Transactions IAU, Volume XXVIIA
Reports on Astronomy 2006–2009
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doi:10.1017/S1743921308025519

COMMISSION 26 DOUBLE AND MULTIPLE STARS

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Div. IV / Commission 26 WG	**Binary and Multiple System Nomenclature**

TRIENNIAL REPORT 2006 - 2009

1. Introduction

Although we were happy to welcome over 20 new members at the Prague meeting, Commission 26 is still one of the smallest in the IAU. Notwithstanding its size, it continues to carry on an active and diversified program of activities. Our web site, maintained at the US Naval Observatory, contains further information on the Commission. The site includes links to other relevant sites, to databases and catalogues, an archive of our Information Circulars, a list of upcoming meetings of interest, as well as an extensive bibliography of recently published papers on double and multiple stars. The site can be accessed at `<ad.usno.navy.mil/wds/dsl.html#iau>`.

2. Meetings

2.1. *IAU Symposium No. 240*

The largest meeting in the history of our Commission was held during the IAU XXVI General Assembly in Prague, August 2006. IAU Symposium No. 240 on *Binary Stars as Critical Tools and Tests in Modern Astrophysics*, was jointly sponsored by Commissions 26 and 42 with support from 11 other commissions and working groups. The 3.5-day meeting was attended by some 500 astronomers from 54 countries and included talks covering all aspects of binary and multiple star research: from very long period, common proper motion pairs and other 'fragile' binaries to short-period contact binaries, binaries with degenerate components, as well as star/brown-dwarf/planet systems, with the aim of exploring interests common to all binary star researchers. Both the observational and theoretical aspects of binary and multiple star research were represented, but the main themes of the program were the new information and physical insights gleaned from the recent advances in instrumentation and techniques. The meeting also attracted those interested in the observational and theoretical aspects of modern stellar astrophysics that

depend very strongly on the fundamental properties of stars found primarily from binary and multiple stars.

The format for the symposium was a mix of invited oral review presentations and more narrowly-focused topical presentations. These 40 invited talks were supplemented by over twenty short oral/poster presentations, selected by the SOC from over 180 submitted posters.

As the first major joint meeting in modern memory of the 'close' and 'wide' binary communities, it was deemed appropriate to dedicate the meeting in honor of Mirek J. Plavec†, and in memory of Charles E. Worley. Also remembered at the meeting was Wulff D. Heintz, who had died two months earlier.

Proceedings of the meeting were edited by William Hartkopf, Petr Harmanec and Ed Guinan, and published by Cambridge University Press in 2007. A companion website at Cambridge Press includes 115 complete posters from the meeting, as well as all talks and poster abstracts in the book.

2.2. *IV International Meeting on Dynamical Astronomy in Latin America*

The meeting was held in Mexico City's Historical Center and was attended by some 55 astronomers from over 14 countries. A large fraction of the papers presented dealt with various aspects of double and multiple stars. Some of the highlights included sub-milli arcsecond accuracy parallaxes applied to associations, VLBI astrometry of young multiple systems, milli-arcsecond binaries, and the effect of circumstellar and circumbinary disks in eccentric binaries. The Proceedings of the meeting are being edited by C. Allen, R. Teixeira and A. Ruelas-Mayorga, and will be published as a volume of the *Revista Mexicana de Astronomia y Astrofisica* (CS).

2.3. *IAU Symposium No. 248*

IAU Symposium No. 248 *A giant step, from milli to micro arcsecond astrometry* was held in Shanghai in October, 2007, with the support of Commission 26. It brought together results from the *Hipparchos* catalog and studies related to the upcoming *Gaia* mission, as well as ground-based projects. It was attended by a significant number of active members of our Commission.

2.4. *Workshop Multiplicity in Star Formation*

The role of multiplicity in star and planet formation was the main focus of this workshop, held in Toronto, Canada, 16-18 May 2007. Topics included multiplicity surveys of protostars, T Tauri stars and brown dwarfs, multiplicity and the initial mass function, and planet formation in multiple systems.

2.5. *ESO Workshop Multiple Stars across the HR Diagram*

This workshop was held in Garching, Germany, 12-15 July 2005, and the proceedings were published in 2008 by Springer. Editors of the volume were S. Hubrig, M. Petr-Gotzens & A. Tokovinin. Topics included observations of multiple stars from ground and space, dynamical and stellar evolution in multiple systems, environmental effects, formation and early evolution of multiples and chemically peculiar objects.

† Professor Plavec, who attended the meeting with his family, unfortunately passed away at his home on January 23, 2008.

3. Information Circulars

Continuing a long-time tradition, the Commission has published *Information Circulars* three times per year. The Circulars are edited by J. A. Docobo and J. Ling, of the Observatorio Astronomico R.M. Aller at the Universidad de Santiago de Compostela, Spain. The *Circulars* are distributed electronically and archived on the Commission 26 web site. During the period October 2006 to June 2008 six *Circulars* were published, announcing a total of 134 orbits, and containing also miscellaneous information, an extensive bibliography on double and multiple stars. Obituaries of Omer Nys (1931 - 2007) and Pierre Bacchus (1923 - 2007) were carried, respectively, in *Circulars* 162 and 163. We deeply regret the passing away of these two distinguished double star astronomers.

4. Catalogues and journals

The U.S. Naval Observatory double star program maintains five astrometric and photometric catalogs, each of which has seen considerable growth during the past three years. These five catalogs are updated regularly on the USNO website.

The *Washington Double Star Catalog* is the principal repository for all published astrometry of visual binary and multiple stars. As of 30 June 2008 the WDS contained 748 343 mean measures of 103 812 systems. The database continues to be improved through correction of errors, removal of duplicate discovery designations and/or measures, and improvements in coordinate, proper motion, and magnitude information. Observing lists based on the WDS are provided on demand for other observers.

As of 30 June 2008, the *Sixth Catalog of Orbits of Visual Binary Stars*, included 2 088 orbits of 1 956 systems, from a 'master file' of 6 028 orbits.

The *Fourth Catalog of Interferometric Measurements of Binary Stars* currently includes 143 903 observations of 73 275 systems. Binary measurements from speckle interferometry, adaptive optics, multi-aperture arrays, *Hipparcos*, and other high-resolution techniques are included, as are negative results from duplicity surveys.

The *Third Photometric Magnitude Difference Catalog* includes 158 946 measures of 52 752 systems. This is somewhat reduced in size from the previous version of the catalog since duplicate photometric information also in the main WDS database was excluded. The *Catalog of Rectilinear Elements* was posted to the web during the past triennium; the catalog currently includes elements for 1 170 (presumably) optical pairs, although this number is expected to increase substantially. Studies have shown that these linear fits often yield more precise differential proper motions than are available elsewhere, due to the long time base of differential astrometry measures available in the WDS database.

The second USNO Double Star CD, containing versions of all five catalogs as of 2006.5, was published just before the Prague GA and distributed to those in attendance as well as all members of the Commission. Additional copies are available upon request.

A new catalogue of 6 330 eclipsing variable stars was completed (Malkov *et al.* 2006). The catalogue was developed from the General Catalogue of Variable Stars (GCVS) including new classifications of 843 systems and correcting the GCVS data. The catalogue represents the largest list of eclipsing binaries classified from observations. Photometric and spectroscopic observations for selected *Hipparcos* eclipsing binaries were undertaken with the aim to derive absolute dimensions (Oblak *et al.* 2008).

For the near future, a catalogue of fundamental parameters of eclipsing binaries is planned (Oblak *et al.* 2009). Fundamental physical parameters will be determined for about three thousands eclipsing binaries. The transfer of the database of double stars (BDB) of the Besançon Observatory to the Astronomical Institute of the Russian Academy of Sciences in Moscow will be completed, with a mirror site of the BDB at Besançon.

The *Journal of Double Star Observations*, a quarterly publication begun in early 2005 by astronomers at the University of South Alabama, has seen considerable growth during the past triennium. This web-based refereed journal now represents a major source of published measures and other double star information by both professionals and amateurs. Other venues for publication of double star information, including the *Webb Society Circulars* and *Observations et Travaux*, also illustrate the high level (and quality) of activity in our field within the amateur observing community. The Webb Society Double Star Section continues to encourage the observation of visual double stars. During the report period two *Circulars* (Nos. 14 and 15) were issued, containing 2 643 measures of pairs with separations ranging from 0.3 to over 100 arcsec, collected by 10 observers.

5. Speckle interferometry and other single-aperture high-resolution astrometry techniques

5.1. *US Naval Observatory program*

The speckle interferometry program also continues at the USNO. Most observations have been carried out on the venerable USNO 26-inch refractor, with $\sim 4\,300$ mean measures published or in press since mid-2005 (c.f., Mason *et al.* 2006a; 2006b; 2007). Much of this observing effort has been directed toward duplicity confirmations and observations of systems not measured for many years, as well as regular monitoring of potential orbit systems. A new 'backup' speckle camera was designed and built at the USNO and installed on the 26-inch in mid-2006; this allows use of the 'primary' camera at larger telescopes with no observing time lost due to equipment in transit.

The 'primary' speckle camera was used on several larger telescopes during the past triennium, including the KPNO and CTIO 4-meters and the Mount Wilson 2.5-meter. Over 3 000 nearby G dwarf stars were examined for duplicity during this period, as were a similar number of massive (O-type, B-type, and Wolf-Rayet) stars. Results from these analyses are being prepared for publication.

Adaptive optics on the 3.6-meter AEOS telescope on Haleakala, Hawaii has been used in searches for faint companions to B-type stars (Roberts *et al.* 2007) and O-type stars (Turner *et al.* 2008). They confirm the Mason *et al.* (1998) result on the paucity of companions of O-type star runaways. Possible stellar companions to exoplanet host stars have also been searched for (Roberts *et al.* in preparation).

5.2. *The Wisconsin-Indiana-Yale-NOAO program*

E. Horch (Southern Connecticut State University) and W. van Altena (Yale University) continued to use the WIYN 3.5-m Telescope at Kitt Peak for speckle observations of double stars, particularly those discovered by the *Hipparcos* satellite. Over 90% of the observable *Hipparcos* doubles have been studied, and characterization of the motions of many pairs have been made. Horch is completing a new speckle camera, the Differential Speckle Survey Instrument, which can take speckle data in two filters simultaneously. This will make color determinations of the components of binary stars highly efficient. The program has also recently obtained an electron-multiplying CCD camera and has used it for the first time in speckle observations at WIYN in June 2008. This device has near photon-counting performance at extremely high quantum efficiency, allowing diffraction-limited imaging of binary systems as faint as at least 15th magnitude.

5.3. *The PISCO program*

The goal of this long-term program is to obtain speckle interferometry measurements of visual binary stars with the Pupil Interferometry Speckle camera and COronograph

(PISCO) instrument. It was developed in the early 1990's at the Observatoire Midi-Pyrenees, Toulouse, France, for the Pic du Midi Observatory where it was exploited on the 2 m 'Bernard Lyot' telescope from 1993 to 1998. After a period of inactivity, PISCO has been used since January 2004 on the 102-cm Zeiss telescope of the INAF - Osservatorio Astronomico di Brera, in Merate, Italy. The PISCO team participants are M. Scardia, L. Pansecchi (both at INAF-Osservatorio Astronomico di Brera, Merate, Italy), R. W. Argyle (Institute of Astronomy, Cambridge, UK), and J.-L. Prieur (Laboratoire d'Astrophysique de Toulouse-Tarbes), along with many collaborators.

From September 2006, until June 2008, 642 different binaries were observed, with a total of 724 observations. Those observations allowed the computation of twelve new or revised orbits. Results are given in the references (under Scardia and Prieur) as well as in the *Information Circulars* Nos. 160, 161, 162, 163 and 165.

Technically, both PISCO and the ICCD detector have continued to perform well. The computers and instrument control software have been updated. The reduction procedure has also been improved, allowing measurements slightly below the diffraction limit of the telescope. A new method to correct the bispectra has been developed. During the next triennial period, the PISCO program should continue to provide results at the same pace.

5.4. *The SAO program*

Speckle interferometric survey of 250 selected low-metallicity stars was performed with the 6-m telescope of the Special Astrophysical Observatory, Russia. 15 new binary and multiple systems were discovered. Taking into account already known spectroscopic pairs, the total ratio between the single : binary : triple : quadruple systems is 147 : 64 : 9 : 1. The distributions of the orbital periods and mass ratios were also determined for this sample of halo stars (Rastagaev, Balega & Malogolovets 2007).

The improved orbital parameters were derived for the massive young binary Θ^1 Ori C using the results of the 6-m speckle and VLTI observations shortly after periastron passage in 2007. The derived elements imply a short-period (P = 11.1 yr) and high-eccentricity ($e = 0.86$) orbit with a total mass-sum of $49 \pm 7\,M_\odot$ (Kraus *et al.* 2007).

Precise speckle interferometric orbits were calculated for 10 new *Hipparcos* binaries using the results of observations with the 6-m telescope in the period 1998-2007. The accuracy of obtained dynamical masses is in the range 10-20%.

A speckle survey of 83 OB stars in the Cas-Tau association was performed at the telescope with an angular resolution of 20 mas. Twelve new binaries were discovered and the mass function was estimated for the stars in the association.

5.5. *The Calar Alto program*

First results of the optical speckle camera with the 3.5 m telescope at Calar Alto were reported by Docobo *et al.* (2008). Fifty stars with separations between 0.058 and 2.0 arcs were observed. Two new (COU 490 and A 2257) and six improved orbits and masses were calculated. Dynamical parallaxes allowed first rough distance estimates for COU 490 (145 pc) and A 2257 (210 pc). High-quality optical speckle data on binaries with separations close to the diffraction limit of the 3.5 m telescope can now routinely be obtained.

6. Long-baseline interferometry

Georgia State University's CHARA Array, located on Mt. Wilson, California, has concentrated to date on single-star science. Nevertheless, several programs aimed at detection of new binaries and orbit determinations are under way with the results to be reported in

2008 and 2009. Surveys to detect new companions to solar type stars primarily through the detection of double fringe packets corresponding to binaries with angular separations in the 5-30 milliarcsec range are being done. Such objects fall in the 'gap' separating speckle detection and spectroscopic detection.

Binaries are also occasionally being found in the course of measuring stellar angular diameters. They show up quite readily, since the distribution of visibilities cannot be modeled as the result of a resolved photosphere from a single star. In a collaboration with spectroscopists at the Center for Astrophysics and at Tennessee State University, several binaries with excellent double-lined spectroscopic orbits are being followed to determine accurate masses and orbital parallaxes. This includes a 1.0 d system with a separation of approximately 1 mas, the shortest-period system for which a 'visual' orbit has been determined. A program is also under way involving triple systems for which the long-period orbit is resolved by speckle interferometry. This then permits the 'wide' component to be used as the visibility calibrator for the short-period system.

Finally, and most dramatically, an imaging capability has been realized at the CHARA Array through a collaboration with a team from the University of Michigan who have fabricated a four-telescope beam combiner. This system has been used to image several binaries, most notable of which is the close and interacting binary Beta Lyrae, for which Roche lobe filling is apparent for one of the components. In another demonstration of the power of imaging binaries, orbital motion amounting to 15 micro-arcsec has been accurately measured for the spectroscopic binary Iota Peg from a series of observations spanning only 45 minutes in time. In contrast with visibility measurements, imaging provides the classical position angle and angular separation measurements in addition to the magnitude difference and, in some cases, the diameters of the components stars themselves.

The SUSI array produced further results. Among others, high-precision interferometric measurements of Spica and γ^2 Velorum allowed an improved determination of the fundamental parameters of these systems.

From the NPOI array new data on the binary system Θ^1 Ori C, which was spatially resolved over the period from 2006 February to 2007 March, show significant orbital motion. However, a definitive orbit solution will require more time. An ongoing survey for multiplicity among the bright stars will complement the visual orbits obtained for known close speckle and spectroscopic binaries, and detect new binary/multiple systems.

7. Other projects

7.1. *Young systems*

Zinnecker and collaborators (Correia *et al.* 2006), searching for hierarchical triples in nearby visual binaries using adaptive optics, found an enhanced fraction of young low-mass hierarchical triples (about 1/3). The *HST*-ACS survey of the outer Orion Nebula Cluster was completed by Reipurth *et al.* (2007) producing dozens of new sub-arcsec low-mass young binaries. Further, Koehler *et al.* (2006) published an adaptive optics results paper with new pre-MS binary statistics in the Orion Cluster. Koehler & Ratzka (2008) studied the orbits and masses in the prototypical T Tauri system. Multi-epoch radial velocity observations aimed at detecting massive companions of young embedded O-type stars were conducted by Apai *et al.* (2007) using VLT/ISAAC at $R = 10\,000$. They found radial velocity variations in two of 10 cases. New ideas about the origin of Trapezium type systems, and more generally, about multiplicity among massive stars, were proposed by Zinnecker at the ESO Workshop 2005 (Zinnecker 2008). Very young embedded Class I

pre-main sequence binaries were studied by Connelley (2008). Surprising dissimilarities in a newly formed pair of 'identical twin' stars in the Orion nebula were recently discovered by Stassun *et al.* (2008).

7.2. *Wide binaries, trapezium systems, runaway stars*

The role of large samples of wide binaries for a great variety of galactic studies was emphasized by Chaname (2007). New faint common proper motion companions to *Hipparcos* stars were identified by Lepine & Bongiorno (2007), who also found that at least 9.5% of the nearby ($d < 100$ pc) stars have companions with separations greater than 1000 AU. The distribution of separations was found to follow Oepik's relation up to separations of 4000 AU.

Poveda *et al.* (2007) continued their studies on wide binaries, trapezium systems and runaway stars. They confirmed that wide binaries from various catalogues follow the Oepik relation for semiaxes larger than about 60 AU up to a critical separation that is a function of the age of the system. Poveda *et al.* (2008) discovered that Giclas 112-29 (NLTT 18149) is a very wide ($s = 1°.09$) companion to GJ 282 AB having a common proper motion, common parallax, common radial velocity and common age. A study of high velocity, metal-poor wide binaries led to the identification of several associated moving clusters in the galactic halo, which may be the remains of either globular clusters or captured dwarf galaxies in the process of disintegration. Chemical peculiarities allow to differentiate between both cases (Allen *et al.* 2007). The discovery (Rodriguez *et al.* 2005; Gomez *et al.* 2005; Gomez *et al.* 2008) that the runaway system BN/I/n in Orion is a multiple in the process of disintegration has confirmed the model for the acceleration of runaway stars by strong dynamical interactions in a compact few-body system (Poveda *et al.* 2008; Allen *et al.* 2008). A new technique ('diffracto-astrometry') has been developed to utilize the diffraction patterns of over-exposed *HST* images of the Orion Trapezium. With this technique recent values of the separation of components A-E have been precisely determined, (Sanchez *et al.* 2008) which, together with older determinations, have shown that the relative proper motion of A-E is 3.5 mas/yr. Further, a radial velocity study (Costero *et al.* 2008a) has shown that the systemic radial velocity of E is 8.3 km/s, larger than the average radial velocity of the ONC members and very similar to the transverse velocity relative to component A derived by Sanchez *et al.*, confirming that component E is leaving the system with a space velocity of about 11 km/s. Unexpectedly component E was found to be a double-lined spectroscopic binary with $P = 9.8952$ d, $e = 0$ (Costero *et al.* 2008b).

The discovery of a planetary-mass body ($M \sin i = 3.2\,\mathrm{M_{Jupiter}}$) orbiting the star V391 Pegasi at a distance of about 1.7 AU, with a period of 3. yr was recently reported by T. Oswalt and collaborators (Silvotti *et al.* 2007) This detection of a planet orbiting a post-red-giant star demonstrates that planets with orbital distances of less than 2 AU can survive the red-giant expansion of their parent stars.

Post-main-sequence mass loss causes orbital separation amplification in fragile binary star systems (with typical separations around 1000 AU). Such wide pairs evolve as two separate but coeval stars. Oswalt and collaborators (Oswalt *et al.* 2007; Johnston *et al.* 2007) have studied the statistical distortion of the frequency distribution of fragile binary separations caused by the mass loss. This process provides a robust test of current theories of stellar evolution and sets constraints on the dynamics of the Galactic disk.

7.3. *Stellar multiplicity*

A. Tokovinin completed several studies on multiple stars including a new catalog of multiples among bright stars (Eggleton & Tokovinin 2008) where it was found that among

4559 systems with (combined) magnitudes brighter than 6.00 the frequencies of multiplicities 1, 2, ..., 7 were 2718, 1437, 285, 86, 20, 11, and 2, respectively. Other relevant statistical results on multiple stars (triples and quadruples) appear to show that the properties of multiple stars do not correspond to the products of dynamical decay of small clusters (Tokovinin 2008). New tertiary companions to solar-type spectroscopic binaries were found using adaptive optics. The periods of tertiary companions are distributed in a wide range, from 2 to 100 000 yr, with most frequent periods of few thousand years (Tokovinin *et al.* 2008).

7.4. *Massive binaries, interacting stars*

Multicolour (*UBVRI*) polarimetric studies (Piirola *et al.* 2006) of massive interacting binaries (W Ser, SX Cas) have provided a detailed view into the dense electron scattering envelopes surrounding the mass-gaining components, and new insights into the heavy mass-transfer phenomenon taking place in the current evolutionary phase of these binaries.

The highest magnetic field ($B = 30$ MG) so far seen in an Intermediate Polar has been discovered by circular polarimetry of V405 Aur at the Nordic Optical Telescope (Piirola *et al.* 2008). This makes the system a likely candidate as a progenitor of a synchronous magnetic binary, polar. Similar studies of other probable candidates have been carried out at the ESO VLT and 3.6 m telescopes in 2006 - 2007.

A new code to calculate light curves, spectra and images of interacting binaries immersed in a moving circumstellar environment which is optically thin was developed by Jan Budaj and collaborators (Budaj, Richards & Miller 2005; Miller *et al.* 2007). It solves simple radiative transfer along the line of sight in moving media. The main applications are in the field of interacting binaries, cataclysmic variable stars, and Algol-type eclipsing binaries. The code is fully public and the latest version can be found at `<ta3.sk/ budaj/shellspec.html>`.

7.5. *Visual binaries and multiples*

H. Abt (2008a) continued his studies of fundamental parameters of multiple stars and completed the MK classifications of the components brighter than $B = 8$ mag in Aitken's Catalogue (2 403 classifications). A study of the difference between metal-poor and metal-rich binaries showed that the metal-poor stars lack short-period binaries relative to the metal-rich stars and that their period distributions are very different (Abt 2008b).

At the Royal Observatory of Belgium, P. Lampens *et al.* (2007a) reported accurate relative astrometry and differential multi-colour (*BVRI*) photometry for the components of 71 visual systems. Basic binary properties were derived for 20 physical systems. The component colors and masses were obtained for two orbital systems .

A new orbital solution based on recent high-resolution spectra and existing long-baseline optical interferometric data was determined for θ^2 Tau. Radial velocities were derived for both components applying a spectra disentangling algorithm (P. Hadrava, Ondrejov, Czech Rep.). With the improved accuracy of the orbital parameters and associated fundamental properties, the component masses and luminosities were found to be compatible with current stellar evolution models adopting the Hyades metallicity (Lampens *et al.* 2007b).

R. Argyle used the 26.5 inch Innes refractor at Johannesburg for a program of double star measurement from 16 May to 1 June 2008 inclusive. 207 mean measures were made of southern visual binaries and systems known to be in motion but not measured for 10 or 20 years.

7.6. *Spectroscopic binaries*

Roger Griffin published his 200th paper on radial velocity spectrometer orbits of binary stars in the June issue of *Observatory*. A paper by V. Trimble will appear in the August issue examining the statistics of binary star mass ratios based on those 200 papers, plus some others. Two papers published by C. Scarfe *et al.* (2007, 2008) deal with spectroscopic binaries of rather long period, whose primaries are giants, and for which secondaries were detected which are also evolved, making these systems of interest for stellar evolution models.

7.7. *Eclipsing binaries*

A new procedure for the automatic classification of eclipsing binaries was developed by Malkov, *et al.* (2007). It is based on the data from 1029 classified systems and allows for the classification of a given system based on a set of observational parameters, even if the set is incomplete. The procedure was applied to six large surveys of eclipsing variables. About 5 300 systems were classified for the first time and can be used for the determination of the astrophysical parameters of their components.

A photometric and spectroscopic observational campaign of newly discovered *Hipparcos* eclipsing binaries has been realized since 1997. The data are collected at Haute Provence (France), Cracow (Poland), Krioneri (Greece), Lvov (Ukraine) and at Ankara University Observatory (AUG) and TUBITAK National Observatory (TUG) in Turkey. Among the fist results from this campaign, out of 36 objects, 24 new double-lined eclipsing binaries were identified. Ten systems were found to be new, spectroscopic triple systems. Two triple systems show time changes of center-of-mass velocity of the eclipsing binaries due to the presence of a third body. 22 Hipparcos periods were updated. Radial velocity curves and orbital solutions were presented. Four systems were identified as good sub-solar mass candidates.

7.8. *Gaia and non-single stars*

For the past two years, Dimitri Pourbaix has been leading the Coordination Unit of the *Gaia* Data Processing and Analysis Consortium, in charge, among others, of the non single stars. He has been involved in the design and coding of methods to deal with resolved and unresolved binaries (and multiples). A review talk on binaries at IAU Symposium 248, Shanghai, 2007 (Pourbaix 2008) deals with these matters. In addition, Pourbaix still maintains the 9th catalogue of spectroscopic binary orbits on behalf of Commission 30.

7.9. *Theoretical work*

Seppo Mikkola has continued his N-body simulations with binaries. Mauri Valtonen has studied the stability of hierarchical triples with A. Myllari, V. Orlov and A. Rubinov. The books by Valtonen & H. Karttunen, *The Three-Body Problem* (Cambridge: CUP, 2006) and G. Byrd, A. Chernin & M. Valtonen, *Cosmology: Foundations and Frontiers* (Moscow: URSS Publ., 2007) deal with binaries in both Galactic and cosmological contexts. These books summarize the roles of binaries in stellar dynamics. With Jia-Qing Zheng, Valtonen has studied unequal mass binary formation in star clusters, as a way of understanding the origin of the Oort Cloud. In connection to the question of the transfer of life between different solar systems (and with Passi Nurmi as collaborator) planets around binary stars as targets for microbe-carrying asteroids were considered.

In collaboration with H. Lehto, S. Kotiranta, P. Heinamaki and A. Chernin, Valtonen has also studied the question of the 'Arrow of Time', one of the fundamental open questions in physics, and has shown that as soon as a third star is added to a binary

system, the arrow of time (which is unspecified for the binary, the system being fully time-reversible) becomes specified through Kolmogorov-Sinai entropy. Papers on these topics have recently appeared (or will appear soon. Valtonen's future plans include writing a popular account of the three-body problem with J. Anosova, K. Tanikawa, V. Orlov and A. Myllari.

Acknowledgements: My sincere thanks to all of you who sent information. I am most grateful for the balanced summaries of the work of their respective groups submitted by W. Hartkopf, Y. Balega, J. Budaj, E. Horch, P. Lampens, H. McAllister, E. Oblak, D. Pourbaix, A. Poveda, M. Scardia, M. Valtonen, and H. Zinnecker. Any errors, omissions and such are, of course, solely mine.

Christine Allen
President of the Commission

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