24. COMMISSION DES PARALLAXES STELLAIRES ET DES MOUVEMENTS PROPRES

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MEMBRES: MM. W. S. Adams, Alden, Cecchini, Finsen, Hertzsprung, Mlle Hoffleit, MM. A. Hunter, C. Jackson, Lindblad, Luyten, Mitchell, W. W. Morgan, Nechvíle, Russell, Shapley, Smart, Stearns, Van de Kamp, van Rhijn, Voûte, Vyssotsky, Wagman.

TRIGONOMETRIC PARALLAXES

The determination of stellar parallaxes photographically using occulting shutters initiated by Schlesinger at Yerkes in 1903 and taken up vigorously at a number of observatories in the northern hemisphere about 1913 and in the southern hemisphere about 1925 has resulted in the determination of more than 9000 parallaxes relating to more than 5000 stars.

The position at the end of 1947 compared with that at the end of 1934 (as shown in *I.A.U. Transactions*, Vol. **5**, 149) is approximately as follows, although for want of official figures some of the data are only estimates.

		Parallaxes determined to	
Observatory	Commenced	1934	1947
Allegheny	1914	1302	1660
Bosscha	—	150	(150)
Cape	1926	620	1525
Dearborn	1913	193	(193)
Greenwich	1913	583	(760)
McCormick	1914	1160	1808
Mount Wilson	1913	394	550
Sproul	1912	340	400
Stockholm	1933	—	46
Uppsala	1894	17	(50)
Van Vleck	1925	94	203
Yale	1925	1174	1550
Yerkes	1903	373	402
	Total	6400	(9297)

In addition there must be plates available for several hundred additional stars.

The increase in the number of trigonometrical parallaxes since the publication of the Yale *General Catalogue* (2nd edition, 1935) is nearly 50%, and I have therefore raised the question of a new edition or supplement. Members of the Commission are agreed that such a compilation is most desirable and there is a general agreement that the second edition is on such a good basis that a new edition could be satisfactorily based on the earlier one. I think most astronomers consider that the system of probable errors adopted by Schlesinger in forming the Catalogue reflects the actual errors better than those published by most of the observers. Although it may be that later lists with observations extending over more epochs than the earlier ones, and often depending on more plates, have truer probable errors there is much to be said for leaving the system unchanged.

The work of preparing a new catalogue or supplement will be very considerable and on a suggestion that Miss Jenkins who collaborated with Prof. Schlesinger would be most suitable to carry out the work I wrote to Prof. Brouwer who answered:

Upon receipt of your letter of November 6 Miss Jenkins made at once a survey of the new parallax material that could be considered ready for publication in an appendix to the *General Catalogue of Parallaxes*. She made counts in six half-hour stretches of right ascension,

$0^h\ 0^m$ to $0^h\ 30^m$, $4^h\ 0^m$ to $4^h\ 30^m$, etc. By multiplying the numbers by eight she arrived at the following numbers:

New stars with trigonometrical parallaxes	1008
Old stars with revised trigonometrical parallaxes	824
First trigonometrical parallax of stars for which spectroscopic or dynamical parallaxes were published in the *General Catalogue*	344
New stars with spectroscopic parallaxes	464
Revised spectroscopic parallaxes	736
Total	3376

Allowing for some overlapping in these five groups it would appear that an appendix prepared at this time would have approximately 3000 entries. This is a good deal more than either Miss Jenkins or I would have guessed before this count was made, and we are inclined to believe that the time has come for preparing such an appendix, which Miss Jenkins would be quite willing to undertake. She would propose to follow the same system as was used in the *General Catalogue*, without going to a revision of the system of weights and systematic corrections.

Prof. Brouwer added that he had considered a supplement rather than a new edition on grounds of economy of time and money.

Members might like to have the distribution of stars in the 2nd edition of the Yale *General Catalogue* according to probable error of the trigonometric parallax. This is

Up to $\pm''\cdot006$	939
$\pm''\cdot007$ and $\pm''\cdot008$	1032
$\pm''\cdot009$ and $\pm''\cdot010$	1353
$\pm''\cdot011$ and $\pm''\cdot012$	480
$\pm''\cdot013$ and $\pm''\cdot014$	107
$\pm''\cdot015$ and $\pm''\cdot016$	22
$\pm''\cdot028$	1
	3934

Although it will be seen from the figures given above that there has so far not been a great falling off in the work there has been a growing feeling that the bulk of the work of determining parallaxes trigonometrically has already been completed. From letters received there is a decided disinclination to undertake new heavy observing programmes of a general nature, although it is admitted that there is still a lot of work which can be profitably carried out. The position is something like this. All the brighter stars (down to magnitude 5·5), except some early-type stars, have been observed. In addition a very considerable number of selected fainter stars have been observed. These are for the most part stars for which a considerable parallax might be expected on account of large proper motion. But other stars have been included for other reasons, e.g. large dynamical or spectroscopic parallax. Recent additions to the working lists of several observatories contain an increasing proportion of faint stars for which Luyten has determined a proper motion exceeding $0''\cdot5$. (The Cape working list contains about 360 stars of which a third are faint stars from Luyten's list, a third are stars being re-observed because the parallax already found exceeds $0''\cdot100$ and the other third a miscellaneous collection.)

There is general regret that after Van Maanen's death the determination of the parallaxes of very faint stars with the Mount Wilson reflectors has been dropped. There is certainly important work to be done by at least one large reflector in determining the parallax of stars too faint for observation with refractors. The practical limit with photographic refractors is not much fainter than 14·0 and certainly stars fainter than 15·0 are out of the question.

From letters received the stars most in need of observation at present are

(1) Faint (and very faint) stars of large (or very large) proper motion.

(2) Stars with definitely dwarf characteristics (M type and white dwarfs).

(3) Stars for which existing determinations are discordant.

There is of course a large overlap between (1) and (2). Amongst the M-type stars at present attracting considerable attention are the dwarfs discovered by Vyssotsky and others at McCormick Observatory from their spectra, before their proper motion was known. A few have very small motion (*Ap. J.* **97**, 381, 1943; and **104**, 234, 1946). Included in (3) are a number of bright stars. There are also

(4) Important stars with early determinations from scanty material. Rather more than two thirds of the stars in the *Yale Catalogue* (2nd edition) for which a trigonometric parallax was available depended on observations at a single observatory. The position has probably slightly improved since 1934, but certainly more than half of the stars will have been observed at one observatory only.

More special stars for which observations are requested are

(5) Stars which may not conform to the normal position in the Russell-Hertzsprung diagram.

(6) Wide binaries, especially those with white dwarf components.

(7) Red giants with dynamical parallaxes for which the trigonometric and spectroscopic parallaxes disagree.

(8) Stars in regions of obscuring matter, e.g. Taurus and Orion.

(9) Dwarf variables of the T Tauri and SS Cygni types.

(10) Individual stars specially named and probably already being carefully investigated, ξ Bootis, α and Prox. Centauri.

A number of observers are replacing stars of large parallax on their observing programmes. Such observations are intended not merely to improve the parallax determinations but to investigate possible displacements not due to parallax or proper motion. In the case of visual binaries there is the determination of mass ratios while for other stars there is the discovery of invisible companions. We know too few mass ratios accurately, but their determination is difficult because we are usually unable to wait long enough for them to be disentangled from other unknowns. For the discovery of unseen companions ignorance of the period greatly enhances the difficulty of the problem and in the case of spectroscopic binaries for which a period is known the fact that the two components may be luminous produces further difficulties both by reducing the minute quantities to be measured and by uncertainty in their interpretation when observed. In the case of spectroscopic binaries with periods of the order of a year the size of the orbit will be comparable with the parallax but the displacement to be measured may be greatly reduced by smaller mass of the companion and (or) fusion of images. The number of favourable cases for observation is very small. See especially orbits deduced by Alden in the *Astronomical Journal* and as an example of the work involved when the period is unknown his orbit of δ Aquilæ (*A.J.* **45**, 193, 1936; and *A.J.* **51**, 59, 1944).

When we seek for companions of planetary size, say 0·01 or 0·001 of the mass of the Sun we can, with a yearly period, only expect displacements of about 0·01 or 0·001 of the parallax and with periods of 10 years these ratios are only about five times greater. If α Centauri had a planetary system similar to our own its Jupiter would produce an orbit 0″·004 in size with a period of 12 years on which would be superposed other orbits of a half and a third the size with periods of 29 and 165 years.

Observations of this kind are therefore for the most part confined to stars with a parallax exceeding 0″·100 or 0″·150. It is not necessary to take plates at the time of maximum parallactic displacement. As indicated above, the longer the period the larger the displacement, so that it will not usually be necessary to take plates at very short intervals. But to get the necessary accuracy very large numbers of plates are required (Van de Kamp reports 1200 plates for Barnard's star). Stars for these special investigations must be carefully selected. The Yale (Johannesburg) plan of taking plates at intervals of 7 and 14 years after the epoch of parallax determination should show up stars for which results may be expected in a reasonable time.

During the past 12 years a number of papers have appeared in the *Astronomical Journal* giving determinations of mass ratios and orbits deduced from parallax plates. Some of the

latter appear to be real but in nearly all cases further confirmation is desirable. It is sometimes hardly realized how difficult the problem is of finding orbital motion of the order of a few hundredths of a second of arc. With a proper motion at our disposal we can close almost any set of residuals to give an apparent period the same in both co-ordinates and closely related to the interval covered by the observations. We still want more and more accuracy in our parallax observations and for orbit work on parallax plates with so many variables at our disposal it is clear that long series of observations of the highest accuracy are essential.

When we consider that there are still many important stars requiring a second parallax determination, many faint stars still to be observed and any amount of the highest quality work in investigating orbital motion we can conclude that there is still ample scope for the parallax telescopes even although a number of them have been continuously engaged in this work for more than 30 years.

Attention may be drawn to a series of articles at the beginning of Vol. **51** of the *Astronomical Journal* (also Vol. **52**, 37) and to papers by Van de Kamp in the same *Journal* dealing with frames of reference for observations of fast moving stars extending over a long interval of time. (Vol. **52**, 226, 1947.)

At one time it was considered unnecessary to preserve parallax plates after measurement. In view of the possibility that the plates may be wanted in connection with orbital motion, proper motion or magnitude, etc. it seems desirable not to destroy them if they can be stored.

In 1939 I circularized members of the Commission with regard to the details given in published lists of parallaxes. There was a difference of opinion about changing the standard equinox from 1900.0 to 1950.0, but those who favoured the earlier equinox were more definite in their views and the result has justified them. It was generally agreed by observers that it was better to give for faint stars a magnitude estimated from the exposure time rather than perpetuate a magnitude seriously in error, e.g. Wolf 629 has been given as a star of photographic magnitude 11 or 11·7, 34^s preceding Wolf 630, while it is more nearly a star of magnitude 14, only $3^s{\cdot}4$ preceding Wolf 630. Prof. Schlesinger stated that it was most useful in preparing a general catalogue to have the DM numbers of stars given in the lists.

One of the desiderata of the present time is more information of the physical characteristics of stars for which the parallax has been determined. Many observers are undertaking the determination of proper motion in both co-ordinates and extending this work to the comparison stars and other stars suitably exposed on the plates. It is most desirable to get accurate magnitudes in at least two colours, and there is a wide field for work of this kind especially for the fainter stars. Also we want spectroscopic observations for accurate spectral classification, absolute magnitude and radial velocity. For much of this work the parallax telescopes are not the most suitable instruments and the co-operation of other observers is specially desirable. Useful work of this kind for stars of large proper motion has resulted from Luyten's co-operation with Harvard, Córdoba, and Arizona.

Spectroscopic Parallaxes

The coating of mirrors with aluminium instead of silver should make it possible to utilize additional lines, in the violet end of the spectrum, for the determination of absolute magnitudes.

At Mount Wilson about 5000 spectroscopic parallaxes have been determined although no additional results have been published since 1935. Some of the McCormick M-type dwarfs have been observed.

With the 13-inch Boyden telescope at Bloemfontein in conjunction with an objective prism giving a dispersion of 45 A. to the mm. Harvard Observatory hopes to determine the absolute magnitudes of all stars brighter than visual magnitude 6·6, later than A 5 in type and south of declination −20°. Results have been published for 300 M-type stars (some in northern hemisphere) and 365 K-type stars (*HC* 448, 449). Results for several

hundred F-type stars should be ready shortly, while many plates have been taken. Some plates show stars to apparent magnitude 7·5.

At Yerkes an extensive programme for the observation of northern B-type stars has been undertaken. Approximately 700 of the brightest have been observed and it is planned to observe all stars brighter than magnitude 6·5. Spectroscopic absolute magnitudes and parallaxes for 75 O9–B5 super-giants and 52 B stars with interstellar lines are ready for publication. *Stockholm Annals*, Vol. **13**, No. 9 (1941), contains spectrophotometric determinations of stellar luminosities for stars in the Hyades and Praesepe down to photographic magnitude 13·5. Further work of the same type is being done in the Lacerta region, Selected Areas and open clusters.

Dynamical Parallaxes

No further lists of dynamical parallaxes have been published. These must depend on double star observations.

Proper Motion

In the last 10 years a great deal has been accomplished in the determination of proper motions by photography. Most important for parallax observers is the discovery of stars of large proper motion. In this field the work of Luyten carried out on plates taken with the 24-inch Bruce refractor of Harvard Observatory has been outstanding as it covers the whole of the southern sky and extends to stars fainter than the 16th magnitude. In all rather more than 100,000 stars have been found to show appreciable motion. The positions and motions for 28,535 stars south of $-50°$ have been published, those for 25,000 stars between declinations $-35°$ and $-50°$ have been determined, while work is in progress on 20,000 stars between $-20°$ and $-35°$. The cream of the results has been published in four special catalogues, *Minnesota Publications*, Vol. **3**, 1–4, in which are listed 904 stars with motions exceeding $0''·5$ annually, 1147 stars with motions between $0''·3$ and $0''·5$ and 832 pairs with common proper motion. The northern sky has not been so systematically surveyed as the southern in this respect although a considerable portion of it was covered by Wolf and Ross. It is most desirable that this be completed.

Proper motions for all stars down to about the ninth magnitude should result from a comparison of positions determined from photographic plates with earlier positions based on observations with the meridian circle. Most of the work for the northern hemisphere has been completed but not published. The largest portion at present available is for the zones $-30°$ to $+30°$ undertaken at Yale. The results have been published for all except* zones $-2°$ to $+20°$ and refer to some 85,000 stars. The zones $-30°$ to $-40°$ are ready for printing at the Cape; the proper motions of some 40,000 stars between $-40°$ and $-52°$ have been published, the second volume referring to stars fainter than 9·0 on the C.P.D. scale. South of $-52°$ photography is well in hand and the zone $-56°$ to $-60°$ is being measured at Greenwich.

Poulkovo Publications, Series II, Vol. **55**, contains the proper motions of about 18,000 stars in 74 of the 91 Kapteyn Selected Areas between Dec. $+15°$ and the north pole. The photographic work was commenced by Kostinsky in 1911 and completed by Deutsch in 1938. Stars down to magnitude 15·0 are included. The instrument used was a normal Astrographic Telescope and two separate determinations were made with time intervals of about 20 years. The probable error of the proper motion in each co-ordinate is about $\pm 0''·0046$. This work can be used in conjunction with the rather more extended work on all the 115 northern areas done at the Radcliffe Observatory, Oxford, with a larger telescope but a shorter time interval.

More than 30 years have elapsed since the first plates were taken for parallax and it is now possible to get accurate proper motions by repeating the earlier series. In particular when the parallax star has had its proper motion well determined in a fundamental

* Further results have now been published.

system, then the relative proper motions of all stars measured with it can be made absolute on that system. In 1937 McCormick published the proper motions of 17,900 faint stars reduced to the G.C. system. A second catalogue* is in preparation which will give the proper motions and photovisual magnitudes of 11,300 stars between the 8th and 12th magnitude with spectral classification for 7600 of them. These are contained in 441 regions distributed uniformly between Dec. $-20°$ and the north pole. The proper motions are on the FK3 system, to which system the 17,900 stars previously measured will be reduced. The whole mass of proper motions has been discussed in combination with the Cape motions between $-40°$ and $-52°$ declination with gratifying results as to agreement of constants derived from different classes of stars (*A.J.* No. 1167, Jan. 1948).

Other observatories have not yet undertaken such extensive proper motion work. With some it is due to shortage of staff or preoccupation with parallax and orbital motion, with others to the shortness of the time interval. In due course we may expect further proper motions in which early parallax plates are used for the first epoch.

It has been found possible at McCormick to get fairly reliable proper motions by comparing the positions of stars on plates with the measured positions on plates of the *Astrographic Catalogue*.

Some special lists of proper motions may be mentioned:

(1) The relative motions of 2920 stars of the Pleiades based on work done at Leiden during the past 20 years utilizing plates from fifteen observatories is in the printer's hands.

(2) Van Maanen has published proper motions of stars in the Pleiades, the double cluster in Perseus and M67.

(3) Plates for the determination of the proper motion of Cepheid variables have been taken at Mount Wilson and proper motions have been determined at Mount Wilson (Van Maanen and R. E. Wilson) and at McCormick (Mitchell).

(4) First-epoch plates have been taken for 438 long-period variables at McCormick Observatory but it is not intended to take second-epoch plates till photometric and spectroscopic data are available for the comparison stars.

(5) First-epoch plates are being taken at Stockholm for regions in Lacerta, Taurus and the north galactic pole.

I think it will be most useful to have a general discussion of parallax work at the I.A.U. meeting. Points which may be considered are:

(*a*) Continuation of the work.
(*b*) Faint stars.
(*c*) Selection of new stars for observation.
(*d*) Repetition of stars not sufficiently observed.
(*e*) Discordant results.
(*f*) Selection of stars for intensive examination.
(*g*) Utilization of plates taken early in the parallax programmes for proper motion, double stars, etc.
(*h*) Accurate magnitudes and spectroscopic observation of parallax stars.

It will be much easier to decide on stars to be observed under (*c*) to (*f*) after a new general catalogue is available.

The heaviest work in parallax determination for all stars except the faint ones is the measurement of the plates. As twenty or more plates centred on the same part of the sky have to be measured for each parallax the possibility of automatic measurement might be explored by some one with the necessary technical knowledge.

J. JACKSON
President of the Commission

* Now published.

Report of meeting

PRESIDENT: Dr J. JACKSON.

SECRETARY: Prof. A. N. VYSSOTSKY.

The President mentioned a few alterations required in the Draft Report as a result of additional publications and later information. Prof. Cecchini had moved from Milan to Turin and the reduction of both the trigonometric parallaxes and the spectroscopic parallaxes was still incomplete. Mrs Burbidge stated that parallax determinations had been undertaken with the former Radcliffe refractor, now at University of London Observatory, the preliminary programme containing 66 test stars.

The second proper motion catalogue from McCormick Observatory and a further volume of the Yale *A.G.* Catalogues with proper motions had been published. Still another Yale Catalogue was in the hands of the publishers. Dr Nechvíle reported that he was continuing his work on proper motions at Prague.

A discussion took place on a third edition of the Yale *General Catalogue of Parallaxes*. There was much new material available and only twenty copies of the second edition remained. It was therefore necessary to prepare a new edition instead of a supplement. Prof. Schilt strongly urged that the new catalogue should contain in detail the relative parallaxes and probable errors of the different observations without alteration so that they might be available for statistical investigations in the future without the need to take out the systematic corrections applied in the second edition. Prof. Mitchell thought that for general use it would be essential to have all the observations reduced to a system. It was agreed that the best plan would be to publish both the original relative parallax and a weighted mean parallax based on all the relative parallaxes reduced to some system—possibly the system of the second edition. An introduction would give details of the system.

Prof. Brouwer described how the work had been carried on at Yale by Miss Jenkins after the second edition had been published. The Yale Observatory could undertake the preparation of a new edition. In deciding the exact form of the catalogue it would be important for Miss Jenkins to be assisted by members of the Commission. Yale Observatory could undertake the preparation of the typed manuscript, but the cost of publication would be heavy. It was therefore resolved that an application be made to the Executive Committee for the sum of $1500 towards the cost of printing and binding the volume.

Prof. Schilt made a short statement on a communication by Profs. Luyten, van de Kamp and himself in which special emphasis was laid on the need for continuing observations especially of very faint stars, for which a large reflector was required, and of stars which might not conform to the Russell-Hertzsprung diagram. Copies of this report were available for distribution.*

Report of second meeting. August 16, 1948

The representatives of the different observatories made a report on the work being done by them. Although there was some falling off in parallax observations it was agreed that there was still much useful work to be done. The observation of very faint stars could only be done by large reflectors which were not required for the observation of bright stars. Amongst classes of stars which should be observed without reference to proper motion or other physical characteristics were the very bright stars of O and B types and stars fainter than magnitude 5·5 of types F8 and G0. Prof. Schilt drew attention to the discordances which exist between the parallaxes determined at different observatories. He did not think these could be explained by accidental errors, but thought they could easily arise from the use of different sets of comparison stars and he urged that this be investigated by examination of the stars used and possibly remeasurement with different comparison stars. Some observers, while agreeing that the discordances required explanation, thought that the labour of measuring plates was so great that remeasurement of a large number of plates could not be undertaken without a large sacrifice of other work.

* See *Pop. Astr.* LVI, 421, 1948.