

26. COMMISSION DES ETOILES DOUBLES

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I. INTRODUCTION

According to the reports which have been received, it appears that the observational efforts in visual double star astronomy have remained at about the same level during the report period as they have been during the preceding period.

Problems in stellar structure and stellar evolution, which receive considerable attention at the present time, are often related to the visual binaries. In these studies, as well as others, it is apparent that there is need for more measures and more observations of astrophysical interest, such as photometric data, spectral classification and radial velocities—especially with instruments of large aperture.

There is still an urgent need for encouragement of young astronomers to take up double-star astronomy and to allow experienced observers in this field increased opportunities to use reflectors of large apertures.

2. DOUBLE STAR CATALOGUES

At the General Assembly in Hamburg, the U.S. Naval Observatory accepted the responsibility for future maintenance of the Index Catalogue of Visual Double Stars and Catalogue of Observations formerly maintained at the Lick Observatory. In accepting the catalogues, the U.S. Naval Observatory has the following obligations:

1. The sole responsibility to maintain the catalogues to date.
2. To furnish the other centers and the Lick Observatory with supplements when new data become available.
3. To furnish individuals with data from the two catalogues at cost.

The other Double Star Centers will be limited for the present to the Observatory at Meudon and to the Royal Greenwich Observatory at Herstmonceux. It may be desirable in the future to also have a center in the southern hemisphere. Lick Observatory will be a depository without the responsibility of the centers.

The obligations of the other centers are:

1. To maintain the catalogue to correspond precisely to the original at the U.S. Naval Observatory.
2. To supply individuals with limited data as requested, at cost.

The transfer of the Catalogues was effected in March 1965, with copies transmitted to the Paris Observatory at Meudon and to the Royal Greenwich Observatory at Herstmonceux.

Duplicates of the data from the catalogue at Washington will be provided at cost, upon request, on punched cards, tabular listings or magnetic tape—depending upon the amount of information required. Requests should be addressed to:

Superintendent
U.S. Naval Observatory
Washington, D.C. 20390, U.S.A.
Attention: Double Star Center

At the Hamburg General Assembly it was further agreed that it was the obligation of the double star observers to communicate to the Center:

1. Any errors found in the Catalogues.
2. Copies of new observational data sent simultaneously to be published. Mr. C. Worley, who is in charge of the Double Star Center, has requested insofar as practicable that observers follow these rules:

- (a) Send a copy of any manuscript containing new observational data to this office at the same time the manuscript is submitted for printing. Notify Mr Worley upon publication of the data, and give the reference. If possible, send a copy of the publication (or reprint of the paper) to him at your earliest convenience.
- (b) Since all records are being maintained by the use of electronic computers and associated punch-card equipment, it is necessary to code much material in a form suitable for these machines.

Therefore, when listing a measure, please give the following information:

- (1) The right ascension and declination for 1900 as tabulated in Part II of the Index Catalogue of Visual Double Stars, 1961.0 (= IDS). Also, if possible, please give the 2000 position.
- (2) the ADS Number;
- (3) the component observed, as described by IDS, Part II, under 'MULT';
- (4) the date, rounded to two decimals of a year, unless a very rapid binary is being observed, when three decimals should be given;
- (5) the position angle as observed, not precessed to a certain epoch;
- (6) the separation;
- (7) the estimated magnitudes or magnitude difference;
- (8) the number of nights included in the mean.

Additional information, such as the close designations of the discoverers (listed on p. xvii of Part I of the Index Catalogue of Visual Double Stars), the discoverers' number, durchmusterung number, etc. are not strictly necessary for maintenance of the catalogue of observations. However, this information is of value in maintaining the Index Catalogue, and hence will be most welcome. The aperture of the telescope, and the type of instrument used for the measure, are also necessary information.

3. COLLOQUIUM 'ON THE EVOLUTION OF DOUBLE STARS'

The response to the invitations to attend the IAU Colloquium at Uccle, Belgium, in September 1966 'On the Evolution of Double Stars' was most gratifying. Of the 65 specialists invited to attend, 39 accepted the invitation, representing 12 countries and 11 IAU Commissions.

In addition to six invited introductory discourses, 25 papers were presented, and five notes by colleagues not present. Time permitted ample discussion of the presented papers.

The proceedings of the colloquium will be published in *Communications de l'Observatoire Royal de Belgique* and the costs will be defrayed by the Belgian government. The volume will be dedicated to Professor G. Van Biesbroeck, in recognition of his devotion to visual observations of double stars of over 60 years.

4. VISUAL OBSERVATIONS

Herstmonceux, 28-inch (71 cm) refractor (Symms): continuation of measurements of pairs with real or suspected motions contained in the list of nearly 500 pairs drawn up when the telescope was re-erected at Herstmonceux in 1957.

Johannesburg, 26½-inch (67 cm) refractor (van den Bos, Knipe, Newburg, Postma): 7775 micrometer measures. Observations have been published in *Republic Observatory Circulars* 123–125. Finsen re-examined 1000 stars in his interferometer survey and discovered two new close pairs. Present status of the survey: 73 new pairs or slightly less than 1% of all stars examined. For 12 pairs it has been possible to compute orbits, three of which have periods as short as 2.65, 2.67 and 3.2 years. The total number of interferometer measures made in the three year period was in excess of 1100, not taking into account many time consuming negative results.

Lamont-Hussey, 27-inch (69 cm) refractor (Holden): continuation of re-measures of selected pairs from the Rossiter's Catalogue with a filar micrometer. It is proposed to complete the re-examination of all hitherto neglected pairs discovered at the observatory, and to commence photographic observations of the wider pairs. Two lists containing 1355 observations were published (1).

Meudon (Muller): The 83-cm refractor has been in regular operation since 1965. Five hundred and eighty measures of close binaries have been made.

Munich, 28-cm refractor (Heintz): observations are continued at a rate of 800 per annum.

Nice, 38-cm refractor (Bertin, Couteau, Morel): 2200 measures of 750 pairs. The program consists of all binaries accessible to the telescope with special emphasis on neglected pairs, such as those discovered by Espin and Jonckheere. The observations are carried out with either a Muller double image micrometer or a filar micrometer. A part of the observations have been published (2).

Since 1963 Couteau has systematically examined, for duplicity, the stars with large proper motion in the Paris Astrogaphic Zone ($+17^\circ$ to $+25^\circ$ dec.). So far he has examined 4858 stars and found 115 new pairs of which 48 have separations less than 1 inch. The percentage of new binaries remains nearly constant, and amounts to one binary for each 42 stars examined.

Paris, 38-cm refractor (Baize): 1322 measures with filar micrometer of 364 pairs which are considered either in a critical orbital phase, are red dwarf or are neglected pairs. Baize intends to observe over the next years chiefly double stars between $+50^\circ$ and $+90^\circ$ declination.

Rio de Janeiro, 46-cm refractor (Mourao): visual observations since 1959. A third series comprising 450 measures of 160 systems has been published (3).

Sternberg Institute, 20-cm refractor (Kuročkin, Starikova): measurements with a polarizing micrometer according to design by Muller of 114 systems (4). Measures of additional 76 systems in press.

Tucson, 84-inch (213 cm) Kitt Peak National Observatory reflector and 61-inch (155 cm) Lunar Planetary Laboratory reflector (Van Biesbroeck): 1300 measures of close binaries with special attention to close pairs in critical parts of their orbits. Measures obtained from 1960 to the end of 1965 have been published (5).

Uccle, 45-cm refractor (Arend, Dommanget): no observations were made during the report period, but are expected to be resumed in 1967 after the installation of a new Zeiss objective.

U.S. Naval Observatory, 26-inch (66 cm) and 12-inch (30 cm) at Washington, 61-inch (155 cm) and 40-inch (102 cm) reflectors at Flagstaff (Walker, Worley), 7601 measures, the majority with a digitized micrometer. 4586 measures made with the 26-inch were published by Worley (6), and 1013 measures made with the 12-inch were published by Walker (7).

5. PHOTOGRAPHIC OBSERVATIONS

The Hertzprung stereotype plate and card catalogue of relative double star positions resulting from multiple exposure photographic plates, according to the Hertzprung method, was transferred from Professor Hertzprung's residence in Tølløse, Denmark to the U.S. Naval Observatory, Washington, D.C. At the same time a total of 2300 plates, consisting primarily of plates taken by Hertzprung at Potsdam, Johannesburg and Lick, and his collection of measurements on these plates were transferred to the Observatory.

Abastumani, 40-cm refractor (Salukvadze): photographic measures of trapezium type multiple systems. In addition *U*, *B*, *V* photometry were made and spectral types were determined (8).

Minnesota, 48-inch (122 cm) Palomar Schmidt telescope (Luyten): nearly 1000 new wide double stars have been discovered during the past three years from blinking of plates of the Palomar Survey. The entire polar cap north of declination $+75^\circ$ has been completed and 280 double stars discovered, some as faint as the 21st magnitude. Some 20 more pairs, containing one degenerate component, were found and will be observed intensively with a view of obtaining orbital motions and statistical values for the masses. On the basis of what has been discovered so far, it appears that there are some 15–20 000 wide binaries, based upon common proper motions of the components, and brighter than 21st magnitude over the entire sky. At least 400–500 of these will contain one white or degenerate component.

Mount Stromlo, 26-inch (66 cm) refractor (Abraham): some 200 plates have been taken, using the Hertzprung technique, and a multiple exposure camera designed by Strand. It is intended to measure the plates on a Grubb Parson digitized measuring machine.

Potsdam, 50-cm visual refractor and 20-cm astrograph (Böttger): the program with the first instrument consists of observations of 120 selected binary systems of special interest, using Hertzprung's technique. Results for 68 systems were published (9). Since 1962 139 plates of 41 systems have been taken. The astrographic program consists of photographic observations of 750 (mostly neglected) binaries brighter than tenth magnitude with wide separations larger than 6".

Pulkovo, 65-cm refractor (Deutsch, Kiselev, Plugin, Kanaev): observations of 75 binary systems with nearly equal magnitudes have been completed. The results for 40 systems have been published (10). A program of observations of 61 Cyg, Lalande 21 185, η Cas, and others, is continued for the purpose of analyzing perturbations due to invisible companions.

Sproul, 24-inch (61 cm) refractor (van de Kamp, Lippincott): mass ratios and parallaxes for nearby stars, mostly within 10 parsecs. Recent results include parallax and mass ratio for ξ Sco (11), $\Sigma 2173$ (12), BD $+77^\circ 361$ (13), Hu 1176 (14). Studies were made of the photocentric orbits of μ Cas (15) and α Oph (16). Observations of Barnard's Star have been continued and have so far confirmed the earlier (17) orbital analysis.

U.S. Naval Observatory, 26-inch (66 cm) refractor at Washington (Mikesell, *et al.*); 24-inch (61 cm) refractor at Lowell Observatory (Priser, *et al.*): the photographic double star program was continued. Approximately 500 objects are under observation. During the report period 1499 multiple exposure plates were taken at Washington and 955 at the Lowell Observatory. 2454 plates, with a total number of 150 000 exposures, were measured. Automatic data recording at the measuring machine and the use of electronic data processing equipment made it possible to keep plate measurements and reductions up-to-date, avoiding accumulation of a large backlog of unmeasured plates.

Van Vleck Observatory, 20-inch (51 cm) refractor (Gasteyer): relative position of 65 double stars were published from 326 plates (18), using the Hertzsprung method and a multiple exposure camera designed by Strand.

Vienna, 32-cm astrograph (Haupt): measures of 250 wide binary systems have been published (19). Another series of 120 pairs is near completion.

6. ORBITAL STUDIES

Since the last general assembly Muller has published *Information Circular* Nos. 33-40, reporting a total of 82 new orbits.

Calculations were made by Baize, Couteau, Djurkovic, Finsen, Heintz, Knipe, Mourao, Newburg, Popolic, Starikova, Symms and van den Bos.

Hopmann published provisional elements of ten binary systems with long periods (20).

Miss Zeller studied ξ Cep, ϵ Equ and ϵ Hya (21).

Miss Starikova published relative rectilinear motions in 31 double stars (22). Similar studies have been published by Arend (23), Dommanget (24), Dommanget and Nys (25), and Nys (26).

Fesenko has carried out statistical studies concerning eccentricities of binary orbits (27).

Arend, in collaboration with Nys, has worked on computing programs in connection with orbital investigations of double stars (28).

Kulikovsky has designed a simple graphical method of determining orbital elements of binaries (29).

Dommanget and Nys is preparing a catalogue of ephemerides of radial velocity curves of visual binaries.

Couteau and Mme François have constructed with an IBM calculator an atlas of orbits which contain the apparent ellipse of all known orbits. The part of the orbit which has been effectively observed is specially marked, which shows at a glance the quality of the elements. The atlas also includes an ephemeris for one revolution, the masses and the dynamical parallax. Copies of the atlas can be requested from Observatoire de Nice.

Wempe reports that a card index initially containing some 20 000 single measurements, copied from the Muller catalogue, is continuously being augmented by all accessible publications and now contains almost 35 000 observations. A card index of known orbits is similarly being augmented and now contains 2007 orbit determinations of 559 binaries, 41 of which were published between 1964 and 1966.

7. SPECTROSCOPIC AND PHOTOMETRIC OBSERVATIONS

The Victoria program of determining radial velocities of visual binaries with relative short periods and with large Δm 's to ensure only one spectrum in visible is being continued at the Dominion Astrophysical Observatory, Victoria, B.C. Initiated by Miss Underhill, the program has been transferred to the coudé spectrograph of the 48-inch (122 cm) telescope.

The Victoria program of spectroscopic observations of wide visual binaries began with the late Dr Petrie, and is being continued by Batten. A detailed discussion of four systems was published by him (30).

Work started by Slettebak (31) some years ago on the spectra of visual double stars is being extended by Meisel, who is investigating some 50 visual double star systems, mostly of early type, with preference to those containing Be, O and supergiant components. The spectrograms were taken with the Perkins 72-inch (183 cm) telescope of the Ohio State and Wesleyan Universities at the Lowell Observatory at Flagstaff. In addition to spectral types, luminosity classes and rotational velocities, Meisel has measured H γ photoelectric indices, Δm 's and radial velocities.

Abt and Sanwal at Kitt Peak National Observatory are obtaining spectral types and U , B , V photometry for most of the systems in the Orbit Catalogue (32) which do not have such data. In addition, they are obtaining $13.5\text{\AA}/\text{mm}$ spectra regularly with the 84-inch (213 cm) coude spectrograph of most of the visual systems having orbits and being brighter than 7.0 magnitudes.

Since 1966 Couteau and Mlle Lacoarret have carried out spectroscopic observations of double stars at the Haute-Provence Observatory with the 193-cm reflector for the purpose of determining relative radial velocities and spectral types.

Franz is using a photoelectric scanner designed by Rakos, in conjunction with the 72-inch (183 cm) Perkins telescope, for obtaining photometric data as well as relative positions of the components of double stars (33).

Preliminary results of photographic B , V photometry of the components of the double cepheid CE Cas in NGC 7790 was obtained by Kholopov and Efremov (34).

8. MISCELLANEOUS STUDIES

Kulikovskiy has published in the *Information Circular* lists of T-Tauri type stars for testing of duplicity with telescopes of different sizes.

Arend and Dommanget are continuing their study of the evolution of double stars, taking into account mass loss.

Harrington is in the process of developing a theory of the motion in triple systems.

James at Manchester is developing numerical methods for determining the structures of stars distorted by strong gravitational fields and/or rapid rotation. He is extending the work to realistic stellar models with the object of exploring mutual interactions of the components of close binary systems.

Piotrowski derived general formulae for the variation of the elements of a close binary system caused by mass ejection, mass transfer and mass infall (35). It was shown that the eccentricity of the orbit has a tendency to decrease if the mass transfer takes place predominantly near periastron.

The problems related to the exchange of matter and period changes in close binaries were reviewed by Kruszewski (36).

Further work of the Polish group is reported by Commission 42.

Theoretical work to establish the major properties of tides in close binary systems and to examine the role the tides play in the dynamical and nuclear evolution of the systems has been carried out by Zahn (37).

PROPOSALS

The Nice Observatory is proposing to hold a colloquium on the subject of different methods of observing visual binaries. If approved, the colloquium is expected to take place at Nice in the fall of 1969 with an expected attendance of 25 workers in the field.

Couteau proposes the establishment of a working group to select and publish periodically a list of definitive or well-determined orbits. The working group should be composed of a small number of members experienced in observing. The list of orbits could be published in the *Transactions* of the Union with revisions and additions each three years. According to the catalogue of orbits published by Worley (32) there are at the present only 43 definitive orbits, so the space requirements for this information would not be excessive.

Muller reports that his orbit catalogue is kept up-to-date with a view of publishing a new edition of the catalogue of ephemerides. He is principally awaiting information as to whether the Commission should designate a committee to select the orbits to be retained for general catalogues of either elements or ephemerides.

Couteau proposes that a census be made of regular double star observers and the instruments which are used primarily for observations of binary stars. He also proposes that a more rapid diffusion of observations for the purpose of preparation of programs should be discussed. Perhaps this could be done by the distribution of copies of manuscripts of observations to regular observers.

Worley would like to hear a discussion of the advisability of further discovery surveys, both of a general and of a special character.

He points out that the Catalogue of Observations includes all known measures of visual binaries south of declination -20° , but north of this limit it contains, with a few exceptions, only those measures made and published since 1927. He wishes to know if the members of the commission feel that the inclusion of the earlier measures in this catalogue are important enough to justify the large amount of effort that the collection of such a list would entail.

Mourao suggests a discussion of whether three or six color photoelectric observations of binaries should be made.

Holden feels that with the catalogue of observations in machine-readable form, it appears timely to suggest that lists of stars in urgent need of observations should be circulated.

Baize wishes to bring up the problem of 'wholesale' orbit computation with high speed computers leading to unacceptable results.

Arend and Dommanget propose:

1. that the Commission at the Prague meeting call attention to the convention adopted by the Commission at the 1935 Paris meeting in regard to a single system of elements.
2. that the Commission support necessary modifications of the system then adopted for the purpose of avoiding the confusion which originates from the usage of \pm in front of the element i , as follows:

i —*Inclination at the ascending node.* For direct motion, in the first quadrant, for retrograde motion in the second. To be counted from the direction of increasing position angle in the apparent plane, to the direction of motion in true orbital plane.

Ω —*Position angle of ascending node for equinox 1900.* When data referring to the third coordinate is not available, the ascending node is always chosen provisionally between 0° and 180° .

ω —*Longitude of periastron.* Angle in plane of true orbit counted always in the direction of motion from the node as given, to periastron.

3. that the computers always give both the Campbell and the Thiele-Innes elements, especially C and H .
4. that to avoid any ambiguity in the position angle of the ascending node, the observed radial velocities with their corresponding residuals should be published as it is required for the observed positions.

In regard to the above proposal, Finsen reports that he would prefer as follows:

i —*Inclination* is the angle between the line of sight and the positive pole of the true orbit, defined as the normal to the plane of the true orbit from the extremity of which the orbital motion is seen to be direct, i.e., anti-clockwise. It is therefore between 0° and 90° when the motion in the apparent orbit is direct, and between 90° and 180° when it is retrograde, and is always positive.

Ω —*Position angle of the ascending node* or, if it is not possible to identify the ascending node, the node with position angle less than 180° . If the node is the ascending node this is indicated by the unambiguous signs of C , H , pL , pN , but it is recommended that it should also be indicated by underlining, thus: 123^o4 (when

written by hand or typed), or by *italics*— $123^{\circ}4$ —(when printed). If it is not possible to distinguish between the ascending and descending nodes, C , H , pL , pN should be given double signs, thus \pm or \mp , the upper signs referring to the node as given, i.e., $< 180^{\circ}$, and the longitude of periastron associated with it.

If the conventional node ($< 180^{\circ}$) is subsequently identified as the ascending node, leave Ω and ω unchanged, and take the upper signs of C , H , pL , pN . If it is identified as the descending node, reverse the quadrants of both Ω and ω , and take the lower signs of C , H , pL , pN .

Eggen proposed that the joint working group of this Commission and Commission 42, of which he is chairman, and Cester, Couteau, Eggen, Fredrick and Popper are members, meet at Prague and discuss a course of action.

K. Aa. STRAND

President of the Commission

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