

26. DOUBLE AND MULTIPLE STARS (ETOILES DOUBLES ET MULTIPLES)

PRESIDENT : M. G. Fracastoro

VICE PRESIDENT : K. D. Rakos

ORGANIZING COMMITTEE : J. Dommanget, O. G. Franz, W. D. Heintz, H. A. McAlister, A. Poveda, C. D. Scarfe.

Commission 26 has changed its name. The new denomination, warmly promoted by Dommanget, represents more adequately the actual field of the Commission itself and appears as a good start for extending its interest beyond the traditional aspects (morphology and statistics) and plunging into problems connected with the origin, evolution, mass spectrum and dynamics of small star associations.

Commission 26 did not organize official meetings during the triennium. However, it was very actively participating to some Colloquia and Symposia.

On the occasion of the 60th anniversary of the Bosscha Observatory, a Colloquium (IAU Nr. 60) was held in Bandung, Java (June 1983). A. H. Batten, J. Dommanget, O. G. Franz, E. P. J. van den Heuvel, Z. Kopal and B. Warner were among the members of the Organizing Committee. During the Colloquium, the role of double and multiple systems received special emphasis. Prof. Kopal presented the V. Bappu Memorial Lecture on "Evolution of Binary Systems". Subsequent sessions dealt with: Physical properties of Double and Multiple Systems; Occurrence of Binaries in different stellar systems; Wide systems and their evolution; Close binaries, new observations and evolution; Generic relations between wide and close systems.

At the end of the Colloquium, Dommanget spoke about the role of double stars within the Hipparcos project (see below).

At the IAU Symposium Nr. 111 in Como, Italy (May 1984) P. Couteau has illustrated a modified HR diagram for 164 visual binaries with measured orbits, by applying Kepler's third law, Pogson scale and mass-luminosity relation, and plotting M_* (magnitude for unit mass) against $B-V$. At the same Symposium, W. D. Heintz has discussed the problem of mass determination in double stars.

Not far from Couteau's research, K. D. Rakos has examined 147 visual binaries for a parallax independent calibration of the mean sequence in the interval $-0.15 < B-V < +0.80$. Furthermore, he has calculated the luminosity distribution for close binary systems and finds that the most probable mass ratio in a close binary system is 0.5. Finally, it seems that the number of triple systems is larger than expected.

In June 1984 an International Conference was held in Bamberg, FRG, in honor of F. W. Bessel 200 anniversary. Z. Kopal (chairman), Dommanget, Fracastoro, van de Kamp were among the members of the Organizing Committee. Significant space was assigned to double star problems and a crowded session was dedicated to astrometric binaries.

Fracastoro spoke on current state of Astronomy of visual binaries, P. L. Bernacca, Dommanget and Söderhjelm illustrated some aspects of

the interaction between the double star population and the astrometric mission of the satellite Hipparcos.

A very important work has been accomplished at the US Naval Observatory, in Washington D.C. USA. The revised and updated version of the IDS, known as the Washington Catalog of Visual Double Stars, 1984 (WDS) has been completed by Ch. Worley and Douglass. They have completely edited, corrected, added to, and revised the Index and Observations Catalog. This new version, which virtually has all published observations up to January 1, 1984, has been transmitted to the Data Centers, where machine-readable copies are available for distribution.

Worley is also performing an assiduous micrometer work with the 61-cm refractor at the USNO and with various instruments at Cerro Tololo Inter American Observatory in Chile. The photographic program at Washington has been formally discontinued, however J. Hershey did get a few plates of Sirius during 1984.

Worley and Heintz have coedited the 4th Catalog of Visual Binary Orbits (Publ. of the USNO, vol. XXIV, part VII; Washington, 1983).

From 1981.5 to 1984.5 Heintz has made some 7200 double star measures (5400 by micrometer at the 61-cm refractor in Swarthmore, 1100 at Cerro Tololo; plus 700 plates). 130 new pairs were found and some 150 corrections of IDS entries were recorded (identifications, revised positions, etc.). Orbits have been determined by Heintz for 42 binaries, trigonometric parallaxes for 39, and photographic mass ratios of 18 pairs.

The 2nd Catalog of Ephemerids, containing the relative radial velocities of the components of visual binaries with known orbit, has been published at the Observatoire Royal de Belgique, Uccle, by J. Dommaget et O. Nys. In this catalog 862 curves of relative radial velocities are plotted for 814 systems, covering the period 1970 - 1990. Furthermore, the geometric elements are reported for 102 stars, for which the ascending node is well established from the radial velocity observations.

E. van Dessel has obtained several hundred spectrograms at the Haute Provence Observatory, St. Michel, France, and at the European Southern Observatory in Chile, of the orbital doubles B 1909, Rst 3352, Kpr 7, φ 363, φ 326, ADS 8119, I 365, ADS 9247 BC, ADS 9979, ADS 12096, I 1416, φ 307 and Kpr 114, as well as for several other systems showing some peculiarities or being suspected for duplicity.

Still at Uccle, Dommaget has oriented the activity of his group towards the problems raised by the presence of double and multiple stars (not necessarily forming physical systems) on the mission of the astrometric satellite Hipparcos. The necessity to provide it with the absolute positions (within 1 arcsecond) of all the individual components has obliged the compilation of a special catalog, which is now under preparation.

Furthermore, Dommaget has organized an international cooperation for the observation and research which are preliminary to the Hipparcos mission in relation to these systems. To this purpose, several thousands of DM identifications, omitted in the Index 1976.5, have

been accomplished and several hundred others, which were erroneous, have been corrected by P. Bacchus and O. Nys.

Orbits have been calculated by O. Nys (γ Cir), E. van Dessel (ADS 9453), A. Norro (B 594) and L. Zimmermann (ADS 1102).

Other orbits have been published by R. R. de Freitas Murão, in Rio de Janeiro. He is also an active observer.

At Flagstaff, Arizona, USNO Station, R. L. Walker is preparing the 5th list of 1270 visual measurements made with the 91-cm refractor at Lick Observatory. He has discontinued his visual observations to devote more time to photoelectric photometry of close visual binary and multiple systems.

At the Dominion Astrophysical Observatory, Victoria B.C. Canada, Batten, Fletcher and Scarfe (University of Victoria) have continued to obtain radial-velocity observations of binary stars, using the 1.2 m telescope and coudé spectrograph. Use of the radial-velocity spectrometer has permitted several additional systems to be added to the observing program.

Observations of Σ 2367 (HD 172865) obtained when the spectra were resolved near the late-1980 periastron passage have been published. Similar observations, but fewer in number, were obtained of Ho 296 (HD 214850). Periastron passage was a few months earlier than expected, but no other major modification to the visually-determined elements seems necessary. The brighter component had the more positive velocity. Attempts to resolve the spectra of Kui 114 (HD 214810) were unsuccessful; it appears that nodal passage occurred when the star was too close to the sun for observation, or that it occurred much earlier than expected.

A published study of coudé radial velocities of ζ Her A, obtained during more than half of the 34-year orbit, indicates less-than-perfect agreement with the astrometric parallax and mass ratio. A reinterpretation of π Cep, based on a new spectroscopic orbit for the primary, has also been published.

Observations of 70 Oph (both components) have been continued, and no evidence for a third component has been found. A paper on the parallax and mass of the system is in press. Work continues on the occultation-spectroscopic triple 64 Ori, the 15-year binary ϵ Hya, the triple system 1 Gem, and both components of 61 Cyg.

From 1981.5 to 1984.5 P. Couteau has discovered, with the two refractors of the Nice Observatory (50- and 74-cm aperture), 246 new binaries, more than one third of them being closer than 0.5 arcsec. During the same interval of time, 1757 measures have been made of different couples, 155 of them with the 91-cm refractor of the Lick observatory in 1983.

Still at Nice, P. Muller has measured 1514 couples, most of them being Mlr's binaries discovered at Nice. During the survey of the polar region ($\delta > 52^\circ$) started in 1969, Muller has examined 5150 stars and discovered 79 new couples, the total number being at present 682. According to the AGK2, the region contains something more than 38

thousand stars; therefore, about 3500 of them have still to be examined.

On his side, Couteau has patrolled more than 102 000 out of 169 243 BD stars contained in his zone ($+17^\circ < \delta < +52^\circ$), discovering 2200 new couples. The situation for the northern hemisphere is now the following:

separation	number of couples
$s < 0''.25$	1066
0.50	3119
1.0	5454

Since 1983, Couteau has succeeded to P. Muller as Editor of the Circulaires d'Information, where the orbits, the newly discovered binaries and all information required by the various authors are assembled and published.

To remain in France, at CERGA, Grasse, Bonneau, Foy and Koechlin are using speckle interferometry techniques: a further list of measurements is expected after the one published in 1980.

Finally, Dr Baize has published some 45 orbits during the triennium, as a demonstration of his indefatigable activity inside our commission.

P. van de Kamp communicates that current analysis of Sproul measurements of the Barnard star yields 32 yearly mean residuals, and for one orbit a perturbation with a period of 12 years. An improvement is made by an additional perturbation with a period of 20 years. The radii of the two perturbation orbits are 0.010 and 0.008 arcseconds.

S. L. Lippincott has published astrometric orbits, mass ratios and masses for ζ Her, 85 Peg and other visual binaries. She also analyses astrometric data on μ Cas and other double or suspected multiple systems. A comparison is made between the Sproul data and the Infrared Speckle ones for the unresolved binary BD +41° 328.

According to Lippincott, the majority of the unseen faint companions to nearby stars, discovered at Sproul, have been detected by IR speckle interferometry by D. Mc Carthy.

The problem of the existence of substellar companions lies in a boundary territory between the astrometric search of double stars (limiting masses slightly below $0.1 M_\odot$) and planetary bodies (the so called "jupiters", with masses of the order of $0.001 M_\odot$). The general feeling is that a certain and definitive answer about the existence of these companions, their masses, orbital periods and so on, depends on new techniques, applied to opportunely selected stars.

The Georgia State University Speckle Camera, Atlanta, USA, has been used at the KPNO 4-m telescope by H. A. Mc Alister, W. I. Hartkopf, O. G. Franz and D. J. Hutter to obtain approximately 5000 series of binary star observations. These data are being reduced and analysed by means of a hardwired vectorautocorrelator and interactive software that removes the seeing component from the autocorrelograms and cen-

troids the binary star peaks. Systems as faint as $V = +15$ can be easily observed, but the gains in astrometric accuracy and the potential for photometric calibration are higher priority goals. A list of results from the new camera is expected to be submitted for publication in early 1985. The camera also continues to be used monthly on the 1.8-m Perkins telescope in Flagstaff for a long-term program searching for low mass companions within a sample of some 65 nearby binaries having separation in the range 0.1 to 1.5 arcseconds. Repeatability tests are indicating astrometric accuracies of 0.1 to 0.3 milliarcseconds, obtained from a single one-minute series of video speckle data.

Mc Alister and Hartkopf published a catalog of interferometric measurements of binary stars as the first contribution from the newly formed Center for High Angular Resolution Astronomy.

In Yugoslavia, visual observations were carried out by G. M. Popović and D. J. Zulević (Zeiss refractor 65/1055; 1780 measurements altogether). The results are published on the Bull. Obs. Astron. of Belgrad, Nrs. 132-3-4, or will appear shortly. This research is going on.

Popović has found 24 new pairs among BD stars ($+34^\circ < \delta < +44^\circ$). He has calculated orbits for ADS 3174, 5959 13028 AB and 1786. Six orbits are due to Zulević (ADS 1371, 7758, 11989, 16877, 4 and 2446) and ten orbits to V. Erveg (ADS 674 AB, 1345, 1393, 2111, 2609, 3058, 3686, 5707, GLE 1, Hu 1566). Popović is also analysing the triple systems contained in the IDS.

Djurković, who died at the beginning of 1981, has left a theoretical research about double stars and the newly discovered galaxy-satellite of the Milky Way, and a paper on the use of Dembowsky's method of double star measurements as a criterion for site selection.

Further visual and photographic measurements of double and multiple systems are planned at Belgrad (Popović et al.) as well as a statistical analysis of the orbital elements as a function of the galactic coordinates (Zulević).

At the Astronomical Observatory of Torino, Italy, G. Massone started (spring 1982) a program of visual double star observations with the 30-cm refractor. 480 measures are under publication. Successively, the observing program is continued with the new 42-cm refractor. It includes mostly double stars with known orbits, to improve their elements, and pairs with quick relative motion, in view of future orbit determinations. Furthermore, from the new IDS, the program will be extended to recently discovered couples or long disattended pairs with quick relative motion and presumably short periods.

A long term program of photographic observations is carried along by R. Pannunzio and R. Morbidelli with the 105-cm astrometric reflector. Beside possible identifications of perturbations due to low mass companions, the observations will continue selecting, from the initial list of pairs, those showing a significant relative motion. To this purpose, the accuracy of the plates is carefully controlled.

With the same instrument, parallaxes and proper motions of faint and late type nearby double stars are the subject of a long term pro-

gram.

In view of the Hipparcos astrometric mission, a statistical model of a binary star has been elaborated from the IDS Catalog by Panunzio and Scaltriti.

Still in the frame of the Hipparcos mission, Fracastoro has analysed the information contained in the Yale Catalog of Bright Stars, examining the trend of Δm 's with separation, and comparing the number of observed couples to the number expected from a random distribution. The results are in agreement with the findings of Rakos (see above).

R. H. Wilson Jr. has 115 micrometer measures of double and multiple stars, done with the 26-inch Innes telescope at Johannesburg.

N. P. Wieth-Knudsen has made 70 measures of double stars with separation smaller than 2.5 arcsec (30-cm reflector, Muller type micrometer).

At Lisbon, Portugal, the restoration of the old 38-cm refractor is planned, in view of systematic observations of visual binaries.

ACKNOWLEDGMENTS

I am very grateful to those who have supplied information and collaborated to the preparation of this report.

M. G. Fracastoro
President of the Commission

Addendum:

Report on the work of Soviet astronomers in the field of visual double stars in 1981-1984

1. Observations

Photographic observations of visual double stars in the region of the sky to the north of 30° declination were continued systematically at the Pulkovo Observatory. More than 1000 plates were taken and studied for about one hundred double stars ($m < 12.0$, $\Delta m < 1.0$, $\rho \geq 3''$) not observed for a long time.

A catalogue of relative positions and motions of two hundred visual double stars containing the results of 20 years of double star observations in Pulkovo was prepared for publication. 23 visual double stars were identified which are possibly situated at distances not exceeding 25 parsec from the Sun.

Perturbations in the orbital motion of the double star ADS 11632 were studied on the base of a 20-year observational series: N.A. Shakht, Astron. Zhurnal Pis'ma, 10, 1984.

A.A. Tokovinin (P.K. Sternberg Astronomical Institute, Moscow) has developed

instrumentation for speckle-interferometric observations of close double stars ($\rho > 0''.06$, $m > 9.0$). The device was used with a 1-m reflector in Crimea:

A.A. Tokovinin, *Astron.Zhurnal Pis'ma*, 8, No. 1, 1982,
8, No. 3, 1982,
9, No. 9, 1983.

Duplicity of the stars ϵ Lyr and ζ Dra was found: G.A. Starikova, A.A. Tokovinin, *Astron.Zhurnal Pis'ma*, 7, No. 11, 1981. The interferometric method for measuring close double stars has been calibrated: A.A. Tokovinin, *Astron.Zhurnal Pis'ma*, 9, No. 10, 1983. The orbits of the following double stars were determined: Cou 292, β CrB, η Vir, ADS 10360, 12973, 14787, 15281; the orbits of the first three stars were determined for the first time: A.A. Tokovinin, *Astron.Zhurnal Pis'ma*, 10, No. 4, 1984.

Observations of double stars using the polarisation micrometer at the 30-cm refractor in Moscow were continued at the Sternberg Institute: G.A. Starikova, *Astron. Circular*, No. 1249, 1983.

Orbits of 98 visual binaries were determined: G.A. Starikova, *Astron.Zhurnal Pis'ma*, 7, No. 4, 1981; 8, No. 5, 1982; 9, No. 6, 1983; Sternberg Institute, *Trudy*, 57, 1984; *Astron. Circular* No. 1325, 1984.

The Special Astrophysical Observatory of the USSR Academy of Sciences (Zelenchukskaya) has introduced the digital speckle-interferometric technique of measuring close double stars. The equipment is installed at the primary focus of the 6-m telescope. Since 1983 about 200 stars were measured with the resolution $0''.027 - 0''.818$. The r.m.s. error of relative positions is $\pm 0''.003$. The observational programme includes:

- speckle interferometric pairs first resolved by McAlister and by Labeyrie;
- spectral binaries observed with the 6-m telescope;
- stars with composite spectra;
- known "rapid" visual stars;
- close double stars recently discovered by P. Couteau.

The results of these observations are published: Y. Balega, D. Bonneau, R. Foy, *Astron. and Astrophys. Suppl.*, 1984, 57, No. 1, 31.

2. Theoretical studies

Studies of the method of derivation of orbits for visual binaries using the observations of a short arc were continued at the Pulkovo Observatory. The orbits of ADS 48, 7251, 14636 (61 Cyg) were determined using this method: A.A. Kiselyov, O.V. Kiyayeva, *Astron. Zhurnal*, 57, No. 6, 1980.

Studies of the dynamical evolution of triple systems were carried out at the Leningrad University. By means of a numeric experiment with a computer it was shown that in 90% of cases triple systems were destroyed into a binary and a single star. The mean lifetime for triple systems in the solar neighbourhood is $10^6 - 10^7$ yrs. 10% of cases lead to quasistable hierarchic systems. Dynamic processes of formation, evolution, and dissolution of double systems in a gravitational irregular field were also investigated. The results of the study are given in the review: Zh.P. Anosova, V.V. Orlov, "Dynamic evolution of triple systems", *Astron. Observ. Leningrad Univ. Trudy*, 40, 1984.

A statistical study of motions of visual double stars was carried out at the Sternberg Astronomical Institute: G.A. Starikova, "On the kinematics of visual double stars and multiple stars of the FK4 catalogue", *Astron.Zhurnal*, 58, No. 2, 1981.

A.A. Kiselyov