34. COMMISSION DE LA PARALLAXE SOLAIRE

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MEMBRES: MM. Carnera, Dyson, Esclangon, Hammond, Hinks, Kopff, Schlesinger, Schorr, Stroobant, Witt.

1. *Catalogue of Primary Reference Stars.* Two lists of primary reference stars containing, in all, 821 stars were prepared by Prof. Kopff and published in *Ast. Nach.* **224**, No. 5375 and **226**, No. 5403. These stars were widely observed at the following Observatories: Babelsberg, Cincinnati, Cape, Greenwich, Bergedorf, Heidelberg, La Plata, Leiden, Lick, Padova, Uccle and Washington. The stars were selected to give as uniform a distribution as possible to a distance of 1° on either side of the path of Eros according to the preliminary ephemeris of Prof. Gustav Witt (*Ast. Nach.* **224**, No. 5375; *M.N.R.A.S.* **85**, 997, 1925). The early observations of Eros in the autumn of 1930 indicated that the actual path of Eros deviated considerably from the path indicated by this ephemeris and that the deviation near the time of opposition, when the motion of Eros was almost entirely in declination, would amount in R.A. to about 15 minutes of arc. The primary comparison stars as selected would thus extend on one side of the path, near opposition, to a distance of only 45′. This necessitated either (1) centring the photographic plates on the computed path of Eros, or (2) centring the photographic plates on Eros itself and selecting and observing sufficient additional primary comparison stars to cover the blank strip. It was finally decided to adopt the second alternative and a third list of reference stars, containing eighty-seven stars, was prepared by Prof. Kopff and published in *Ast. Nach.* **240**, No. 5756, with a recommendation that sufficient stars of the second list should be re-observed along with the stars of the new list to enable the new observations to be reduced to the system which Prof. Kopff had meanwhile derived from the observations of the two main lists.

The number of stars of the three lists observed at various Observatories are given below. Under List II, two series of numbers are given. The first contains the number of stars observed in the main series of observations. The second contains the number of stars of this list which were observed concurrently with List III.

	List I	List II (*a*)	List II (*b*)	List III
Stars in list	419	402		87
Observed at:				
Algiers	—	—	34	65
Babelsberg	419	155	9	48
Cape	—	395	95	79
Cincinnati	—	60	—	—
Cordoba	—	—	0	76
Greenwich (T.C.)	400	70	0	37
,, (Altaz.)	370	63	—	—
Hamburg (Bergedorf)	194	22	6	24
Heidelberg	50	84	—	—
La Plata	—	398	0	76
Leiden	131	26	13	38
Lick	419	260	45	76
Padova	—	43	0	40
Uccle	410	—	—	—
Washington	411	184	97	65

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It will be seen from the above table that List II was not so well observed as List I. This is unfortunate, as the stars in List II are along the portion of the path in which the parallax of the planet was large and in which the observations have the greatest value for the determination both of the solar parallax and of the mass of the Moon. The mean errors for a single observation in R.A. and Dec. of a star in each list and the average weight for a single star of the combined observations are as follows:

	$m \leq 8^{m}\cdot8$		$m \geq 8^{m}\cdot9$		Average weights	
	F_{α}	F_{δ}	F_{α}	F_{δ}	α	δ
List I	$\pm 0^{s}\cdot058$	$\pm 0''\cdot70$	$\pm 0^{s}\cdot061$	$\pm 0''\cdot69$	42	35
List II	$\pm 0^{s}\cdot060$	$\pm 0''\cdot76$	$\pm 0^{s}\cdot083$	$\pm 0''\cdot93$	28	26
List III					38	34

It will be seen that the mean error for unit weight is rather larger for Lists II and III than for List I. Several stars in these lists have very low weight: it is advisable that such stars should not be used as primary reference stars.

The observations of the primary reference stars have been discussed very thoroughly by Prof. Kopff and his collaborators at the Astronomisches Rechen-institut and have been reduced to a uniform system. The definite catalogue of primary reference star positions has been published in two sections as follows: Generalkatalog der Eros-Anhaltsterne, 1. Ordnung für die Opposition 1930–31: 1. Teil, *Ast. Nach.* **241**, Nos. 5781–2, 2. und 3. Teile, *Ast. Nach.* **244**, Nos. 5852–3, by A. Kopff, H. Nowacki and F. Gondolatsch.

The catalogue contains the following data: Serial number of reference star; B.D. or Co.D. number; visual and photographic magnitudes and spectral type; α (1930·0) and epoch; δ (1930·0) and epoch; number of instruments providing observations for position of star; total weights in α and δ; proper-motions in α and δ; number of catalogues upon which proper-motions are based.

In general the proper-motions are only approximate, but the mean epoch of the observations of the reference stars rarely differs by as much as three years from the epoch of the plates on which these reference stars appear.

In addition to the observations referred to above, observations of 193 stars selected from the 3 lists were made at Besançon (*J.d.O.* **14**, 129, 1931). It is unfortunate that Prof. Kopff was not provided with a copy of the results, which became available to him too late for incorporation in the General Catalogue.

It may be noted here that the star corrections for the reduction to mean place of the observations of the primary reference stars were computed in the Nautical Almanac Office and were published in the *Astronomische Nachrichten* with the aid of a grant from the International Astronomical Union. The preparation of the catalogue of these stars has been made possible by means of grants to Prof. Kopff from the Preuss. Akademie der Wissenschaften and the Deutscher Gemeinschaft zur Erhaltung und Förderung der Forschung (Notgemeinschaft).

2. *Secondary Reference Stars.* The distribution of the primary reference stars is such that on the average ten to twelve will be found on a field of 2° × 2°. The primary stars are therefore suitable for the reduction of photographs obtained with instruments which cover a field of, or greater than, this area. For plates covering a smaller field, fainter stars must be used as reference stars. For the portion of the path of Eros extending from + 48° to − 14° declination, a selection of secondary reference stars has been made at the Bergedorf Observatory, using a series of twenty-three photographs on plates of 24 × 30 cm. obtained with the Triplet K of the Lippert Astrograph. The selected stars are in general of magnitudes between

10^{m}·0 and 12^{m}·0 (photographic), except in areas containing few stars, where it has been necessary to include some fainter stars. The stars have been chosen so that in any field of 1° × 1° centred on the path of Eros six or eight secondary reference stars will be found.

The lists of selected stars have been published in the *Ast. Nach.* in three instalments as follows:

Bergedorfer Anhaltsterne, 2. Ordnung für die photographische Beobachtung der Eros-Opposition 1930–31, 1. Teil, *Ast. Nach.* **239**, Nos. 5730–1.
Ditto, 2. Teil, *Ast. Nach.* **240**, No. 5741.
Ditto, 3. Teil, *Ast. Nach.* **242**, No. 5798.

Teil 1., containing 2247 stars, covers the portion of the path in which the motion of Eros was mainly in right ascension (R.A. 5^{h} to 10^{h}, Dec. + 44° to + 26°). Teil 2., containing 1635 stars, covers the remainder of the path down to Dec. − 14°, when the motion of Eros was almost entirely in declination. Teil 3., containing 651 stars, is a supplementary list, necessitated by the departure of Eros from the provisional ephemeris.

Down to declination − 14°, the secondary comparison stars for the reduction of plates obtained with long-focus instruments should be selected from the above lists, in order to reduce to a minimum the number of stars for which positions will have to be derived.

South of − 14°, a list of secondary comparison stars has not been prepared, and stars of appropriate magnitude should be selected for each plate to give the most suitable distribution for measurement. With a view to the determination of the secondary comparison star places, the path of Eros has been photographed at Bergedorf with the A.G. Astrograph, down to declination − 14°, at Greenwich with the astrographic telescope down to declination − 4°, at Leipzig with the refractor of 3·6 m. focal length down to declination − 13°, at the Cape with the astrographic refractor from declination + 16° to − 25° and at Lick with the 15-foot camera from declination + 11° to − 23°. Of these series, the Cape and Lick series therefore do not cover the northern portion of the path but they are the only ones which cover the southern portion; there are good overlaps with the series obtained at the northern Observatories in order to provide adequate comparison of the secondary star places.

It is hoped that co-operating Observatories which require positions of secondary comparison stars will make their selection of stars with as little delay as possible and forward lists of the stars for which positions are required to the Bergedorf, Greenwich, Leipzig, Cape and Lick Observatories. The measurement of the path plates for the derivation of secondary star positions can then be taken in hand without undue delay.

At Bergedorf the 84 path plates taken in 1930 and 1931 have been already measured. The measurements include all the stars in the three Bergedorf lists of secondary reference stars and, in addition, other reference stars requested by observers of Eros, in all 4500 stars. The reduction of these measurements has been started at Bergedorf, and it is intended to derive the plate constants and to make them available together with the measured rectangular co-ordinates of the stars, in analogy to the catalogues of the Astrographic Chart.

For micrometric observations the requirements differ from those for photographic observations. For the latter a uniform distribution of stars of about the same magnitude is required. But for micrometric observations it is in general necessary to use as comparison star the nearest star to the planet at the time of observation; in poor fields this may necessitate using stars which are fainter than the secondary comparison stars or which are not included in Prof. Schorr's lists. Selections of suitable comparison stars for micrometric observations were prepared by Prof. G. Struve:

Verzeichnis von Anhaltsterne, 2. Ordnung für die Eros-Opposition 1930–31, *Ast. Nach.* **239**, No. 5718.

Ergänzungsliste der visuellen Anhaltsterne, 2. Ordnung für die Eros-Opposition 1930–31, *Ast. Nach.* **240**, No. 5752.

Micrometric observers should send particulars of comparison stars, for which positions are required, to the Observatories which have obtained series of path plates.

3. *Differential Atmospheric Dispersion.* A difference between the colour of Eros and the mean colour of the comparison stars would introduce a systematic error arising from differential atmospheric dispersion, which would enter fully into the derived value of the solar parallax. A knowledge of the colour or effective wavelength of Eros and of primary and secondary comparison stars would therefore be desirable. Unfortunately the information on this important matter is unlikely to be as complete as could be desired.

The spectral types of the primary reference stars, not contained in the Henry Draper Catalogue, have been determined at Harvard and are published in *Harvard Bulletin*, No. 871. These spectral types are given by Prof. Kopff in the definitive catalogue of Primary Reference Stars.

The photo-visual and photographic magnitudes and colour indices of the primary comparison stars north of $-17°$ have been determined by Dr Ross and Mr Zug at the Yerkes Observatory, using a twin 3-inch camera of 21 inches focal length (*Ast. Nach.* **239**, No. 5728). The supplementary stars in List III were not included, as these had not been selected at the time the investigation was carried out. The magnitudes and colour indices of the stars in List II have been determined by Dr Seares, Mr Sitterly and Miss Joyner at the Mt Wilson Observatory, using the 10-inch Cooke triplet (*Astroph. Journ.* **72**, 311). The mean colour index of the stars investigated by Ross and Zug is $+ 0{\cdot}63$, corresponding on their system of colour indices to type G5. The mean colour index of the stars investigated by Seares, Sitterly and Joyner is $+ 0{\cdot}56$, corresponding to spectral type G4. The two investigations thus agree in indicating that the mean colour of the primary reference stars is that corresponding to a spectral type of about G5.

In general, owing to the rapid motion of Eros, the same comparison stars cannot be used for observations made at one place in the evening and the following morning: a displacement of the position of the star image which arises from abnormal colour of a single reference star can therefore be treated partly as an accidental error, increasing the error of the star position. Systematic error in the derived value of the solar parallax will only enter in proportion as the colour of Eros differs from the mean colour of the comparison stars. For the primary reference stars the mean colour is that corresponding to spectral type G5.

In a note entitled "The Observations of Eros, 1930–31. Notes on Methods of Reduction and Publication of Results" (*M.N.R.A.S.* **92**, 12, 1931), observers were recommended to exclude stars of extreme colour and spectral type. This procedure will reduce those effects, arising from differential atmospheric dispersion, which are largely accidental, but unless it results in the mean colour of the comparison stars being brought more nearly into agreement with the colour of Eros, it does little to reduce the more serious systematic effects. It appears also that, if this procedure were to be rigorously followed, it would be necessary to exclude about 25 per cent. of the primary reference stars; this would result in serious loss of weight and increase in accidental error.

The colour index of Eros has been investigated by MM. E. Delporte and P. Bourgeois, *Ast. Nach.* **241**, No. 5784. A colour index of $0^{m}\cdot77$ was found, the magnitudes of Ross and Zug having been used as a basis. This colour index corresponds, on the scale of Ross and Zug, to spectral type G7. This result is a little uncertain, however, as the colour correction of the objective for photographic and photo-visual magnitudes does not appear to have been sufficiently investigated. Accepting the result provisionally, it indicates that Eros is slightly redder than the mean of the primary comparison stars. On the other hand, the exclusion of B, A0 and K5 to M stars makes the mean colour of the comparison stars slightly bluer, as more red than blue stars are excluded; an increase in systematic error would therefore result. It thus appears advisable that no comparison stars should be excluded at present on account of colour, pending further information as to the colour of Eros.

Some photographs were obtained at both Greenwich and the Cape, using a wire grating with equal bar and space, from which some information as to the colour of Eros will be derived. The Chairman of the Solar Parallax Commission desires to receive the results of any further observations bearing upon the colour of Eros. When additional information is available, it may be possible to make a recommendation with regard to the rejection of a number of stars of extreme colour: the numbers of blue and red stars rejected must be adjusted so that the mean colour of the comparison stars will approximate closely to the colour of Eros.

There is practically no information available as to the colours of the secondary comparison stars. Spectra of a number of faint stars in a belt extending to $\frac{1}{2}°$ on either side of the computed path of Eros were classified by Miss Cannon at Harvard Observatory. Unfortunately, at the time these classifications were made, the large departure of the path of Eros from the computed path was not known. The belt within which the classification was made does not therefore cover the region within which secondary comparison stars must be selected. Moreover, the classification is very incomplete: many of the secondary comparison stars selected by Prof. Schorr are too faint for their spectra to be classified on the Harvard photographs.

Bearing upon the mean colour of the secondary comparison stars, Sir Frank Dyson reports that the mean effective wave-lengths of stars near the pole determined with the 30-inch reflector at Greenwich are as follows:

Mag.		λ
10·0–10·4		4342
10·5–10·9		4325
11·0–11·4		4337
11·5–		4334
	Mean	4336

The mean effective wave-length corresponds to type about G1, which is bluer than the mean type found for the primary comparison stars at Yerkes and Mt Wilson. The question also arises as to the effects of galactic latitude and as to how far this result can therefore be regarded as applicable to the stars along the path of Eros.

Comparison of the values of the solar parallax from observations with long and short focus instruments and from observations with photographic instruments and visual instruments used in conjunction with a colour screen should prove of interest.

4. *The Definitive Ephemeris of Eros.* A provisional ephemeris of Eros, for the period covered by the observations, was computed by Prof. Witt. This ephemeris was based on the elements derived by E. Noteboom ("Beiträge zur Theorie der Bewegung des Planeten 433 Eros," *Ast. Nach.* **214**, Nos. 5122–3, 1921). Noteboom's investigation was based upon observations of Eros extending from 1893 to 1914 and at the end he remarks: "Die Bahnelemente des Planeten selbst und die Erdmasse glaube ich aber mit einer Genauigkeit bestimmt zu haben, die selbst für eine derartige Untersuchung ausreichen wird." Noteboom's elements were brought forward by Prof. Witt from the initial epoch 1898 August 2·0, M.T. Berlin, applying perturbations due to Venus, the Earth, Mars, Jupiter and Saturn and secular changes arising from the action of Uranus and Neptune.

The ephemeris was published month by month in the *Ast. Nach.* as follows: 1930, Oct. No. 5729; Nov. No. 5736; Dec. No. 5743; 1931, Jan. No. 5753; Feb. No. 5760; Mar. No. 5764; April and to May 18, No. 5772. The early observations showed an unexpected discordance from the ephemeris. Prof. Witt found that the observations could be approximately represented if the mean anomaly was decreased by 74″. A provisional correction of this amount was therefore applied in the computation of the ephemeris and the later observations were then fairly well represented. The cause of the discordance has not yet been satisfactorily elucidated; its magnitude was surprisingly large when the close representation by Noteboom's elements of the observations from 1893 to 1914 is considered (vide *Ast. Nach.* **214**, No. 5122, Tafel 4). The ephemeris gives the following data: R.A. and Dec. at intervals of 0·5 days for 1930·0; the reduction to the barycentre in R.A. and Dec.; precession + nutation in R.A. and Dec.; aberration in R.A. and Dec.; the light time in minutes and seconds and also in decimals of a day; log Δ; log r; the magnitude and phase.

Prof. Witt has undertaken the investigation of the orbital elements and the computation of the definitive ephemeris of Eros. Observations near the recent opposition are available from 1930 Aug. 26 to 1931 June 30, so that a long arc of the path is available. The computation of provisional perturbations has been completed. Normal places of Eros from the observations around opposition have been computed, and the computation of provisional improved elements of Eros will shortly be undertaken. Prof. Witt has also undertaken the computation by special perturbations of an accurate ephemeris of the Sun; this is required for the investigation of the mass of the Moon, since Newcomb's Tables of the Sun are not sufficiently accurate for this purpose. This work is being carried out, under Prof. Witt's direction, by Dr von Schelling. The computation of this ephemeris, at 4-day intervals, by numerical integration of the equations of motion has been completed and the integration for each second day is in progress. The computation of the planetary perturbations was carried out by Encke's method, at 8-day intervals, for Mercury, Venus, Mars, Jupiter and Saturn, the small secular perturbations due to Uranus and Neptune being omitted at this stage, as they were not included in Newcomb's Tables of the Sun. These secular perturbations will be applied later. The data given on pp. 9–17 of Newcomb's Tables of the Sun were used as the basis for the computations: the Tables themselves have been used only as a control. In general, there is good agreement between the computed values of the perturbations and the values derived from the Tables, except in the case of Venus, where some of the differences are considerably larger than can be accounted for by errors of interpolation. The cause of this discordance has not yet been investigated. The computed ephemeris has again shown, as was previously shown by Lagarde and Noteboom, that there are uncertainties in the longitudes derived from Newcomb's Tables of about $\pm 0''\cdot 05$. There are appreciable errors also in the latitudes. What has proved surprising is the periodic run in some of the discordances. In order to check that errors in the computations of the perturbations were not the cause of these periodic runs, these were recomputed at 4-day intervals backwards from the epoch of osculation, 1931 January 18. The values thus derived differed only 1 to 2 units in the tenth decimal place from the original 8-day values, which had been computed independently by Prof. Witt and Dr von Schelling. Prof. Witt states that the final rectangular co-ordinates of the Sun will not be liable to computational errors of more than 2 units in the ninth decimal place. Observations of the Sun during the period of the Eros observations will be utilized to derive a correction to Newcomb's mean longitude. Prof. Witt has received a grant from the Akademie der Wissenschaften, Berlin, in aid of these computations. A sum of £50, granted by the Executive of the International Astronomical Union, for the work of the Solar Parallax Commission, has also been used to further these computations.

The preliminary computations, calculation of perturbations, etc. are well in hand and it is probable that the definitive ephemeris of Eros will be available before the reductions of the various series of observations obtained near the recent opposition have been completed. The ephemeris will be barycentric and will be referred to the mean equinox of 1930·0. The lunar equation will be given separately.

5. *Instructions to Observers.* Several notes were published prior to the commencement of the observations to bring various points of importance to the notice of observers and to secure, as far as possible, general uniformity.

A note by G. Witt and A. Kopff, "Bemerkungen zur Beobachtung des Planeten Eros bei der Opposition 1930–31" (*Ast. Nach.* **237**, No. 5680), was concerned mainly with micrometric observations. The observation of rectangular co-ordinates rather than of distance and position-angle was recommended and, in right ascension, micrometric measures were urged in preference to observations by transits. A note by H. Spencer Jones, "Observations of Eros at the Opposition 1930–31" (*Ast. Nach.* **239**, No. 5736; *A.J.* **40**, No. 933; *M.N.R.A.S.* **90**, 724), dealt more particularly with photographic observations. Other points of importance were referred to by F. W. Dyson, "Note on the Observations of Eros" (*Ast. Nach.* **240**, No. 5737), and by G. Struve, "Mikrometrische Beobachtungsmethoden für Eros in der Opposition 1930–31" (*Ast. Nach.* **239**, No. 5726).

A further note dealing with various points connected with the reduction of the photographic observations and with the method of publishing results, to secure uniformity as far as possible, has been published by H. Spencer Jones, "The Observations of Eros, 1930–31. Notes on Methods of Reduction and Publication of Results" (*M.N.R.A.S.* **92**, 12, 1931). In preparing results for publication, the observed place of the planet should be corrected first to geocentric place (correction for diurnal parallax), then to barycentric place (correction for lunar equation, computed for the actual time of observation, not for the antedated time) and the circular aberration terms are to be added. The position so obtained is to be compared with the antedated position of the planet derived from the barycentric ephemeris.

6. *Variation in Brightness of Eros and Physical Observations.* The early observations of Eros showed an appreciable range of variation. Published observations by different observers of the amplitude of the variation are somewhat discordant,

and it is possible that there were irregular variations in the amplitude. Thus L. Jacchia reports an amplitude of $1^m{\cdot}08$ on 1930 Nov. 12; of $0^m{\cdot}78$ on Nov. 13 and of $1^m{\cdot}20$ on Nov. 14 (*Ast. Nach.* No. 5761). Such variations in amplitude are greater than can be accounted for by errors of observation. In the mean the amplitude of variation appears to have increased gradually from less than one magnitude early in October until about the middle of December when it was $1^m{\cdot}5$ or even greater (Zessewitsch and Florja, *Ast. Nach.* No. 5814, give amplitude 1930 Dec. 1–11, of $1^m{\cdot}5$; Jacchia, *Ast. Nach.* No. 5764, gives amplitude 1930 Dec. 11–12, of $2^m{\cdot}25$). Thereafter the range of variation decreased rapidly and by the middle of January was only about $0^m{\cdot}5$. There was subsequently a further slow decrease, and by the end of March the amplitude was only about $0^m{\cdot}25$. (Cox and Dufour find for the photographic range, December 22–23, $1^m{\cdot}44$; December 25–26, $1^m{\cdot}11$ and $0^m{\cdot}87$; December 28–29, $1^m{\cdot}6$; January 24–25, $1^m{\cdot}8$; January 27–28, $0^m{\cdot}6$ and $0^m{\cdot}4$. Rigaux finds for the visual range, December 26, $0^m{\cdot}5$. There is some evidence for variation of the colour index during the period of light variation.)

The period of variation appears to have been constant and equal to about $5^h16^m9^s$. There were two minima in a complete period of rotation, the principal minimum being deeper than the secondary minimum. Observations published up to the end of January are well represented by the elements given by R. Müller (*Ast. Nach.* No. 5768), viz.

Principal minimum	J.D. 2426266·9999 +	$0^d{\cdot}219552$ E.
Secondary minimum	J.D. 267·1108 +	·219555 E.

It is possible that photographic observations taken at the time when the magnitude of Eros was changing rapidly may prove discordant, as the centre of the small trail on the plate due to the motion of the planet may not correspond to the mid-time of the exposure.

Where occulting shutters were used to reduce the magnitude of Eros, it was possible to make approximate allowance for the variation of brightness. This procedure was followed, e.g. at the Cape, where the shutter opening for each plate was adjusted to bring the images of Eros into approximate equality with those of the comparison stars.

Of interest in connection with the variations of brightness are the observations of W. H. v. d. Bos and W. S. Finsen (*Ast. Nach.* **241**, No. 5780) who found from observations with the 26½-inch visual refractor of the Union Observatory that Eros appeared to be of a figure-of-eight shape, resembling a nearly separated double star with a distance of $0''{\cdot}18$. They found, moreover, that the direction of elongation made a complete revolution in 5^h17^m, i.e. in the period of variation of brightness. This observation renders it probable that the variation is due to unequal surface brightness of different portions of the planet's disc. The change in the amplitude of variation would be accounted for by change in the Earth's position with respect to the pole of the axis of the planet's rotation. An inequality in the place of the planet, depending on the light-variation, will need to be looked for, though no definite evidence of such an inequality was found in the discussion of the 1900–1 observations.

7. *Summary of Observations obtained for the Determination of the Solar Parallax and of the Mass of the Moon.* A summary of the observations obtained at different Observatories which can be utilized for the derivation of the solar parallax and of the mass of the Moon is given below. Reports from a few Observatories have not yet been received, and several others have not supplied the full information asked for.

The weather conditions throughout the period available for observations were particularly bad in middle and northern Europe generally. Observatories which had intended to take a large share in the programme were able to do very little. The amount of material obtained by European Observatories was thus unfortunately much less than had been anticipated. Fortunately somewhat better conditions prevailed in the United States and in Southern Europe. In the southern hemisphere, where observations were obtained in the summer, good series of observations were made at Cordoba, La Plata and the Cape, though a particularly bad spell of definition was encountered at the Cape.

The photographic material is somewhat scanty until near the end of December, with a number of days when no observations were obtained at any Observatory. Sufficient material is available, nevertheless, for a good representation of the path of Eros, which is of importance for the mass of the Moon. Towards the end of December, Observatories in the southern hemisphere began to participate in the programme, and from early January until the end of March the material is very abundant, observations being available for every day of this period. From the middle of January to the middle of February, the material is most plentiful, Eros being accessible at this time to both the northern and southern Observatories. During this period, thirty or more plates are available almost every day. After the end of March, the material becomes much less plentiful and during April there are several days without observations. A number of observations were obtained in May for the purpose of providing positions of Eros over as long an arc as possible with a view to the investigation of the orbital elements. The amount of photographic material is such that both the solar parallax and the mass of the Moon should be derived with considerable weight.

The amount of micrometric material available is very much less than the amount of photographic material. At the opposition of 1900–1, the micrometric observations gave a value of the solar parallax having a weight not greatly inferior to that given by the photographic observations. The relative distribution between photographic and micrometric of the total material obtained at the last opposition emphasizes the extent to which visual observations have been replaced by photographic; a number of large visual refractors are now engaged entirely upon photographic observations, using a colour filter. A moderate number of micrometric observations are available during the months of January and February, but otherwise the number is small and there are many gaps.

In addition to observations at large east and west hour angles, to provide material for the determination of the solar parallax by the diurnal method, three co-operative schemes were arranged between northern and southern Observatories to secure nearly simultaneous observations and so to eliminate errors arising from uncertainties in the reference star places. Greenwich, Bergedorf, Radcliffe and Cambridge Observatories in the northern hemisphere co-operated with the Cape and the Yale station in Johannesburg, in simultaneous photographic observations with long-focus instruments, whilst Eros was near the meridian; also Greenwich, Bergedorf, Leipzig and Algiers co-operated with the Cape and Harvard station near Bloemfontein, in similar observations with instruments of astrographic focal length. The Berlin-Babelsberg Observatory and the Union Observatory, Johannesburg co-operated in a programme of simultaneous micrometric observations using the same comparison stars. Owing to the prevailing bad conditions in Europe during the period of these observations, the number of nights when both northern and southern observations were obtained falls considerably short of what had been hoped. Sufficient material was obtained, nevertheless, to provide an independent determination of the solar parallax with fair weight.

Photographic Observations.

Greenwich. Thompson refractor (66 cm. aperture : 684 cm. focal length). 50 plates at large easterly hour-angles on 14 nights; 60 plates on the meridian or at small westerly hour-angles, on 16 nights. First plate Oct. 13; last plate Jan. 31.

Astrographic refractor (33 cm. : 343 cm.). 130 plates at large easterly hour-angles on 36 nights; 90 plates on the meridian or at small westerly hour-angles on 31 nights. First plate Oct. 9; last plate Jan. 31. Normally three or four exposures on Eros per plate.

Radcliffe. Photographic refractor (61 cm. : 686 cm.). 51 plates near the meridian on 11 nights; normally four exposures on Eros for each plate. First plate Jan. 2; last plate Feb. 8.

Cambridge. Equatorial coudé (30·5 cm. : 590 cm.). 20 plates near the meridian on 7 nights; about eight exposures per plate. First plate Jan. 9; last plate Jan. 30. There were also 9 plates on 7 nights on which Eros was not shown. The rapid deterioration in the surface of the flint lens of the objective at this time reduced the transparency. After the conclusion of the programme the lens was sent away to be refigured.

Bergedorf. Photographic refractor (60 cm. : 900 cm.). 12 plates on 4 nights, Jan. 9 to 27, at various hour-angles. About four exposures per plate.

Lippert Astrograph (34 cm. : 340 cm.). 22 plates on 15 nights between Sept. 27 and Jan. 27, mainly at eastern hour-angles; two to five exposures per plate.

A.G. Astrograph (15·3 cm. : 206 cm.). 10 plates on 4 nights, Dec. 31 to Jan. 27, at various hour-angles; about six exposures per plate.

Reflector (50 cm. : 300 cm.). 4 plates on the night of Jan. 26–27, near meridian, thirty exposures.

Leipzig. Photographic refractor (30 cm. : 360 cm.). 32 plates on 17 nights between Oct. 15 and Feb. 10, mainly at eastern hour-angles, but on 3 nights at large western hour-angles. Exposures on Eros per plate range from one to eight.

Bordeaux. Astrographic refractor (33 cm. : 340 cm.). 13 plates on 6 nights between Dec. 19 and Apr. 14, mainly easterly hour-angles. Two exposures per plate.

Uccle. Zeiss Astrographic triplet (30 cm. : 150 cm.). 45 plates on 19 nights between Nov. 27 and Jan. 25, at various hour-angles. One exposure per plate. Also a series of 19 plates, each with one exposure, on the night of Jan. 24–25, taken primarily to study the light-variation.

Astrographic refractor (29 cm. : 343 cm.). 9 plates on 7 nights between Dec. 2 and Jan. 14, at eastern hour-angles or near meridian. About three exposures on Eros per plate.

Algiers. Astrographic refractor (33 cm. : 343 cm.). 34 plates between Oct. 8 and Dec. 27, generally with three exposures of Eros in each of four orientations of plate, photographed near meridian.

Between Dec. 27 and Mar. 17, 65 plates on 39 nights, with four exposures of Eros in each of four orientations of plate. Also 94 plates exposed film-down, with eight exposures of Eros in the same orientation of plate, but after Mar. 2, in each of two orientations. All exposures near meridian.

Between Mar. 17 and May 15, plates obtained near meridian, with three exposures of Eros in each of four orientations of plate. The number of nights in March is not reported; plates were obtained on 12 nights in April and on 12 nights in May.

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Catania. Astrographic refractor (33 cm. : 347 cm.). 86 plates obtained between Oct. 22 and Mar. 22 on 63 nights, with from one to nine exposures on Eros per plate. On 51 nights, exposures were obtained at eastern hour-angles greater than 2^h, and on 14 nights exposures were obtained at western hour-angles greater than 2^h.

San Fernando. Astrographic refractor (33 cm. : 346 cm.). 13 plates obtained on 11 nights between Jan. 20 and Feb. 20. No details are available as to hour-angles at which plates were obtained or number of exposures per plate.

Prague. Astrographic refractor (21 cm. : 340 cm.). 16 plates obtained on 8 nights between Jan. 10 and Mar. 5, with generally three exposures per plate, and at varying hour-angles.

Pulkovo. Astrographic refractor (33 cm., stopped down to 29·4 cm. : 346 cm.). 20 plates on 12 nights between Nov. 2 and Jan. 21, at varying hour-angles. Three or four exposures per plate.

Allegheny. Photographic refractor (76 cm. : 1410 cm.). 146 plates obtained on 33 nights between Nov. 21 and Feb. 16, at varying hour-angles. On 14 nights plates were obtained at both eastern and western hour-angles. There are usually five or six images of Eros per plate.

Dearborn. Visual refractor with colour filter (46 cm. :). 246 plates obtained on 53 nights between Dec. 9 and May 14, at varying hour-angles. On many nights plates were obtained at both eastern and western hour-angles. The number of images of Eros per plate varies from one to sixteen.

Leander McCormick. Visual refractor with colour filter (66 cm. : 1000 cm.). 34 plates obtained on 19 nights between Jan. 9 and Feb. 26, at various hour-angles. The number of images of Eros on one plate varies from three to fourteen.

Lick. Crossley reflector (91·4 cm. : 536 cm.). Panchromatic plates used with yellow-orange filter. 73 plates obtained on 15 nights between Jan. 10 and Feb. 12. On 12 nights plates were obtained at both eastern and western hour-angles, with the zenith distance of Eros about 65°. The number of exposures on Eros was normally four or five.

15-foot camera (12·7 cm. : 457 cm.). 12 plates obtained on 12 nights between Jan. 18 and Feb. 25, each having exposures at large eastern and at large western hour-angles. Normally three or four exposures on Eros were given both evening and morning. These plates, which have a field of 5° square, are intended also to provide positions of faint comparison stars for the reduction of the Crossley photographs.

Swarthmore. Visual refractor with filter (61·0 cm. : 1100 cm.). Full details not available. Owing to unfavourable weather conditions, only a few plates were obtainable. On one night, sixty exposures were made, with good images.

Yerkes. 24-inch reflector (59·5 cm. : 236 cm.) and the 12-inch refractor (30·5 cm. : 551 cm.) were used to obtain occasional plates, but only in an incidental manner. No further details have been received.

Washington. Visual refractor (30·5 cm. : 459 cm.) used with colour filter and yellow sensitive plates. 50 plates were obtained on 18 nights between Dec. 16 and Mar. 24, at various hour-angles. On several nights, plates were obtained at both eastern and western hour-angles. There are from one to four images of Eros per plate.

Van Vleck. Photographic refractor (50·8 cm. : 850 cm.). 156 plates obtained on 33 nights between Dec. 16 and Mar. 14. In general there are eight images of Eros per plate. About half the nights have exposures at both eastern and western hour-angles.

Zô-Sé. Photographic refractor (40 cm. : 690 cm.). 44 plates obtained on 37 nights between Oct. 4 and Mar. 23. Number of exposures per plate varies from two to nine. Exposures mainly at eastern hour-angles or near meridian.

Tokyo. Photographic refractor (65 cm. : 1021 cm.). 92 plates obtained on 48 nights between Oct. 29 and Apr. 23, at wide range of hour-angles. The average number of exposures on Eros per plate is seven.

Lembang. Photographic refractor (60 cm. : 1072 cm.). 80 plates obtained on 23 nights between November 24 and February 20. The range of hour-angle on any one night is small. The number of exposures on Eros per plate varies from one to five.

Hyderabad. Photographic refractor (20·3 cm. : 350 cm.). 212 plates were obtained between January 8 and March 4. Of these 148 were obtained at large east and west hour-angles, and 64 near the meridian. The number of images per plate varies from eight to eleven. The exposure time for each image was 2 minutes.

Cape. Photographic refractor (61 cm. : 686 cm.). 24 plates were obtained on 11 nights between Jan. 1 and Jan. 16, near the meridian in co-operation with northern Observatories and for the path of Eros. From Jan. 17 to Mar. 31, 304 plates were obtained at large eastern and western hour-angles and 110 plates were obtained near the meridian on 69 nights in all. The former were mainly for the determination of the solar parallax, the latter were partly for the determination of the solar parallax in co-operation with northern Observatories and also for the determination of the path of Eros and of the mass of the Moon. From Apr. 1 to May 17, 37 meridian plates were obtained on 29 nights for the determination of the path of Eros and of the mass of the Moon. Normally, on each night 3 plates were obtained at both eastern and western hour-angles, and 2 plates were obtained on the meridian. The number of exposures on Eros was generally six per plate for the east and west plates and twelve per plate for the meridian plates.

Astrographic refractor (33 cm. : 343 cm.). 35 meridian plates were obtained on 12 nights between Jan. 1 and Jan. 15. From Jan. 16 to Mar. 31, 468 plates were obtained at large eastern and western hour-angles and 147 plates were obtained near the meridian, on 72 nights in all. During April 28 meridian plates were obtained on 23 nights. Normally, on each night 4 plates were obtained at both eastern and western hour-angles and 3 plates were obtained on the meridian. The number of exposures on each plate was generally six per plate for the east and west plates and twelve or more per plate for the meridian plates.

Yale (*Johannesburg*). Photographic refractor (66 cm. : 1100 cm.). 59 plates were obtained on 40 nights between Jan. 3 and Apr. 29. All plates were taken near the meridian, partly in co-operation with northern Observatories and to provide material for the determination of the path of Eros and of the mass of the Moon. The average number of exposures on Eros is eight per plate.

Harvard (*Boyden Station*). Bruce refractor (61 cm. : 340 cm.). 71 plates were obtained on 38 nights between Jan. 13 and Apr. 27, some on the meridian in co-operation with northern observers and others at east and west hour-angles. The number of exposures on Eros per plate varies from three to sixteen.

Union Observatory. Franklin-Adams II Telescope (25·4 cm. : 233 cm.). 176 plates were obtained on 89 nights between Dec. 21 and May 17. The series includes 129 plates obtained near the meridian between Dec. 21 and May 17, and 47 plates at large eastern and western hour-angles between Jan. 29 and Mar. 15. Normally, one colour-sensitive plate was exposed through a yellow screen when Eros was about 4^h E. of the meridian; one ordinary plate when Eros was approaching the meridian; one colour-sensitive plate through screen when Eros was on the meridian; and one colour-sensitive plate through screen when Eros was about 4^h W. of the meridian. Each plate has generally six images of Eros on it.

Melbourne. Astrographic refractor (33 cm. : 343 cm.). 43 plates were obtained on 16 nights between Jan. 13 and Feb. 12, at various hour-angles. The number of exposures per plate ranges from one to eighteen.

Sydney. Astrographic refractor (33 cm. : 343 cm.). 17 plates were obtained on 14 nights between Jan. 22 and Feb. 25 at the branch Observatory at Pennan Hills. There are four or six exposures of Eros on each plate. Unfortunately, the observer did not realize the necessity of recording the exact time of beginning and ending each exposure; in consequence the plates cannot be used.

Wellington. Photo-visual refractor (23 cm. : 386 cm.). 18 plates were obtained by amateur assistance between Jan. 15 and Feb. 15. Four plates were rejected; the presence of Eros on four others is doubtful and for one plate the times of exposure were not noted. There are one to four exposures per plate.

Cordoba. Astrographic refractor (33 cm. : 343 cm.). Between Jan. 16 and Mar. 27, 112 plates were obtained near the meridian and 172 plates were obtained at east and west hour-angles on a total of 43 nights. Normally, 3 plates were obtained at large eastern hour-angles, 3 near the meridian and 3 at large western hour-angles. There are generally five images per plate. From Apr. 1 onwards, observations were restricted to near the meridian, to provide additional material for the path of Eros and the determination of the mass of the Moon. During April, 22 plates were obtained on 11 nights. Details of later observations have not yet been received.

La Plata. Astrographic refractor (34·2 cm. : 340 cm.). The programme of observations was divided into three parts. (1) Refraction series. 18 plates were obtained on 18 nights between Jan. 8 and Feb. 6, with generally five or six exposures on Eros per plate. These plates were taken at a zenith distance of about 75°. (2) Parallax series. 54 plates were obtained on 30 nights between Jan. 8 and Mar. 14, with from four to ten exposures per plate. These plates were obtained at large eastern hour-angles, with Eros at zenith distances between 65° and 60° and were intended for combination with plates taken approximately simultaneously in Europe or North Africa. (3) Meridian series. 48 plates were obtained on 34 nights between Jan. 8 and Apr. 28. The exposures range from two to ten per plate. These plates were obtained for position of Eros and to provide material for the determination of the mass of the Moon.

The co-operation of the University Observatory, Oxford, had been promised but, owing to the death of Prof. Turner, the Observatory was not able to take part in the programme. There remain a few Observatories, believed to have participated in the programme, from which reports have not yet been received.

Micrometric Observations.

Berlin-Babelsberg. Zeiss refractor (65 cm. : 1040 cm.). Observations were obtained on 54 nights between Aug. 26 and Apr. 25. There were 39 groups in which two co-ordinates were measured, and 365 groups in which one co-ordinate was measured. p and s or x or y were measured; a minimum of six settings, but more usually ten or twelve settings, forms a group. There was no deliberate division into east, west and meridian groups. Observations were obtained whenever the state of the sky permitted. Many observations were obtained with large eastern hour-angles, but none were obtained at western hour-angles exceeding 2 hours.

Heidelberg. Visual refractor (32·5 cm. : 422 cm.). Observations were obtained on 19 nights between Sept. 28 and Feb. 14, mostly at large eastern hour-angles. In general one group was obtained per night, involving five measures in x and ten in y, but on 3 nights measures in y only were obtained.

Vienna. Grubb refractor (68 cm. : 1058 cm.). 31 groups of measurements were obtained on 7 nights between Dec. 19 and Feb. 10, at eastern hour-angles or near the meridian. One group comprises about eight measures of x or about five measures of y.

Besançon. Equatorial coudé (33 cm. : 658 cm.). 15 sets of observations were obtained on 10 nights between Nov. 15 and Feb. 18.

Arcetri. Visual refractor (36 cm. : 539 cm.). 35 groups were observed on 19 nights between Jan. 8 and Feb. 12, at various hour-angles. Each group consists of about eight measures in x and eight measures in y.

Padova. Visual refractor (18·7 cm. : 320 cm.). 115 groups were observed on 31 nights between Dec. 4 and Feb. 25, including observations at large hour-angles, both east and west. The x co-ordinates were measured by the method of transit, the y co-ordinates micrometrically. In general, a group is composed of ten sets of measures, a set consisting of five transits for x and one or two measures for y.

Teramo. Cooke refractor (39·4 cm. : 592 cm.). 102 groups were observed on 24 nights between Dec. 6 and Apr. 1, including observations at large hour-angles both east and west. x and y co-ordinates were measured; each group comprises from four to eight measures in x and four or five measures in y.

Milan. Merz-Repsold refractor (49 cm. : 698 cm.). 97 groups were observed on 32 nights between Nov. 12 and Feb. 10; the earlier observations are mainly at eastern hour-angles; the later observations are at various hour-angles. x co-ordinates were determined by transits, y co-ordinates by micrometric measures. Each group comprises about six sets of measures, a set involving five to seven measures of each co-ordinate.

Lisbon (Tapada). Merz-Repsold refractor (38·2 cm. : 682 cm.). 77 groups were observed on 29 nights between Dec. 18 and May 13, at various hour-angles. x and y co-ordinates were measured micrometrically. Each group comprises about five measures of both x and y.

Washington. Warner and Swasey refractor (66 cm. : 990 cm.). 101 groups were observed on 48 nights between Dec. 31 and June 30. The later observations are primarily for determining the path of Eros over as long an arc as possible, to provide material for an accurate determination of the orbital elements. x co-ordinates were determined by transits, y co-ordinates by micrometric measures. Each group consists of from sixteen to forty measures of x and from four to ten measures of y.

Yerkes. 40-inch refractor (101·6 cm. : 1934 cm.). Micrometric observations were obtained on 5 nights between Aug. 22 and Feb. 1. On a number of other nights, Eros was examined but no measures were made because no comparison stars were sufficiently near. No further details have been received.

Kwasan. Cooke refractor (30 cm. : 455 cm.). 47 groups of observations were obtained on 39 nights between Oct. 12 and May 19. 19 groups were obtained at eastern hour-angles, with Eros at about 60° zenith distance; 11 groups were obtained at western hour-angles, with Eros at about 60° zenith distance. The remaining groups were obtained near the meridian. In general, each group consists of ten micrometric measures of both x and y, but on the first 3 and last 2 nights of observation, x was determined by transits. For one group, only y was measured.

Union Observatory. Grubb refractor (67·3 cm. : 1070 cm.). 82 groups were observed on 26 nights between Dec. 22 and Mar. 6. Normally a group comprises twenty micrometric measures of x and ten micrometric measures of y; in two groups, the x measures are lacking. The observations were obtained over a wide range of hour-angles.

La Plata. Visual refractor (43·3 cm. : 960 cm.). All observations were made through a yellow filter. Forty-nine groups were observed on 21 nights between Jan. 7 and Feb. 20. Both x and y were measured micrometrically; in general, one group comprises from twelve to sixteen measures of both x and y. A few groups consist of measures in one co-ordinate only.

8. It is hoped that the Observatories which have co-operated will not delay unduly the measurement of photographic plates, the reduction of the observations and the publication of the results. Where stars, other than those contained in Kopff's catalogue, have been or will be used as reference stars in micrometric observations or in the measurement of photographic plates, details should be sent at the earliest possible date to the Observatories which have series of path plates.

After the Opposition of 1900–1, the combination and discussion of the results obtained at different Observatories were rendered unnecessarily difficult owing to the many different methods in which the observations had been reduced. It is hoped that this difficulty will be avoided on the present occasion by a uniform system of reduction and publication; co-operating Observatories are urged to follow the method of reduction and publication given in the note in the *M.N.R.A.S.* 1931 November.

The Commission propose to entrust the discussion of the combined observational material obtained at the recent Opposition to Dr H. Spencer Jones and Prof. G. Witt.

H. Spencer Jones
President of the Commission