which the emulsion is coated forms a fixed base to keep the emulsion undistorted during and after development. It is remarkable that the errors due to irregularities in the distribution of silver grains in the emulsion and other causes within the plate itself are so small even for commercial products where these refinements are not required. In any case these errors if present are accidental in character and do not introduce the systematic errors which are so much more serious in vitiating our measures.

The ordinary photographic plate however is only slightly sensitive to the light which affects the human eye. If therefore we attempt photographic work with a visual telescope it is

*Publication of the Yerkes Observatory, Vol. II., p. 390.

necessary to use special colour-sensitive plates and at the same time to screen off other rays to which the plate is sensitive, but which are not properly focussed by the visual lens. This prolongs the exposure over that required with a photographic telescope in the ratio of from five to ten times, depending upon the materials employed. Photo-visual plates possess some advantages, as the relative intensities of star-images on such plates approximate to the relative visual brightness of the stars. They use a relatively narrow spectral range, with a strong central maximum, so that they give an approximation to monochromatic light. Thus differential atmospheric dispersion effects due to differences in effective wave-length are largely eliminated, since all stars are photographed in light of the same colour. Furthermore, stars of all spectral types send us light within the range of wave-length used. This is not the case with the photographic lens and the ordinary plate. For stars of spectral type K, M, N, and R are deficient in light of the shorter wave-lengths and images of such stars are displaced on photographs taken at large zenith distances relative to the images of stars of other types owing to the atmospheric dispersion. These differential displacements can be quantitatively determined and applied if necessary when the spectral types of the stars are known.

It would be possible, by the introduction of additional components in the lens, to eliminate the chromatic aberration altogether or reduce it to a minimum. But the cost of such lenses and the added weight involved have prevented their use on large instruments. Hence we are usually forced to choose between the visual and the photographic lens. In spite of some of the disadvantages of the latter type, it is frequently preferred because of the gain in speed which allows of the more rapid accumulation of observational material.

Attempts have been made to introduce correcting lenses into the cone of light from the visual lens in order to focus the actinic light. Theoretically this is possible, but practical difficulties have nullified such attempts, especially where large fields are required.

It has been stated that the accuracy obtainable on a plate with several exposures is of the order of 0.″01 to 0.″03 depending on the focal length of the telescope. By taking a number of such plates we can determine the position of an object at a given time with any reasonable accuracy desired. In order to illustrate the meaning of small angles of this size it might be stated that 0.″01 is the angle subtended by one inch at a distance of 325 miles. It would represent only six feet at the moon, four and a half miles at the sun, and one astronomical unit at a distance of 326 light-years or 2,000,000,000,000,000 miles. To what investigations shall we apply this great accuracy?

The photographic plate is a fairly permanent record of the relative positions of the stars at the time of exposure. It naturally occurs to one that by preserving this record for some years and comparing it with a similar plate taken with the same telescope on the same region at a later date, the relative motions of the individual stars may be obtained. The accuracy of such determinations of relative proper motions is limited only by the number of plates taken at each epoch and the interval one is willing to wait before repeating the plates. To attempt the measurement of these motions over any great portion of the celestial sphere would prove a colossal task. Hence investigations of this character are limited to regions of special interest or to the fields of certain selected areas in the programme initiated by Kapteyn, which are assumed to give a good representation of the average for similar stars throughout the remainder of the sky.

Naturally it was expected that an accuracy of this degree would prove useful in the measurement of stellar parallaxes. To deal adequately with this phase of the subject would occupy a whole hour and only the high spots can be touched upon. Beginning with experiments in the photographic determination of stellar parallaxes by Pritchard at Oxford, the attempts by Kapteyn to derive wholesale parallaxes of all stars on the plate and the work of Russell and Hinks at Cambridge we find successive improvements in methods and in accuracy. An increasing appreciation also of the difficulties arising from the systematic effects of diurnal and annual variations upon the parallaxes arose and suggestions were made for their elimination or nullification.

The modern era in parallax determination by photography begins however with the work of Schlesinger with the Yerkes refractor from 1903-05. The methods there used have formed the basis on which all later work has been founded. In the last quarter of a century many of the largest telescopes in the world have been devoted to carrying on this line of investigation, of which the Allegheny and McCormick telescopes have been the most fruitful. All of these instruments were in the northern hemisphere however and the area south of —30° declination was untouched by the photographic method with long focus instruments. With the establishment of the Yale 26-inch refractor at Johannesburg in 1925 and the beginning of parallax work with the Victoria telescope at the Cape about the same time, parallax data are now being accumulated in the southern hemisphere even more rapidly than in the northern.

With all our foresight in avoiding sources of systematic error we still find systematic differences present in the results, but these are for the most part relegated to the third decimal place in seconds of arc. But, owing to the great distances of the stars, even the thousandth of a second of arc becomes important. Fortunately other methods, based on the assumption that stars throughout space have the same physical characteristics as those of the same spectral type nearby, have been developed, which enable us to penetrate deeper into space than is possible by the trigonometrical method with the comparatively short base line provided by the earth's orbit about the sun. These methods must be calibrated by means of the trigonometrical parallaxes, however, so that any gain in the latter serves as a corresponding gain in the former.

Other uses for the large scale photograph are for the determinations of the absolute positions of selected objects, such as Eros. As already stated, the positions of some reference stars on the plate must be known. But these are never known with an accuracy approaching that obtainable from the measures, so that the positions thus obtained are never more precise than the mean of the positions on which they are based.

Telescopes of this kind have been used in photographing the relative positions of the satellites of various planets; in this field the photographic measures exceed in accuracy those made visually with telescopes of the same focal length, as is nearly always the case where photographic methods are applicable.

Various observers have applied the long focus telescope to the photographic measurement of double stars, of which the work of Hertzsprung at Potsdam is by far the most thorough study. Considerable gain in accuracy over the visual measures is obtained, but unfortunately the photographic observations are limited to the wider pairs owing to the finite size of the star images. But the suitability of the photographic plate for the measurement of larger intervals than are possible with the filar micrometer, with little or no loss in precision, is useful in the observation of the wider pairs and in determinations of the ratio of the masses of the components of a double by determining their individual motions with reference to other stars in the field. It is to be hoped that the use of the long focus telescope will be extended in this direction, as it is our only source of information with regard to the masses of individual stars. The observation of the orbital motions of the components of binary stars would also lead to refinements in the orbital elements. It would be desirable if large telescopes could devote a part of their time to researches of this kind over relatively long periods of time.

Other lines of investigation made possible by the accuracy of the photographic method might be mentioned, but they are not of general application such as those mentioned above.

In conclusion, it must be pointed out that astrometry is not an end in itself. The parallax of a single star is of little value—unless it is the only measure in existence—and the same applies to the motion of the star. It is incumbent upon us to shape our programmes so that they will prove most useful in enabling us to draw reliable conclusions regarding the present distribution of the stars in the universe and their motions, systematic and individual. Only thus can we provide the cosmical physicist and the cosmologist with the necessary data on which to found their conclusions as to the present state of the universe and the possible course of its past history and future development.

TRANSIT OBSERVING AND PERSONAL EQUATION.

By the late W. H. Cox.

The term Personal Equation is employed to denote systematic errors in observing which originate in the observer, in distinction from those that arise from instrumental and atmospheric conditions. In this article a short account will be given of its discovery and of some of the methods for overcoming it. For a proper understanding of this it is necessary to give some account of transit observing.

One of the chief duties of certain Observatories is to determine the instants of meridian passage of the heavenly bodies. On this depends the keeping of true time, and in this very process the personal equation is involved. The instrument for making these observations is called the "Transit Instrument." It is not necessary to give here a description of this instrument. That is fully done in most text-books; it will suffice to say that it is a telescope mounted on an East and West axis and turning in the plane of the meridian. In the focal plane of the instrument is a set of fine parallel wires (spider webs), five or more in number. These wires are mounted on a rectangular frame. Through one end of the frame passes a screw, by which the whole system of wires may be moved. The screw terminates, outside the instrument, in a micrometer head, by means of which the wires may be adjusted so that the middle wire lies in the meridian. Generally the micrometer head is boxed in to prevent accidental movement during the observations. As the image of the star moves across the field the instant of its bisection by each of the wires is taken, and the average of the times, provided the intervals between the wires are equal or the inequalities are known, gives the time of bisection by the central wire with much less liability to accidental error than if that wire had been used alone.

At the time of the first notice of personal equation the method of fixing the time when the star crossed a wire was that of Bradley or, as it is generally called, the "eye and ear" method. When the star is about to transit, the observer picks up the second from his clock, and as he watches the star in the telescope continues to count the second beats. He makes a mental picture of the position of the moving image at the last beat before it crosses a wire and the first after, and from the distance of these two points from the wire, estimates by the eye the time of crossing in tenths of a second. Though this may seem quite simple, a great deal of training is necessary to become proficient. A few astronomers were accustomed to estimate the fractional part of a second directly by ear; that is, they treated the passage of the wire as a sudden event like an occultation. But this was generally regarded as a poor method.

Although Bradley (Astronomer Royal 1742-1765) initiated the "eye and ear" method, he made little attempt to subdivide the second, and usually took the time to the nearest second, sometimes estimating in terms of the half or third of a second, and again at others marking the second with a + or a — to indicate that the true time exceeded or fell short of the time recorded. On 29th September, 1755, an observation of Castor is recorded thus:—

h	*m*	*s*
7	18	49½
	19	35 —
	20	20½
	21	6 +
	21	51½

The low magnifying power of his eyepiece gave to the star such a small apparent motion in one second that subdivision was difficult. Also, except for planets and the standard stars he was generally content to take the time of transit over the meridian wire only. Notwithstanding these drawbacks his results are wonderfully good, and his catalogue of over 3,000 star-positions for the year 1755 forms the basis of most of our knowledge as to the actual movements of individual stars.

Another thing about this transit of Bradley's that strikes the modern observer is the long interval between the wires. Transit observing with such intervals must have been terribly monotonous. It may be that this had something to do with Bradley's liking for a single wire observation. Those who have read the account of his discoveries of Aberration and Nutation will know that he was a man of many activities, and possibly he grudged the time required for observing all stars over 5 wires at such long intervals. Still the same, or nearly the same, wire intervals were used by his successors for many years. The wires of those days were made of fine silver wire about 1/750 inch in diameter. The diameter of a spider's web is less than one-third of that amount. From whatever delicate material the wires are made, once they are fixed there is an aversion to interfering with them, not because the astronomer is nervous about handling them, but because the slightest change in their position entails a considerable amount of extra observing and computation. But accidents sometimes happen, and in looking through the Greenwich volumes I found a note of one on the 11th July, 1812, which proved particularly fortunate. On that date, the note says, the horizontal and 4 vertical wires were found broken. This was practically a clean sweep and the opportunity was taken to place the new wires at intervals of about one-half of those of the old. This must have been a great boon to the observers. Many years later the interval was still further reduced to about 14^s for an equatorial star. Now-a-days 10^s to 12^s is considered sufficient.

Bradley's successor, Maskelyne (A.R., 1765—1811), after overhauling the instruments and obtaining higher power eye-pieces, introduced the practice of observing all objects over 5 wires, and subdividing the second. At the beginning of his career he divided the second into eight parts, but from September 1772 his times are all recorded to tenths of a second, and he made a long series of observations which compare very favourably with the best observations of the present time made by the same method. It was this improvement in transit observing that led to the first record of a persistent personal difference between the observations of experienced observers. About 1795 Maskelyne noticed such a difference between himself and his assistant. Towards the end of the third volume of his Greenwich observations he writes:—

"I think it necessary to mention that my assistant, Mr. "David Kinnebrook, who has observed the transit of stars and "planets very well in agreement with me all the year 1794, and "for the greater part of the present year, began from the be- "ginning of August last to set them down half a second of "time later than he should do according to my observations; "and, in January of the succeeding year, 1796, he increased "his error to eight-tenths of a second. As he had unfortunately "continued a considerable time in this error before I noticed "it, and did not seem to me likely ever to get over it and return "to a right method of observing, therefore, though with reluct- "ance, as he was a diligent and useful assistant to me in other "respects, I parted with him.

"The error was discovered from the daily rate of the clock "deduced from a star observed on one of two days by him and "on the other by myself, coming out different from what it did "from another star observed both days by the same person, "either him or myself.

"I cannot persuade myself that my late assistant continued "in the use of this excellent method (Bradley's) of observing, "but rather suppose he fell into some irregular and confused "method of his own, as I do not see how he could have otherwise "committed such gross error."

Thus Maskelyne had an important discovery within his grasp, but failed to realize the significance of the difference between the two observers, for he goes on to say that with care no observation of a single wire should be more than two-tenths of a second from the *truth* and that of course the mean of 5 wires would have a much smaller error.

Consequently this germ of a discovery lay dormant for 20 years, until it was brought to the notice of Bessel, a distinguished German astronomer, who became desirous to know whether such a difference could be found between other pairs of observers. He had not far to search, for he found that he himself differed considerably from other observers and from Argelander by as much as one and one-quarter seconds. It would be wearisome to relate the numerous comparisons and investigations carried out by Bessel; it will be sufficient to give the general conclusions to which they led. In brief, they were: The fact of personal equation was established; its spontaneous variation in considerable periods of time; and its artificial change, for himself at least, with change of clock beat and from transits to sudden phenomena; and that up to declination 60° the rate of motion had no influence.

It was a fortunate coincidence for the knowledge of the subject that the discoverer of the personal equation should himself have had so large a one. But its very size has provoked incredulity. It seems almost impossible that two practiced astronomers observing the transit of a star with a clock beating seconds could differ by a whole beat and a quarter, and it has been suggested that Bessel differed a second from other astronomers in reading his clock face. But it is difficult to believe that such a resourceful mind as Bessel's would have overlooked such a possibility.

Perhaps it would be as well to describe here some of the methods by which the amount of the personal equation, or the relative personal difference between two or more observers, is determined. For although many schemes have been devised for finding the absolute personal equation it is generally the relative personal differences between the observers that are determined in an Observatory. There are many ways of finding the amount of these differences, but it will be sufficient if a few are described.

The difference may be determined by two observers observing the same transit, one observing the passage over the first half of the wires, and the other over the second half, changing the order in which they observe from star to star so as to eliminate possible errors in the corrections for the distances of the wires. The difference in the resulting clock corrections will show the amount of the personal equation. The objection to this method is that it is a bit of a scramble for the observers to change places and the second observer is hardly as composed as he ought to be.

The images of the sun and wires may be projected on a semi-transparent screen and a number of observers can observe the transit and thus get a direct comparison.

But the method adopted at the Greenwich and Cape Observatories is the following:—On every observing night, in addition to the observations by the regular observers, a second observer takes two or three standard stars, and thus during the year a number of comparisons are made, from which, by adopting one observer as a standard, the relative personal equations of the others are determined. Usually the observations for one year are discussed and the resulting values are used for the following year. If an observer should develop a change in his personality it will soon shew in the clock book.

Although the difference between Bessel and Argelander is unique, there have been many instances of differences as great or greater than that for which poor Kinnebrook suffered. In

1883, when I joined the Cape Observatory, the "eye and ear" method of transit observing was employed, and my personal equation was found to be $-0^{s}.12$. In February, 1885, a break occurred in the observing, during which the object-glass of the transit circle was repolished. Observing was resumed in August, when it was found that my personal equation had changed to $-0^{s}.3$. In January, 1886, it had risen to $-0^{s}.4$, and by the middle of the same year to $-0^{s}.7$, at which point it remained fairly steady. The difference between the chief assistant, Mr. Finlay, and myself, was even greater than this, amounting to almost a whole second; so that I must consider myself very fortunate in having my lot cast after the discovery of personal equation, otherwise I would probably have shared the same fate as Kinnebrook.

I must here explain that these somewhat large personal errors do not affect the resulting positions of the stars. In the reductions the personal equation is not brought in unless the observations of different observers, between whom a difference exists, are united in computation. Usually an observer's observations are reduced with his own determination of the clock corrections. These corrections are found from observations of certain standard stars, whose times of meridian passage are predicted in the Nautical Almanac. If the observed time of meridian passage does not agree with the predicted time, it indicates that the clock is so much fast or slow, and in this correction the personal equation is included. It is only when the daily rate of the clock is required that the personal equation becomes important, but even here it may be overcome by obtaining the clock rate from the different groups of stars by the same observer. This will be better understood by an example taken from the Cape Observatory clock book:—

		(1)		p.e.	(2)	(3)
		s	s	s	s	s
1889 March						
4	M	— 54.40		— 0.11	— 54.51	
5	C	53.28	+ 1.12 (losing)	— 0.69	53.97	+ 0.54
6	M	53.44	— 0.16 (gaining)	— 0.11	53.55	.42
7	C	52.29	+ 1.15	— 0.69	52.98	.57
8	M	— 52.45	— 0.16	— 0.11	— 52.56	+ 0.42

— indicates fast. + indicates slow.

The clock corrections for the same time of each day, as determined by observers M and C are given under (1). They are exactly similar to those found by Maskelyne and Kinnebrook. As they stand they denote that between the 4th and 5th the clock was losing at the rate of $1^s.12$ per day, while between the 5th and 6th it was gaining at the rate of $0^s.16$, and so on. If you found your watch performing like this you would probably be quite satisfied, but for astronomical purposes it is altogether too erratic. If, however, the clock rates are obtained on alternate days, they become for observer M, between the 4th and 6th, $+ 0^s.96$ or $+ 0^s.48$ per day, and between the 6th and 8th $+ 0^s.99$ or $+ 0^s.50$ per day. In a like manner for observer C the rate between the 5th and 7th is $+ 0^s.99$ or $+ 0^s.50$ per day. The adopted personal equation correction for M was $- 0^s.11$ and for C $- 0^s.69$. Applying these corrections to (1) they become (2), *i.e.*, the clock corrections reduced to the standard observer, and the daily rates are now as given under (3), not quite perfect, but very different from those obtained from the uncorrected clock corrections. The small irregularities shewn in the rates may be due to actual irregular going of the clock, but more probably, in view of the agreement of the rates found from alternate days, to a slight change in the personal equation of one or both observers. It is this liability to variation that makes the personal equation problem somewhat complex. Thus in accurate determinations of terrestial longitudes it is necessary to combine the work of two observers, and the personal equation must be overcome either by bringing the two together to make a series of comparisons for finding the amount and allowing for it, or by an interchange of observers and a repetition of the observing programme. Both plans assume that the personal equation remains constant for some time, an asumption that may or may not be perfectly true.

Although the effect of personal equation could be evaded in the manner just now indicated, the error was in the eyes of astronomers a blemish on the fine accuracy of their science, and from time to time efforts were made to abolish it. It was early realized that it might be reduced or abolished by giving the observer but one thing to attend to—that is, by eliminating the ear, and many experiments were made to that end, which eventually materialized in the shape of the chronograph.

The chronograph consists of an evenly revolving drum or running tape, with which a marking apparatus under electric control is connected in such a way that each beat of the clock is automatically recorded on the moving paper. A key under the control of the observer enables him to record his observations on the same line or on a parallel one. By this method of recording the process of observation is much simplified. The observer has simply to watch till he sees the star bisected by the wire and then tap his key. All that remains to do then is to indicate the time by the clock to which the second-marks on the chronograph correspond, and there is a permanent record from which the time of the observation can be read off with ease to a small fraction of a second. In this method, as in the "ear and eye," there is a difference of application. Some observers tap when they see the star bisected by the wire; others aim to tap the key, so that they shall hear the click of it at the instant of bisection; while the late Prof. Newcomb had yet another method which, I believe, was peculiar to himself. This consisted of noticing at each tap of the key, whether the sound was simultaneous with the bisection of the star by the wire. If at the transit of any wire the tap was found to have been made too late, an effort was made to make the next tap too early, and this process of equalization was continued through the series of wires. For myself I cannot but think that the first method is the correct one, and that in these, as in all observations, the observer should aim at recording the truth exactly as he sees it.

This chronographic method was first used with much success on the Coast Survey of the United States of America. In 1851 a chronograph was exhibited at the Ipswich meeting of the British Association for the Advancement of Science, and in 1854 the method was introduced at Greenwich. From time to time other observations have followed and until recently the method was the generally accepted one.

The adoption of the chronographic method did not do away with personal equation, but it greatly reduced it. The extreme range between a number of observers being generally between two or three-tenths of a second, but in rare cases it has amounted to as much as six-tenths. In my own case it dropped to a few hundredths of a second. A more important point is that the chronographic method increased the accuracy of the observations. From a comparative study of the observations made with the Greenwich transit instrument in the last year of the "eye and ear" method, with those made a few years later by the chronographic method, it was found that the probable error of the observations was considerably reduced.

As observation became more refined, it gradually became clear that the personal equation varied with stars of different brightness. Means have been found to disentangle this magnitude personality from the general body of the personal equation, but it would be far better if a method of observing could be found which would do away with this and other difficulties, and so the search for new methods with that end in view had to continue. Transits have been taken by photography, but at present the difficulties and restrictions are too great for that method to be generally adopted. A new method that seems to meet the requirements has within recent years come into general use, called the impersonal micrometer or travelling wire method. It was suggested many years ago, but remained in abeyance owing to mechanical difficulties. The method consists of making a wire to move across the field of view with motion equal to that of the image of the star, so that the wire appears at rest with respect to the star; the revolving head of the micrometer screw that causes the wire to travel being fitted with electric contacts, which automatically register on a chronograph the instant when the star is at known angular distances from the meridian. The method has been likened to that of a gunlayer on board a battleship, who keeps his gun continually pointed on a moving target, so that a hit may be secured at any moment the gun is discharged by electricity from the conning tower of the ship.

There are two ways of applying this method. First by hand-guiding. In this the axis, which imparts motion to the frame on which the travelling wire is mounted, is provided with a disc at each extremity, so that the observer can use the thumb and finger of both hands in rotating it. After a little practice there is no difficulty in keeping the wire constantly bisecting the star. The other way is to introduce clockwork or motor power for conveying the chief motion to the travelling wire, leaving to the observer only the task of perfecting the guiding with a hand control. Means must be provided for causing the rate of the wire to vary according to the declination of the stars. At the Cape this is accomplished by means of a "cone apparatus." A small cone is driven at a regular speed by a motor. On this cone rests the driving wheel, from which, by means of suitable shafts and train of wheels, the motion is conveyed to the travelling wire. Provision is made for moving the driving wheel, which is turned by friction-contact with the cone, to the proper position on the cone for observing at any required declination. The observer has also under his control the means of reversing the direction of the travelling wire (necessary for following below-pole stars) and of disengaging the driving gear altogether. In the field of view are, in addition to the travelling wire, 6 fixed wires. These wires are now no longer necessary for the observations, but they serve the useful purpose of warning the observer when the travelling wire is approaching that part of the field where the micrometer will record contacts on the chronograph. These contacts are made between wires 1 and 2, 3 and 4, and 5 and 6; for the remainder of the field the circuit is broken, thus preventing a number of unnecessary and confusing records. The observer having set all his apparatus and placed the travelling wire some distance before the first fixed wire, watches the star approach. Immediately it reaches the travelling wire he starts, by means of a lever, the wire on its journey, in company with the star, across the field. As the same machinery that moves the wire also slides the eyepiece across the field, thus always keeping the star and wire in the centre of the field of view, the impression on the observer is that the fixed wires are moving, while the star and travelling wire are fixed, and all he has to do is to make a careful bisection of an almost stationary object by means of his hand control.

The chronograph used for these observations is of the running tape type—somewhat similar to the tape of the Morse telegraph instrument—with three pens making parallel lines. As the micrometer head is turned a series of "make" and "break" signals is transmitted to the chronograph. Each "make" and each "break" on the centre line corresponds with a known reading of the micrometer head; that is, with a known position of the travelling wire, the clock times at which it reaches these known positions being obtained from the adjoining line of clock records. In practice it is found that one set of contacts is quite sufficient to give a good result, so that the observer need only concentrate his efforts for perfect guiding for the short time the star takes to move from, say, the 3rd to the 4th fixed wire—about 8^s for an equatorial star. This materially lightens the labour of observing.

In 1905 the new reversible transit circle of the Cape Observatory was fitted with a hand-driven travelling wire. This was used for several years, and the effect on the personal equation was most marked. In the last year of extensive observing with the old chronographic method the personal differences amounted in the extreme to $0^s.23$, while with the new method the extreme discordance was reduced to one-quarter of that amount, that is, to $0^s.06$. In 1911 the mechanically driven wire was employed and with this the personal differences were still smaller, the extreme range among 6 regular observers for any subsequent year being never greater than $0^s.03$.

For some years past wireless time signals have been sent out by various Observatories. In July, 1912, an apparatus was set up at Greenwich for receiving the French and German signals, with the result that they were received on the average about three-tenths of a second late according to the Greenwich clock. As the wireless signals depended on observations made with the travelling wire method, while the Greenwich time was then still deduced from observation by the old chronographic method, the Astronomer Royal, in his Report for 1913, had no hesitation in stating that the difference was mainly due to the personal error of the standard observer at Greenwich. In the following year he reports that an altazimuth had been fitted with a travelling wire, and the time found by this instrument, after allowing for difference of longitude, was about a quarter of a second slow on the time found by the Transit Circle. The altazimuth was taken as the standard instrument and Greenwich time was altered about one-quarter of a second on the 2nd January, 1914. Probably few people in England knew anything about the alteration in their time. At any rate, I am unaware of any complaint about the loss of daylight by the transaction!

The travelling wire method has been used with much success in field operations for determining terrestrial longitudes, and it has now generally supplanted the older chronographic method in Observatories. With it the personal equation has not absolutely disappeared, but it is reduced to such proportions that we seem to have approached the limit in human observing. Whether the final stage in this struggle for perfection will be the elimination of the observer himself and the substitution of the photographic plate or some other mechanical means of taking transits, I should not like to predict.

REVIEWS.

"The White Dwarf Stars." By E. A. Milne, M.A., F.R.S. (Pp. 32 + 3 figures.) [Oxford: At the Clarendon Press, 1932. Price 2s. 6d. net.]

The subject matter of this volume formed the Halley lecture delivered in Oxford by Professor E. A. Milne on 19th May, 1932. It deals with the properties of the small but important group of stars known as "white dwarfs," *i.e.*, stars of low intrinsic luminosity, which are much whiter than the normal red dwarf stars. The known members of this group comprise the faint companions to Sirius, Procyon and o^2 Eridani, van Maanen's star with large proper-motion and possibly the faint component of o Ceti. These stars all occur within the region of space immediately around us and, as there is no reason to suppose that this region of space is in any way abnormal, it must be concluded that the white dwarfs are not uncommon objects in space, but that they escape observation on account of their low intrinsic luminosity.

Professor Milne traces an interesting link with Edmund Halley. In the *Philosophical Transactions* for 1718, Halley brought forward certain "considerations on the change of the latitude of some of the principal first stars." By comparing with the positions given in Ptolemy's Almagest, he concluded that Aldebaran, Arcturus and Sirius were found to be "above half a degree more southerly at this time than the Antients reckoned them." He remarked that "these Stars being the most conspicuous in the Heaven, are in all probability the nearest to the Earth, and if they have any particular Motion of their own it is most likely to be perceived in them, which in so long a time as 1,800 years may show itself by the alteration of their places, though it be utterly imperceptible in the space of a single century of years."

Thus Halley discovered the proper-motions of certain stars, including Sirius. Later, Bessel noticed that the proper-motion of Sirius was not uniform, but contained a periodicity of about 50 years. In 1844 he suggested that Sirius and Procyon were in reality double stars, in revolution about their centre of mass, with one component relatively faint. "If we were to regard Sirius and Procyon as double stars, the change of their motions would not surprise us. There have also been stars which seemed to possess the peculiarity of a bright body passing over, and which have lost it; for example, the star of Tycho." Bessel in this passage suggests a similarity between the invisible faint companions of Sirius and Procyon and the ex-nova, which after its blaze may disappear from view like Tycho Brahe's celebrated star of 1572.

The companion of Sirius was first observed by Alvan Clark in January, 1862. Its mass is known from investigations of the orbital motion. The parallax of Sirius is well determined, so that the absolute magnitude of the companion is known. In 1915, the spectrum was obtained at the Mount Wilson Observatory and the effective temperature of the companion is therefore known. All the data are available for determining the radius of Sirius B. This proves to be about three times the radius of the Earth. Its mass is almost equal to that of the Sun, whence its density is 1.1 tons per cubic inch. This result is apparently startling, but can be checked in another way, as was pointed out by Eddington. According to the theory of relativity, the observed frequency of a spectral line depends upon the difference of gravitational potential between the emitting atoms and the observer. For Sirius B, with its small radius but considerable mass, the gravitational potential at the surface is high and calculation shows that, after eliminating effects due to relative orbital motion, the lines in the spectrum of Sirius B should be displaced redward as compared with those of Sirius A by an amount corresponding to a velocity of about 20 kms. per sec. This prediction was verified by Adams' observations at Mount Wilson in 1925.

The extremely high density is only possible when the atoms are stripped of their electrons, so that the matter is composed of an assemblage of bare nuclei and free electrons. The physical properties of matter under these conditions have been investigated by R. H. Fowler.

Professor Milne proceeds to correlate these facts concerning the white-dwarf stars with his theory of stellar constitution, in order to find a place for these objects in the scheme of evolution. He concludes from his investigations, summarised in the lecture, that under certain circumstances a cataclysm takes place. "Physically we see that with waning luminosity and accordingly waning light-pressure a situation supervenes in which light-pressure is inadequate to sustain a gaseous configuration. Part of the mass is precipitated at the centre in the degenerate state. But the material so precipitated has less opacity than it had before, light-pressure decreases still further, and the small yielding of this core to the reduced light-pressure causes yet further precipitation, and so the process goes on. A core of finite size grows cataclysmically from the point-core. This sudden collapse will be accompanied with an equally sudden liberation of gravitational energy . . . and the star will exhibit a temporary brightening, for the rate of surface radiation must temporarily exceed the normal rate of generation. We therefore get a state of affairs resembling in almost all respects a nova outburst, with the expulsion of the gaseous atmospheric layers under the enhanced light-pressure."

Thus the typical phenomena of a nova outburst, as shewn for instance in the case of Nova Pictoris, can be accounted for, at least qualitatively. Moreover, there seems no escape from the conclusion that the densities of ex-novae must be very much greater than those of normal stars, though not so large as the density of Sirius B. Further, Milne shews that if the star is in rotation, the collapse may give rise to rotational instability; fission into two or more masses would then occur. According to the partition of mass between the two fragments, one or both fragments may subsequently re-expand. In this way, a system such as Sirius, consisting of a star of normal density accompanied by one of high density, may be produced. Bessel's suggested connexion between the companion of Sirius and the nova of 1572 may therefore be strikingly near the truth.

Professor Milne's theory, embracing the cause of a nova outburst and the mode of genesis of the white-dwarf stars, is undoubtedly attractive. In this lecture it is outlined, without the introduction of mathematics. Those who wish to gain an insight into Milne's researches on stellar constitution cannot do better than read and study this booklet.

"Signals from the Stars." By George Ellery Hale. (Pp. xxii + 138, with frontispiece and 56 figures.) [London: Charles Scribner's Sons, 1932. Price 7s. 6d. net.]

"Signals from the stars, of the greatest variety and significance, are constantly reaching the earth." So runs the opening sentence of Dr. Hale's preface; this small volume is, however, concerned more with the astronomer's receiving sets—his telescopes and auxiliary equipment—than with the actual interpretation of the signals received. Two of the four chapters deal with large telescopes and emphasise the need for larger telescopes than have yet been constructed. Some of the results obtained with the 100-inch telescope at Mount Wilson are passed in review. "They have given us new means of determining stellar distances, a greatly clarified conception of the structure and scale of the galaxy, the first measures of the diameter of stars, new light on the constitution of matter, new support for the Einstein theory, and scores of other advances. They have also made possible new and surprising researches beyond the boundaries of the Milky Way in the region of the spiral nebulae." A fine record, indeed! With a view to extending the range of exploration farther into space, the project of a 200-inch telescope has been considered by Dr. Hale and his collaborators and some account of this project is given. The mechanical difficulties can undoubtedly be surmounted, but the optical difficulties involved in the construction of a 200-inch mirror, weighing about 30 tons, are more serious, and experience with smaller mirrors affords no guidance; various possibilities for the construction of the mirror are outlined. An instrument of this size can only be used to advantage on a site where the observing conditions are of the best, and detailed tests of a number of sites in California have been made with a view to ensuring that the telescope, when constructed, can be used to the fullest advantage.

The two remaining chapters of the book deal with signals from the nearest star, the Sun. In this field, useful work can be done with instrumental equipment of a modest nature. Dr. Hale, by the invention of the spectrohelioscope, has provided solar observers with an instrument of the greatest value. He has designed a simple and inexpensive form of this instrument and hopes that a network of such instruments, in the hands of amateurs in various parts of the world, will enable the Sun to be kept under more or less continuous observation.

In the concluding pages, Dr. Hale gives a brief answer to the question so frequently asked: "What is the good of astronomy?" After referring to its purely utilitarian value for the measurement of time, for surveying and mapping and for navigation by sea and air, he refers to our larger debt to astronomy; how it has been instrumental in freeing mankind from superstition and fear, and has taught us the existence of the laws of nature, the understanding of which is the purpose of all science. Astronomy has proved invaluable in the investigation of the nature of the atom; it has provided the tests for the Einstein theory, and it supplements the work of the physicist and chemist in that the astronomer can study matter under conditions of density and temperature which are not obtainable in the terrestrial laboratory.

The volume is well printed and is provided with many excellent illustrations.

TO EROS.

[When that interesting little Asteroid—Eros—was at its nearest approach to the Earth, Dr. Waterfield, Astronomical Correspondent of the *News-Chronicle,* stated that its brightness varied considerably and regularly in a period of five hours and a half. This shows, he said, that Eros, instead of having the orthodox celestial shape—that of a billiard ball—is more like an irregular gigantic boulder tumbling along its orbit round the Sun.]

Twinkle, twinkle, little Planet,
Whirling, though one scarce can scan it,
Up above the world so high,
Like a boulder in the sky!

Though not spherical in form,
But a rugged rock enorm,
Your rotations give a bright
Three hours' day, and three hours' night.

When the blazing sun has set,
And with stars the sky is fret,
Then you show your tiny light,
Twinkle, twinkle, all the night!

Then the watcher in the dark
Searches for your little spark,
Measuring, from many a station,
Right Ascent and Declination.

D.C.S.

OBITUARY.

Walter Hubert Cox: 1864-1932.

By the death of Mr. Walter Hubert Cox on the 7th February, 1932, the Astronomical Society of South Africa lost one of its foundation members. For many years he took an active interest in the welfare of the Society, and was Vice-President of the Society for the year 1931-32.

W. H. Cox was born on the 2nd September, 1864, at Southampton. On the death of his father at an early age he was sent to be educated at the Royal Hospital School, Greenwich.

W. H. Cox.

While there the opportunity of entering upon an astronomical career presented itself, and he joined the Service of the Royal Observatory, Greenwich, at the age of 16.

Three years later he was transferred to the Royal Observatory at the Cape, where he was privileged to help in the wonderful development of that institution under Sir David Gill.

As a young man he threw himself with zest into the social life of the Cape. He soon appeared in amateur operatic performances, and his prowess at tennis is shown from the fact that he was Singles Tennis Champion of the Western Province in 1895.

His equable disposition and lovable nature endeared him to a host of friends. In 1897 he married Miss Annie Duncan, of Sea Point, who, with two daughters, survives him.

At the Observatory he was eventually promoted to the rank of Assistant, and was largely responsible for the reduction of observations used in the formation of the various meridian catalogues of stars issued from the Cape Observatory. He retired in 1925 after 42 years of faithful and zealous service.

ASTRONOMICAL SOCIETY OF SOUTH AFRICA.

Session 1931-1932.

Annual Report of the Council.

In presenting its Annual Report, the Council is able to record steady progress during the session 1931-1932. The close of this session marks the completion of the tenth year since the inception of the Society by the Union of the Cape Astronomical Association and the Johannesburg Astronomical Association. The Society was inaugurated with a foundation membership of sixty-one. The progress during the intervening ten years is reflected in the increase in the roll of membership, which now bears 128 names, 120 being members and 8 associates.

The negotiations with the Natal Astronomical Association for incorporation as a Centre of this Society have now reached a stage when accomplishment may be expected. The Committee of the Natal Association will submit to the forthcoming Annual Meeting of the Natal Association a proposal in favour of union with this Society.

The Council presents a similar motion to you to-night, and hopes that by its adoption you will strengthen the Society as a body representative of all astronomical interests in South Africa.

Arising out of the situation created by the above negotiations, your Council appointed a sub-committee, which has been actively engaged in the examination of the existing Constitution, with a view to offering for your consideration in due course such amended form as may appear desirable. For the present only such amendments as are necessary for the entry of the Natal Astronomical Association are being placed before you.

The Council has met four times during the year, those members who are eligible under Article VII (iii) of the Constitution being represented by alternates. Its enquiry into the circumstances determining the ownership and responsibility for the Herschel reserve and obelisk at Feldhausen has been continued and culminated in the appointment of a deputation consisting of Dr. Spencer Jones, Mr. D. G. McIntyre and the Hon. Secretary, which met the Improvements and Parks Committee of the City Council on 11th July, 1932. The South African National Society and the Claremont Ratepayers' Association were invited to send representatives, and did so. The representations of the Society's deputation that the City Council should register in the Deeds Office the title to the Herschel reserve, and the right of way to it (which, it has been ascertained, have already been offered), were favourably received.

The Council views with regret the withdrawal of South Africa from the International Astronomical Union. Representations on this matter have been made by the National Committee on Astronomy to the Minister of Mines and Industries. The Council welcomes the assurance, which the Minister has given, that the withdrawal is temporary, due to the present financial position, and that South Africa will rejoin the Union when conditions improve.

The financial statement at the end of the year shows a balance of £22 17s. 4d. That the Society is able to show a balance is due largely to the generous donations to its funds by the two Centres. The cost of printing the Journal is a heavy drain on the Society's financial resources. It is greatly to be desired that its publication will not be hampered by lack of funds. The Council would welcome the opportunity for the further development of the Journal, that would be afforded by the active support and membership of all eligible persons interested in astronomy.

During the year Vol. III, No. 1, of the Journal was issued, containing Capt. Cameron-Swan's Presidential Address, reports on the Society's activities, articles and reviews. Exchange of publications has been established with several additional institutions, who have requested it. This will result in further valuable additions to the library, which will be useful to the members of our active observing sections.

The work of observing sections has been steadily continued throughout the year. Mr. Houghton and Mr. Ensor are to be congratulated on the independent discovery of the comet which bears their joint names. The Council expresses its appreciation of the painstaking labour that directors and members of observing sections are devoting to the fulfilment of one of the objects of the Society, and would urge all who can to become active members of observing sections.

It is with deep regret that the Council has to record the death of Mr. W. H. Cox, one of its Vice-Presidents. He was a foundation member, and gave faithful service to the Society as a member of the Journal Committee since its formation and on the Council continuously since 1925, as either a member or alternate member.

REPORTS OF SECTIONS.

For the Year ended 30th June, 1932.

COMET SECTION.

This year, through the alertness of members of the Variable Star Section, we have much pleasure in being able to place to the credit of the Society the discovery of another new comet. Mr. H. E. Houghton, F.R.A.S., on the evening of the 1st April, 1932, while turning his telescope to pick up the variable star T Apodis, came upon a large, nebulous object. Being familiar with this part of the sky and unaware of ever having seen a nebula there, the object attracted his attention. By its rapid motion he was soon able to recognise it as a comet. The following evening Mr. G. E. Ensor, while observing the same variable, came upon this object and, being also an alert observer, quickly discovered its cometary nature. We heartily congratulate these observers on their vigilance and we hope their good fortune will be the forerunner of a new series of comet discoveries to the credit of the Society.

A good deal of regular search has been done for new and returning comets by Mr. Blathwayt, Mr. Watson and the writer during the year, but the results are only of negative value. We have been helped in many ways by the Directors and Staffs of the Royal and the Union Observatories, which have given us much encouragement.

In the following notes a few particulars of new and periodical comets which have appeared during the year are given:—

New Comets.

Comet 1931*b* (Nagata) was discovered in California on 17th July by Mr. Nagata. Prof. G. van Biesbroeck reports a remarkable outburst of light from this comet. About 6th October the light increased nearly a hundred fold, from mag. 12 or 13 to 8. By 21st October it had fallen to mag. 10.

Comet 1931*c* (Ryves). This comet was found on 10th August by Mr. P. M. Ryves at Zaragoza. It is notable as having the smallest perihelion distance of any comet observed since 1887 (with the possible exception of the eclipse comet of 1893). Dr. Crommelin reckons it must have approached to within 13 million miles of Jupiter.

Comet 1932*b* (Houghton-Ensor). This comet was discovered at Cape Town by Mr. H. E. Houghton on the evening of 1st April. Its position at discovery was given as R.A. 13^h 42^m 30^s Dec. 76° 53′ South. It was independently discovered at Pretoria by Mr. G. E. Ensor on the evening of 2nd April. At discovery it was about the 9th magnitude and was a large, diffuse, circular object. It had no nucleus or tail, but had a slightly granular appearance at the centre. The comet was well seen and followed by many members of the Society. It traveller rapidly in a northerly direction, varying little in R.A. until it got too faint to be seen.

The following parabolic orbit by the Rev. M. Davidson (published in the *B.A.A. Journal*) is derived from observations by Mr. Bobone at Cardoba:—

T	1932 March 1·2062 U.T.	
ω	304° 40′ 47″	1932·0
☊	212° 25′ 36″	
i	74° 47′ 27″	
$\log q$	0.1020150	

Comet 1932*c* (Carrasco), mag. 12, was discovered by Mr. Carrasco at Madrid on 22nd April. It rapidly became fainter; Dr. Steavenson found it to be only mag. 13 on 24th May.

Comet 1932*g* (Geddes), mag. 10, was discovered at Otago, New Zealand, on 22nd June by Mr. Geddes. Like the Houghton-Ensor comet it was also found far south and was travelling north. Its position at discovery was given as R.A. 138° 45′ N.P.D. 174° 36′. Cape members of the Society who saw it report it as being small, but having a distinct nucleus and coma, but no tail.

Periodical Comets.

During the year under review the following periodical comets were due to return:—

Neujmin (1) 1913 III, Schorr 1918 III, Wolf's Second Periodical, Grigg-Skjellerup, Neujmin (2), Kopff, Borelly, and Brooks (2). Of these Neujmin (1), Grigg-Skjellerup, and Kopff have already been observed.

A. F. J. Forbes, *Director.*

VARIABLE STAR SECTION.

In presenting his report for the 1931-32 Session, your Director is pleased to be able to record a year of steady progress.

Mr. Houghton's absence in England on holiday naturally affected the year's aggregate very materially, and since one observer's records only were available during the latter part of 1931, the compilation of the list of maxima and minima was a difficult matter.

2,668 observations of 128 variables were recorded during the Session, an average of over 20 observations per variable. The observations are divided between two members of the Section as follow:—

H. E. Houghton: 1058 observations of 83 variables.
G. E. Ensor: 1610 observations of 126 variables.

Your Director appeals to those members of the Society in possession of telescopes of 3″ aperture and over, who are not members of other observing sections, to give variable star work a trial. When the initial difficulties have been overcome, the work will be found to be extremely interesting and of great value to the professional astronomers engaged in the investigation of the causes of variation. The more numerous the individual observations obtained, the more reliable the light curve, and therefore more reliable data are available for research workers.

The discovery of a new comet in Apus by Mr. Houghton, on the night of 1st April, and the independent discovery of the same comet by your Director on the following night, are two of the many occasions on which comets have been found by variable star observers during the course of their work. A variable star observer covers a large portion of the sky at least twice in each month, and the areas surrounding each of the variables on the observer's list are so well known that the presence of a comet could hardly escape notice.

Your Director's thanks are due to H.M. Astronomer, Dr. H. Spencer Jones, for particulars relating to the spectral changes in Nova Pictoris, and to Dr. van den Bos, of the Union Observatory, by kind permission of the Union Astronomer, for measurements of the components of the nova. Also to the Union Observatory and Harvard College Observatory for circulars and star charts; to Mr. V. Tschernov, of the U.S.S.R., for the Bulletin of the Society of Amateur Astronomers of Moscow; and Mr. Martin Dartavet, of the La Plata Observatory, for the Journal of the Astronomical Society of the Argentine.

NOTES.

Nova Pictoris.—Very slight change has been recorded in the brightness of this nova during the past year; the present magnitude is 8.7, a decline of not more than three-tenths magnitude during the year. The following particulars in connection with the spectroscopic changes in the nova have been very kindly supplied by Dr. H. Spencer Jones, H.M. Astronomer at the Cape:—

"A spectrogram of the nova was kindly obtained for me by Mr. Worssel, of the Union Observatory, on 4th, 5th, 6th and 7th April last. The spectrum this year is essentially unchanged from that of last year. There is well-marked continuous spectrum, with bright lines. The stronger radiations are the one of unknown origin at λ 6087, the ionised helium line at λ 4686, $H\alpha$, the line of unknown origin at λ 5723, and $H\beta$. There are a number of weak lines, several of which agree in wavelength with lines which are present in the spectra of various Wolf-Rayet stars. As in the case of several previous novae, the spectrum has passed into the Wolf-Rayet stage. The most interesting features of it are the two very strong lines of unknown origin at $\lambda\lambda$ 6087, 5723, which have not been observed in any previous stellar spectrum. These lines are not among the predicted metastable lines, whose presence in the spectrum might be expected, given the appropriate conditions, and no suggestions can at present be made as to their origin. Their relative intensity has not been constant in the spectrum of the nova, so that they are not related lines in the sense that the typical nebular lines at $\lambda\lambda$ 5007 λ, 4959 are related. Their presence and intensity may be due to unusual abundance of a particular atom, or to some peculiar conditions of density in the gaseous shell around the nova."

The following micrometer measurements of the components of the nova and notes have been received from Dr. van den Bos, of the Union Observatory:—

NOVA PICTORIS, OPPOSITION 1931-32.

Observer—van den Bos.

AB.	1931.909	$77^\circ.7$	$1''.14$	$9^m.5 - 12^m.5$	
	2.115	$78^\circ.6$	$1''.15$	$9^m.0 - 12^m.2$	
	2.266	$74^\circ.3$	$1''.09$	$9^m.5 - 13^m.0$	
	1932.097	$76^\circ.9$	$1''.13$	$9^m.3 - 12^m.6$	$3n$
AC.	1931.909	$225^\circ.0$	$0''.90$	$9^m.5 - 13^m.5$	
	2.115	$241^\circ.0$	$1''.05$	$9^m.0 - 13^m.5$	
	2.266	$234^\circ.8$	$1''.44$	$9^m.5 - 14^m.5$	
	1932.097	$233^\circ.6$	$1''.13$	$9^m.3 - 13^m.8$	$3n$

NOTES.

1931.909.—Visible nebulosity small, more on the south side of A than on the north side; B and C are outside, but very faint; measures very difficult.

1932.115.—B well seen, C very difficult.

1932.266.—B faint, but well seen, C hardly visible, both well outside the nebulous blur of A.

2.252 $232^\circ.8$ $1''.34$ $9^m.0 - 12^m.5$

Observer—Finsen.

AB.	1932.203	$79^\circ.2$	$1''.03$	$9^m.0 - 12^m.0$	
	2.252	$72^\circ.1$	$1''.20$	$9^m.0 - 12^m.0$	
	1932.228	$75^\circ.6$	$1''.12$	$9^m.0 - 12^m.0$	$2n$
AC.	1932.203	$230^\circ.1$	$1''.13$	$9^m.0 - 12^m.5$	
	1932.252	$232^\circ.8$	$1''.34$	$9^m.0 - 12^m.5$	
	1932.228	$231^\circ.4$	$1''.24$	$9^m.0 - 12^m.5$	$2n$

NOTES.

Difficult, nebulosity round A much fainter, both B and C are well outside.

GENERAL HISTORY OF COMPANIONS.

	1928 +	85° — 145°	0″.35±	△m 0.6	AB.
	29.07	65°.0	0″.55	1.6	
	29.99	74°.0	0″.84	1.8	
	31.07	71°.7	0″.95	mags. 8.9 — 11.5	
	32.15	76°.4	1″.13	9.2 — 12.4	
	28 +	231° — 257°	0″.38±	△m 1.0	AC.
	29.07	229°.4	0″.60	2.1	
	29.99	230°.0	0″.80	2.6	
	31.07	226°.0	0″.98	mags. 8.9 — 12.5	
	32.15	232°.7	1″.17	9.2 — 13.3	
AD	1928 +	356° ?	0″.25 ?	△m 1.5 ?	Suspected only
	29 +	8° ?	0″.25 ?	3 ?	„ „
	30 +	15° ?	0″.3 ?		„ „
	31	Not seen			
	32	„ „			

The increase of the distances of both B and C from A is still maintained, as also the fading of B and C. In fact, it was a pleasant surprise that they could still be seen, and measured, albeit with great difficulty.

The fact that the nebulosity round A appears to us to be contracting rather than expanding does not mean that no such expansion takes place. It seems more likely that the decrease of brightness is faster than the expansion can make up for.

Similarly in the case of Nova Aquilae, 1918, the last visual measures of the expanding shell before it became too faint (by Aitken with the 36-inch Lick) gave a diameter which was too small as compared with the later photographic observations with the 100-inch Mount Wilson reflector. The latter showed that the expansion was still going on at a sensibly uniform rate. A visual refractor of small aperture ratio (ours is 1 : 16, the Lick 1 : 18) is far from an ideal instrument for observing faint nebulosity. A photograph taken with a great reflector would be very desirable for Nova Pictoris. The refractors fail because of the chromatic aberration; the well-known rings obliterate the nebulosity."

RY Sagittarii has reached the 7th magnitude, with signs of reaching its normal maximum of 6.5 magnitude in the near future.

S Apodis has been fainter than magnitude 13.4 since 18th February and is at present invisible in small telescopes.

G. E. ENSOR, *Director.*

CAPE CENTRE.

Eighteenth Annual Report, 1931-1932.

Your Committee, in presenting this, the Eighteenth Annual Report, has to record a period of continued progress and activity of the Centre during the session now closed.

Membership.

Fourteen additions have been made to the roll of membership during the year, while eleven names have been struck off owing to resignation and other causes. The total membership is now one hundred and seven (one hundred members, two members *emeriti,* and five associates).

It is with sincere regret that your Committee record the death of Mr. W. H. Cox, a foundation member, not only of the Society, but also of the Cape Astronomical Association. Mr. Cox had been a member of the Council of the Society since 1923 and was at the time of his death one of the Vice-Presidents and a member of the Journal Committee.

Meetings.

In accordance with the resolution adopted at the last Annual General Meeting, the meetings of the Centre have been held on the third Wednesday of the month instead of the second Wednesday as previously. This change appears to have given satisfaction.

During the period under review there have been nine ordinary meetings of the Centre. The first seven meetings were held as previously at Benson House, Long Street, in the rooms of the Mountain Club of South Africa. The lease of these rooms having expired and the Mountain Club having secured a room in the chambers of the Standard Bank (A.B.C. Branch), St. George's Street, the last two meetings of the session were held there.

The incoming Committee of the Centre will be called upon to consider the advisability of continuing to hold meetings of the Centre in this room.

By the invitation of His Majesty's Astronomer, the Annual Observational Meeting in February was held at the Royal Observatory, where members were privileged to observe through the Victoria telescope, observing conditions being sufficiently good to enable members to see the companion to Sirius.

The Committee has met six times.

Addresses and Papers.

The addresses and papers presented at the meetings were of a high standard and include the following, viz.:

"The Dimensions of the Solar System": Mr. H. Horrocks, M.A., F.R.A.S.
"The Cold Bokkeveld and Victoria West Meteorites": Mr. D. G. McIntyre, F.R.A.S.
"The Zodiacal Light": Mr. R. Watson.
"The Value of Astronomy as a Practical Training": Mr. H. C. Mason.
"Historical Eclipses": Mr. D. C. Burrell.
"The Theory of Eclipses": Mr. R. Watson.
"The Velocity of Light": Mr. S. Skewes, M.A., B.Sc.
"The Habitability of Mars": Mr. B. Jeary, F.R.A.S.
"The Moon and Radio-activity": Mr. V. S. Forbes.
"The Rotation of the Galaxy": Mr. H. Horrocks, M.A., F.R.A.S.
"The 1931 Meeting of the British Association for the Advancement of Science": Mr. H. E. Houghton, F.R.A.S.
"Records of the Colour of Sirius": Mr. H. W. Schonegevel.
"A Visit to the Observatories of America": Dr. H. Spencer Jones, M.A., Sc.D., F.R.S.

Discovery.

The Committee have pleasure in recording the discovery of a comet by Mr. H. E. Houghton at Cape Town on 1st April. The comet was found independently by Mr. G. E. Ensor, of Pretoria, on the following evening. The comet is designated "Comet Houghton-Ensor 1932*b*."

Finance.

The financial statement to be presented by the Hon. Treasurer will show several items of abnormal expenditure. A donation of £10 has been made to the funds of the Society and a register, as required by Society's By-law No. 2, has been purchased. Otherwise the finances are satisfactory.

Publication.

Articles detailing predicted astronomical phenomena have been published monthly in the *Cape Times*, these articles being accompanied by diagrams and charts of the sky. Articles in Afrikaans were also published in *Die Burger*. Both series of articles were contributed by members of the Centre, and are greatly appreciated by members and the public generally.

Financial Statement for the Year ended 30th June, 1932.

INCOME.	£ s. d.	EXPENDITURE.	£ s. d.
To Balance in hand at 30th June, 1931 .	14 6 6	By Contributions under Article IX. of Constitution ..	33 14 1
„ Subscriptions: Arrears .. 6 16 6; Current Year 57 19 3; In Advance 2 12 6	67 8 3	„ Donation to Astronomical Society	10 0 0
		„ Rent of Meeting Room	10 0 0
		„ Rent of P.O. Box	1 5 0
„ Subscriptions to *Cape Times* ..	0 6 0	„ Typewriting & Stationery	4 13 0
„ Commission on Cheques	0 3 4	„ *Cape Times* and Postage to Country Members ..	4 11 3
„ Amount received from Astronomical Society adjusting Account for Register ..	0 7 9	„ Subscription to Astro. Society of the Pacific ..	1 2 10
„ Adjusting error between cash book and bank statement carried forward from previous years	0 1 5	„ Folders for Star Maps	0 18 0
		„ Register for names of members	4 0 6
		„ Binding B.A.A. Journals	3 5 0
		„ Secretary's Expenses	3 7 0
		„ Treasurer's Expenses	1 0 0
		„ Bank Charges . ..	2 1 11
		„ Balance	2 14 8
	£82 13 3		£82 13 3

JOHANNESBURG CENTRE.

Annual Report, 1931-1932.

In the affairs of this Centre the year just closed presents a marked similarity to its predecessor—like most variable stars "the curve was of the usual type, but one or two maxima were unobserved," might epitomise the period under report.

The members now number nineteen and there are two associate members.

As in the previous year, eight meetings of the Centre were held, those in October and May being visits to the Union Observatory, by courtesy of the Union Astronomer. In August a question night was held, when a number of matters of astronomical interest were discussed. The November meeting was held on the premises of Mr. Karno, when a demonstration of lens manufacture was given, shewing the grinding of bi-focal lenses of cylindrical and spherical types and other matters incidental to their production. At the meeting held in March a general discussion on matters of astronomical interest was held, in the course of which Dr. Innes gave an interesting account of his visit to Europe and the activities of the astronomical societies there, at a number of whose meetings he was present. The June meeting was devoted to an address on the "Franklin-Adams Star Chart," by Mr. Johnson, of the Union Observatory. He gave an instructive account of the project from its inception to the present time, outlining the improvements in technique that experience had brought and of the difficulties that had delayed its compilation in certain areas. Mr. H. E. Wood followed with a short notice of the newly-discovered asteroids which approach the earth more nearly than Eros, mentioning that they might lead to an even more precise determination of the scale of the solar system than the means hitherto available, although gravitational perturbations by the earth might introduce serious complexities.

The interest of the members in the meetings was well maintained and the keenness of the discussions made evident the desire of those present to broaden their knowledge and understanding of the problems presented in astronomy. In this latter connection the assistance and courtesy of the Union Astronomer and the members of his staff, as well as of Dr. Innes and Dr. Alden, were greatly appreciated.

The cordial thanks of the Centre are tendered to the Union Astronomer and his staff for the courtesy and hospitality extended to the Centre on their visits to the Union Observatory and to the members, whose kind offices have facilitated carrying on the business of the Centre, and lastly, to those who, by papers, addresses and discussions, have furthered the success of the Centre during the year under review.

FINANCIAL STATEMENT FOR THE YEAR ENDED 30TH JUNE, 1932.

INCOME.		£ s. d.
To Balance on hand 1st July, 1932		25 16 10
„ Members' Subscriptions received	16 19 3	
Less Subscriptions Paid in Advance	2 0 0	
		14 19 3
		£40 16 1

EXPENDITURE.	£ s. d.
By Donation to Astronomical Society of South Africa	15 0 0
„ Postages, etc. (including membership to British Astronomical Society	3 0 0
„ Bank Charges . . .	0 11 2
„ Balance carried forward	22 4 11
	£40 16 1

ASTRONOMICAL SOCIETY OF SOUTH AFRICA.

FINANCIAL STATEMENT FOR THE YEAR ENDED 30TH JUNE, 1932.

INCOME.	£ s. d.
To Balance 30th June, 1931	22 18 10
„ 50% Subscriptions (Cape Centre) . .	33 14 1
„ Sale of Journals . .	2 17 7
„ Sale of Sundial . .	1 0 8
„ Donation (Johannesburg Centre)	15 0 0
„ Donation (Cape Centre)	10 0 0
	£85 11 2

EXPENDITURE.	£ s. d.
By Printing Journal,	
„ Vol. 3, No. 1	48 19 4
„ Sundry Printing & Stationery	6 12 1
„ Postages	3 1 0
„ Sundries	1 13 3
„ Refund ex Sundial Account	2 2 0
„ Bank Charges	0 6 2
„ Balance carried forward	22 17 4
	£85 11 2

Examined and found correct:
E. J. STEER.

22nd July, 1932.

W. H. SMITH,
Hon. Treasurer.
30th June, 1932.

[The sum of £7 10s., being 50% of subscriptions to the Johannesburg Centre for the year 1931-32, was received by the Hon. Treasurer after the close of the financial year and therefore does not appear in the above statement.—Ed. Note.]

AMENDMENTS TO CONSTITUTION AND TO BYE-LAWS.

The following amendments to the Constitution, proposed by the Council, were approved at the Annual General Meeting:—

"That in Article II. the title read 'Foundation' instead of 'Centres.'

That in Article VIII. the title read 'Centres and Branches' instead of 'Branches,' and that the following be added:—'A Centre of the Society may be established at a General Meeting of the Society upon the recommendation of the Council. If such Centre be formed by the entry of a previously existing organisation, all members in good standing of such organisation shall be deemed elected to membership of the Society.'

That in Article XI. 'either Centre or any Branch' read 'any Centre or Branch.'

That in Article XV. (viii.) 'each of the two Centres' shall read 'each Centre,' and 'which two members' shall read 'and these.'"

The following amendment to Bye-Law 1, adopted by the Council, was confirmed at the Annual General Meeting.

"That the words 'either Centre or any Branch' be amended to read 'any Centre or Branch.'"

ASTRONOMICAL SOCIETY OF SOUTH AFRICA.

Officers and Council, 1932-33.

President: H. Spencer Jones, M.A., Sc.D., F.R.S., Royal Observatory, Cape of Good Hope.

Vice-Presidents: G. E. Ensor; D. L. Forbes, F.R.A.S.; J. S. Paraskevopoulos, Ph.D.

Hon. Secretary: H. Horrocks, M.A., F.R.A.S., Royal Observatory, Cape of Good Hope.