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COMMISSION 26: DOUBLE AND MULTIPLE STARS
(ETOILES DOUBLES ET MULTIPLES)

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1. Introduction

Commission 26, one of the smallest in the IAU, nevertheless maintains an active program. In the current triennium our website has been transferred by the vice-president, W.I. Hartkopf, from CHARA in Atlanta to the U.S. Naval Observatory in Washington. Its url is

http://ad.usno.navy.mil/wds/dsl.html#iau

and it includes a variety of links to other sites, major databases and catalogues, as well as to current and future events.

2. Meetings

The most notable achievement of the past triennium was IAU Symposium 200, on the Formation of Binary Stars, held in Potsdam, Germany, in April 2000. That meeting was perhaps the first devoted to star formation since it became widely accepted that stars usually form as members of binary and multiple systems. Perhaps more than ever before, the meeting drove home the realization that many processes are involved in the formation of stars, and that many kinds of observations are necessary to elucidate those processes. Complex theoretical models are in turn needed to interpret the data, since the interactions between the many components of embryonic binary and multiple systems must be understood, and the roles of various initial conditions must be interpreted. The meeting brought observers and theorists together, and led to many lively discussions and fruitful exchanges of ideas. The proceedings have been published, edited by H. Zinnecker and R.D. Mathieu. The meeting also set a precedent in being the first symposium for several triennia to take place in a General Assembly year but apart from the General Assembly itself.

By the end of the period covered by this report, planning was well advanced for IAU Colloquium 191, on the Environment and Evolution of Double and Multiple Stars, to be held in Mérida, Mexico, in 2003 February. Its theme is to follow the evolution of those objects beyond the formative stages, and in particular to examine the mutual interactions between them and their surroundings.

3. Information Circulars

For many years the Commission has published information circulars three times annually. Edited by P. Muller, their founder, for 30 years and by P. Couteau for another 10, the circulars are currently edited by J.A. Docobo and J.F. Ling. In the present triennium, they have been converted to electronic distribution, and are placed on the Commission's website.

During the current triennium, ten circulars, numbered 138 to 147 inclusive, have been published. Their contents are summarized below.

3.1. New Orbits

A total of 245 new orbits were announced, 183 of them for objects north of the celestial equator, and 62 for southern systems. Numerous authors contributed orbits, some of which appeared in every circular.

3.2. Newly Discovered Double Stars

Circulars 138, 140, 141 and 143 listed new discoveries, and circular 139 presented micrometer measurements.

3.3. Publication Lists

Circulars 140, 143 and 146 included lists of papers on double stars published in 1999, 2000 and 2001 respectively, and circular 145 added a few more to the list for 2000.

3.4. Obituaries

Circular 141 carried an obituary and an appreciation of Paul Muller, and circular 142 included an obituary of Kaj Strand, two distinguished former Presidents of the Commission.

3.5. Miscellaneous Announcements and Reports

Several circulars contained announcements, whose subject matter ranged from the publication of new catalogues, and revisions to older ones, to information on new instruments and proposals for meetings. A report of the Commission's business meeting in Manchester was published in circular 142.

4. Catalogues

4.1. Catalogues Maintained at the U.S. Naval Observatory

The USNO double star program maintains four astrometric and photometric catalogues, each of which has seen considerable growth during the past three years:

1. The Washington Double Star Catalog is the principal repository for all published astrometry of visual binary and multiple stars. As of July 2002 the WDS contained 585,254 mean measures of 98,084 systems, 20% increases over their July 1999 totals. Along with a substantial increase in size, the database continues to be improved by

   (a) correction of many thousands of errors,

   (b) making method codes, notes, and references common to other catalogues in the database,

   (c) removal of duplicate discovery designations,

   (d) removal of many spurious binaries or identification of the same system at more than one coordinate,

   (e) determination of arcsecond-precise coordinates (completed at present for 80% of the entries),

   (f) determination of secondary proper motion (currently for 37% of the entries), and

   (g) the creation of a 'neglected doubles' observing list so as not only to improve the astrometric data, but also to root out other spurious detections.

   This last task has involved the preparation of finder charts for over 6,400 systems. Results from new observations of these targets are being added to the database of measurements.

2. A successor has been created to the Worley & Heintz (1983) "Fourth Catalog of Orbits of Visual Binary Stars", including a more objective method for determining orbit quality. The current (sixth) catalogue contains 1,702 orbits of 1,660 systems, nearly double the size of its predecessor. The web catalogue includes elements, notes, ephemerides, and figures showing all published measures. A subset of these orbits, considered of sufficient quality for scale calibration, has also been posted to the web.

3. The CHARA "Third Catalog of Interferometric Measurements of Binary Stars" was moved to the USNO in July 1999. Now the USNO "Fourth Catalog..", it includes 107,274 observations of 51,319 systems, increases of roughly 250% since July 1999.

4. A previously internal USNO catalogue of photometric magnitude differences was posted to the web in 2001. It currently includes 64,168 measures of 24,572 systems, some four times the size of the mid-1999 version.

Copies of all four USNO double star astrometry catalogues, current to 2001.0, were written to CD-ROM and distributed to members of Commissions 8 and 26, as well as amateur observers and other interested parties. Web versions of all catalogues are updated on a regular basis, and future CD versions are anticipated as well.

Following a Multi-Commission Meeting at the Manchester IAU on component designations for all types of double and multiple systems, work was begun on developing the preliminary nomenclature scheme. A half-hour band of the planned Washington Multiplicity Catalog is being compiled from the USNO visual binary catalogues, as well as catalogues of spectroscopic binaries, eclipsing and interacting systems, as well as extra-solar planets and other substellar companions. This sample WMC will be presented at a Special Session during the next General Assembly for discussion and final approval, then the full catalogue will be compiled during the next triennium.

4.2. Catalogue of Orbits of Visual Double Stars and their Ephemerides

This catalogue (Docobo et al. 2001) has been completed at the Universidad de Santiago de Compostela, and is linked to the Commission's webpage. It is complementary to the USNO catalogues because of somewhat different selection criteria, but the similarity of the catalogues permits mutual correction of errors.

4.3. Catalogue of the Components of Double and Multiple stars (CCDM)

J. Dommanget and O. Nys at the Royal Observatory of Belgium report that the Catalogue of the Components of Double and Multiple Stars (CCDM), created to serve as a double star database for the preparation of the Hipparcos Input Catalogue, has been completed with data for nearly 5000 systems of the Index Catalogue, in such a way that its second edition (January 2002) contains 171 astrometric systems, 43,753 double, 4,138 triple, 903 quadruple and 360 multiple systems with more than four components, i.e. a total of 49,325 systems properly located and identified on the sky.

This is basically a manual cross-identification job that uses some old catalogues complemented by recent accurate astrometric ones. It aims to produce the most accurate positions for the components of the systems, generally to an accuracy better than $1''$. Its format is the same as that of its first edition in 1994, described in "Communication de l'Observatoire Royal de Belgique, Série A, no. 115". One important difference lies in the addition of all double systems discovered by Hipparcos as well as all new components of known systems. The catalogue is available from the CDS at Strasbourg under reference no. I-274 and its description will be published in "Observations et Travaux".

5. Long Baseline Interferometers

One of the most important developments for double-star astronomy in recent years has been that of long-baseline interferometers. Several of them are active, and achieving angular

resolutions well beyond the range possible with older techniques. The status reports below provide a sample of the accomplishments of the past triennium, but do not exhaust them, since several other instruments, such as VLTI/VINCI, COAST and IOTA are also in use. A more complete list can be found in the Optical Long Baseline Interferometry Newsletter (http://olbin.jpl.nasa.gov). So far the binary of shortest period for which results have been published is β Aurigae, with a period of 3.96 days, but this is likely to be surpassed soon.

5.1. Navy Prototype Optical Interferometer (NPOI)

The NPOI was upgraded early in 2002 to six stations for beam combination, which yield 15 simultaneous baselines, with a maximum length of 64 m. Ultimately this will be increased to 430 m. It operates with 16 channels between 570 nm and 850 nm, the limiting V magnitude is currently 5, and the maximum magnitude difference is estimated to be 3.5.

5.2. Palomar Testbed Interferometer (PTI)

Orbits for nearly a dozen systems have been published by the PTI group. The PTI (Colavita et al. 1999), with three elements, operates in both the H and K bands with a baseline of either 110 or 85 m, giving a minimum fringe spacing of ~ 3 mas. An upgrade to operations on three baselines simultaneously is planned for the near future. The limiting magnitude in K is ~ 6; the largest magnitude difference is estimated at 3.5.

5.3. Sydney University Stellar Interferometer (SUSI)

SUSI (Davis et al. 1999) has been used to observe a number of systems that were first identified as binaries 25 years ago with the Narrabri Stellar Intensity Interferometer. Orbits are being determined that, in combination with spectroscopy, will enable masses and distances to the systems to be determined. The instrument has been restricted to binary systems brighter than B ~ 2 for technical reasons, but a new beam-combination and detection system is conservatively expected to reach V ~ 6. A major program for the new system will be the study of binary stars in collaboration with spectroscopists to determine not only masses and distances but also the radii and luminosities of at least the primary components and, in favourable cases, the secondary components as well.

As an adjunct to the SUSI program, a study of video recordings of binary star images from a 0.35 m telescope has shown that the diffraction limit of the telescope can be reached by the selection of frames recorded in instants of good seeing (Davis & North 2001).

5.4. Center for High Angular Resolution Astronomy (CHARA) Array

The CHARA Array is a six-telescope optical-infrared array located on Mt. Wilson, California. Construction of the instrument is essentially complete, with all six 1 m telescopes operational. A program of observation of spectroscopic binaries and "wide" binaries ($\rho > 0.050''$) was initiated in the spring of 2002. CHARA has also produced a new bibliographic listing of orbital elements of spectroscopic binaries to aid in planning and scheduling observing programs. So far all observations have been made in the K band, but optical observations will become possible soon. The current magnitude limit is near K = 6, but it is expected that a further two magnitudes will become possible. Ultimately it is hoped to resolve separations of about 10^{-4} ".

6. Other Topics

6.1. Radial Velocities

Although most programs of very precise radial velocity observations have focused in recent years on the detection of planet-sized companions to stars, accurate radial velocities of visual systems are being pursued by several members of the Commission. In combination

with interferometric data, these yield reliable masses and some of the most accurate stellar distances in the literature. During the previous triennium, for example, D. W. Latham and his colleagues published studies of a few objects in the Hyades, which yielded distances significantly better than those from Hipparcos parallaxes. This matter has recently been taken up again by J. Tomkin, with accurate radial velocities of Hyades systems that should be resolvable with long baseline interferometers (Tomkin & Griffin 2002).

6.2. Brown Dwarf Binaries

Brown dwarfs (BDs) develop degenerate cores during their gravitational contraction, which prevent them from settling on the hydrogren-burning stellar main-sequence. While their existence was predicted in the 1960s, they have become truly astronomical objects only since 1995. In 1999 the first binary BDs were discovered. One is a double-lined spectroscopic binary with a period of 5.8 days (Basri & Martín 1999) It is a member of the Pleiades, and thus its age, distance and metallicity are known. Despite its short period, the eccentricity is relatively high (e = 0.4), which indicates that the timescale of orbital circularization is rather long for BDs. Two more binary BDs within 25 pc of the sun were found in 1999 with the HST (Martín et al. 1999) and the Keck I telescope (Koerner et al. 1999).

Following these discoveries, systematic searches for BD binaries have been undertaken using HST and adaptive optics in large ground-based telescopes. About 30 BD binaries are currently known. For one of them, orbital parameters and dynamical masses have been obtained, and these permit a test of models of substellar evolution (Lane et al. 2001). The BD binary frequency is estimated at $> 20\%$. The distribution of orbital separations is different from that of binaries with solar-type primaries. There are no brown dwarf binaries with separations larger than 15 AU. The binary frequency and distribution of separations of BDs are important constraints to models of the formation of these objects (Bate et al. 2002). A review of these results has been given by Martín & Basri (2001).

6.3. Astrometry and Photometry at ESO

Astronomers of six European countries have collaborated on a key program running at ESO between 1992 and 1995 that aimed to collect accurate astrometric and photometric data for the components of visual double stars which formed part of the program of the Hipparcos astrometric space mission. The technique of CCD imaging has been employed. The results include homogeneously and carefully calibrated relative positions as well as differential colour indices and magnitudes for the individual components of more than 500 southern visual double stars of the "intermediate" class, i.e. with angular separations between $1''$ and $15''$ (Oblak et al. 1999; Cuypers & Seggewiss 1999; Lampens et al. 2001).

Monitoring of several orbits of close visual binaries and multiple stars was done on the basis of newly collected relative positions obtained either with a CCD camera (Lampens & Strigachev 2001) or with the speckle imaging technique (Prieur et al. 2001). The multicolour CCD observations permitted component masses and colours to be computed for several binary systems with Hipparcos parallaxes larger than $0.04''$, which belong to the ARI Data Base of Nearby Stars of Jahreiss & Wielen. From the speckle data, a first estimate of the mass ratio for the single-lined spectroscopic binary β Del was obtained.

6.4. Participation in the DIVA Astrometric Project

The combination of many "Sky Mapper" images of a single object is a subtask defined in the preparation of the astrometric mission DIVA that is being handled at the Royal Observatory of Belgium. The higher signal-to-noise ratio and increased resolution of the combined image will permit detection of new, faint components of stellar systems.

6.5. Observing Programs at USNO

The program of differential astrometry of visual binaries continues at the USNO, by the technique of speckle interferometry. Most observations have been carried out on the USNO 0.7 m refractor, with over 6,500 measures published or in press since mid-1999. Much of this effort has been on duplicity confirmations and observations of systems neglected for many years, as well as regular monitoring of potential orbit systems. The speckle camera has also been used at the KPNO and CTIO 4 m telescopes, for an all-sky duplicity survey of 3,600 G dwarfs, and at the McDonald 2.2 m, for a survey of over 1,000 other stars, mainly Hipparcos problem stars and Hipparcos and Tycho double stars needing confirmation.

6.6. The Distribution of True Separations of Double Star Components

In a preliminary research on this distribution, based on the Hipparcos product, Dommanget (2001) has shown that despite the discovery of many new close binaries by the satellite (categories: DMSA/C and O, G, V, X, S) it clearly appears that many systems with separations less than 1 AU remain to be discovered. For example, systems with separation of some $0.01''$, and $\Delta m < 0.60$, could not be discovered, photocentre and centre of gravity being too close. The sample of nearby double stars (within 25 parsecs) is thus far from complete at present. Of course some fine analysis pursued on some specific Hipparcos results may improve the situation somewhat.

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