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PROFILE OF A KEY PROGRAMME:

CCD and Conventional Photometry of Components of Visual Binaries

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1. Introduction

The study of double stars, apart from long being recognized as a basic key to the understanding of star formation and evolution, actually deserves particular attention for many additional reasons:

(1) the ratio of known double to single stars is continuously upgraded and the rate of detection is steadily increasing, both from ground-based and space observations;

(2) space observations (Hipparcos, HST) significantly improve the quality and the importance of stellar samples. They permit to better take into account some of the former selection effects as they reveal a lot of new double stars, especially among the close visual pairs;

(3) the high-quality astrometric (and partly photometric) data that will be made available for a large number of double stars by the space results should be matched accordingly with accurate and homogeneous complementary astrophysical information such as colour indices and spectral types.

(4) Such accurate ground-based information for each of the components of close visual double stars (angular separations less than some ten arcseconds) is almost nonexistent on a large scale – e.g. the astrometric "Catalogue des Composantes d'Etoiles Doubles et Multiples" (CCDM; Dommanget, 1989) contains over 65,000 systems but fewer than 10 % have accurate and reliable photometry –, but is recently made possible with the breakthrough of CCD detectors in spectroscopic and photometric techniques.

The importance of studies of visual double stars lies not only in the traditional determination of stellar masses in orbital pairs – however fundamental these may be – but also in the determination of the characteristics and the frequency of double stars in different stellar populations and evolutionary stages. The distributions of the characteristics typical of double stars such as periods, eccentricities, mass ratios, relative ratios of double and multiple star systems are actually not sufficiently well known to provide valuable constraints on the different star formation scenarios.

In order to acquire this knowledge, the astrophysical information available from magnitudes, colours, spectral types and velocities is fundamentally needed. The usefulness of photometry of visual binaries is especially obvious in applications concerning, for example, luminosity calibrations, the mass-luminosity relationship, mass-ratio determination from differential magnitudes, age and evolution determination. But the type and the accuracy of the photometric information depend very strongly on the separation of the binary components:

– Wide visual double stars (with separations larger than 12″) present no difficulty to conventional photoelectric photometry. Individual data are easily secured, even though a more careful procedure (choice of sky, centring) than in the case of single stars may be desirable to obtain high-quality data.

– To the extreme other end of the range in separation, the interest for the very close binary systems (visually non-separable) arose during the last decade because of the physically interesting underlying mass transfer problem. In these cases, global photometry is performed.

– The technical difficulties of observing two images in close proximity to one another are especially pronounced in carrying out conventional photoelectric photometry for the remaining class of double stars with separations in the intermediate range. This class of objects has therefore largely been neglected in past photometric programmes. When available, global photometry in combination with visual or photographic estimates of the magnitude differences are not sufficiently precise to match the actual requirements and the accuracy achieved in other techniques.

With the introduction of CCD detectors on photometric telescopes, it now also appears feasible to obtain accurate photometric data for each of the components of close visual double stars with angular separations between 1 and 12″.

2. The Scientific Justification

A comprehensive catalogue of physical pairs – from the very close to the

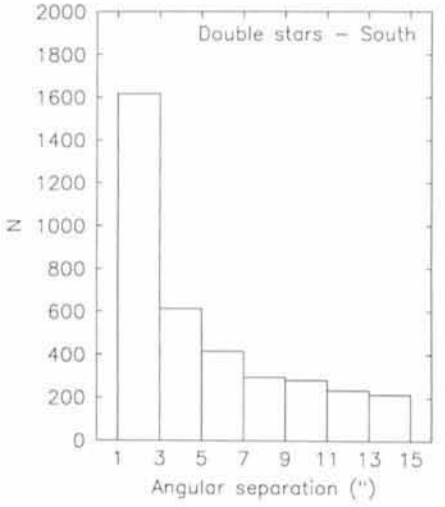

Figure 1: *Distribution of the angular separations between the components of the double stars for the southern hemisphere* ($\delta < +10°$).

very wide ones – with a maximum number of astrometric, spectroscopic and photometric good-quality data would be a highly valuable astrophysical tool because it would contain several clues concerning the mode of star formation and consequently also the structure and the evolution of our galaxy.

The construction of such a basic sample of double stars is now within reach, thanks to the ground-based technological progress as well as to the huge preparational work and fine results from the Hipparcos space mission. On one side, its systematic all-sky survey has permitted the detection of a large number of new double stars, with separations small enough to partially fill the known "gap" between the spectroscopic and the visual double stars. On the other side, the mission will provide accurate parallaxes and proper motions for all the double stars included in the Hipparcos Input Catalogue (more than 10 %), allowing to precisely define the distance-limited samples but also to recognize more surely optical systems. Moreover, different groups have already addressed the spectroscopic aspect (ESO Key Programmes for radial velocities) of the Hipparcos stars, containing at least partially the basic sample we wish to investigate.

The aim of this group, collaborating in the frame of a European network of laboratories (Oblak et al., 1992), is to contribute to a systematic and unbiased photometric survey of the components of double and multiple stars.

The available photometric data, obtained at ground-based observatories or in space programmes, are mostly concerned with the global system. To obtain the relevant astrophysical information we need the individual photometric data on all the components of a double or multiple system. A programme of systematic and homogeneous acquisition of precise colour indices for several thousands of components of double and multiple systems has been defined in both hemispheres, with the following priorities:

(1) to supplement the Hipparcos magnitudes by astrophysically significant colour indices providing the additional physical parameters such as temperature and gravity;

(2) to complete the photometric information for the components not included in the Input Catalogue. This is important since accurate micrometric data for the wider pairs may indicate whether or not the components are optical. Our principal scientific objective is to provide the missing photometric data needed to supplement the high quality and extensive astrometric and photometric data on known and newly detected double stars in order to be able to adequately study the mechanisms of formation and evolution of double and multiple star systems.

Such a less-biased survey is urgently needed to improve current theories on formation, evolution and structure of the Galaxy. Indeed, ground-based and space observations reveal that at least half of the stars belong to double and multiple systems but current theories still cannot explain the formation of such a large number of systems.

3. The Observational Programme

The selection of the programme stars (Oblak and Lampens, 1992) was made amongst 11,434 double systems, 1960 triple systems, 536 quadruple systems and 237 multiple systems from Annex 1 of the Hipparcos Input Catalogue, containing objects to a distance of 500 pc (Turon et al., 1992).

In view of repeated photometric campaigns distributed over both hemispheres the observational programme consists of a northern (declination of the primary component > -10) and a southern sample (δ A $\leq +10$). The overlapping zone in declination $-10 < \delta$ A $\leq +10$ is only once observed according to feasibility.

Since both classical photometry and CCD are considered, the selection further included splitting according to

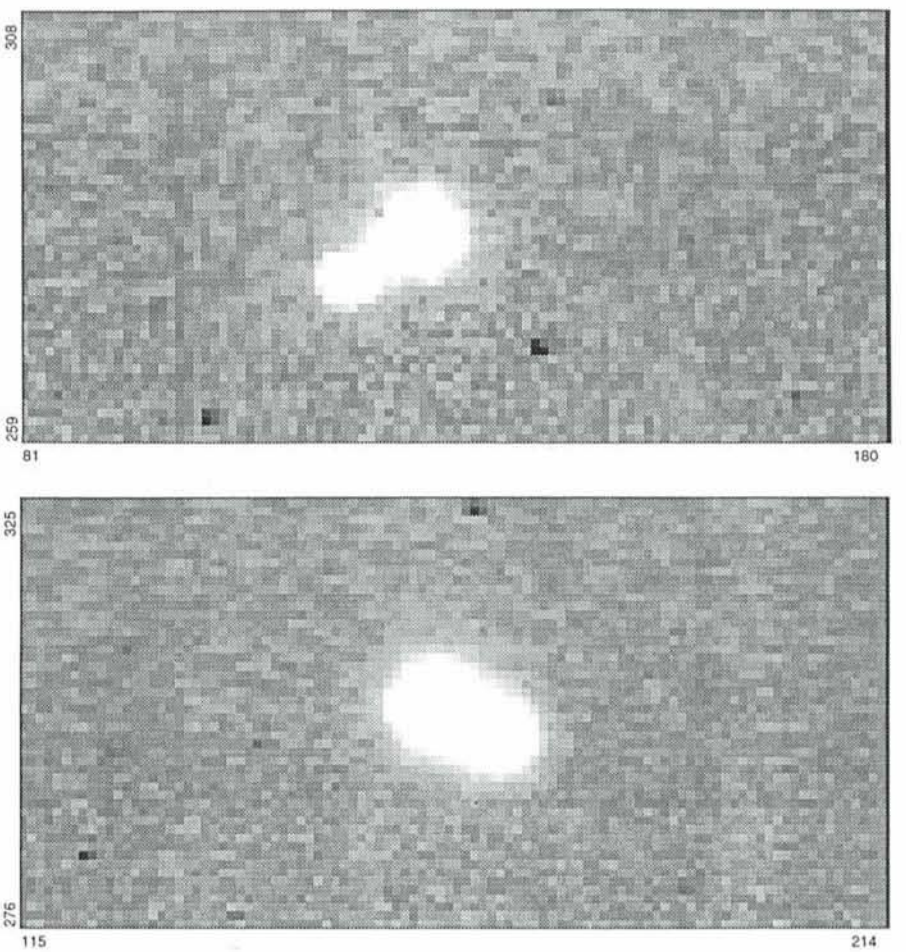

Figure 2: *CCD frames for the stars HD 24445:* $\varrho = 8''.2$, *V(A) = 8.3, V(B) = 10.6, in the I filter and HD 87239:* $\varrho = 6''.3$, *V(A) = 9.0, V(B) = 9.6, in the V filter (OHP – seeing = 2", December 1991).*

angular separation and differential magnitude. For separations larger than 12″, individual magnitudes and colours are easily obtained from classical photometry on small telescopes. For separations smaller than 15″, CCD photometry is more efficient and adequate as long as the difference in magnitude is smaller than three. Astrometric information is obtained as a by-product. The overlapping range in separation has been considered for calibration purposes between two very different techniques. A comparison with the "Catalogue Photométrique des Systèmes Doubles et Multiples" (CPSDM; Oblak, 1988) allowed to identify those systems lacking individual photometric information.

Observations have already started in various observatories located in both hemispheres: Calar Alto, Jungfraujoch, Observatoire de Haute-Provence and La Palma (Argue et al., 1992) for the northern part and La Silla for the southern part.

The ESO Key Programme has been introduced to obtain photometry (occasionally astrometry) in the Cousins VRI bands for those selected systems of the southern hemisphere lacking such precise information (Fig. 1). The observations are made with the CCD detector attached to the 90-cm Dutch telescope for the close visual pairs and on the 50-cm telescopes for the conventional VRI photometry for that part of the programme consisting of wide double and multiple stars.

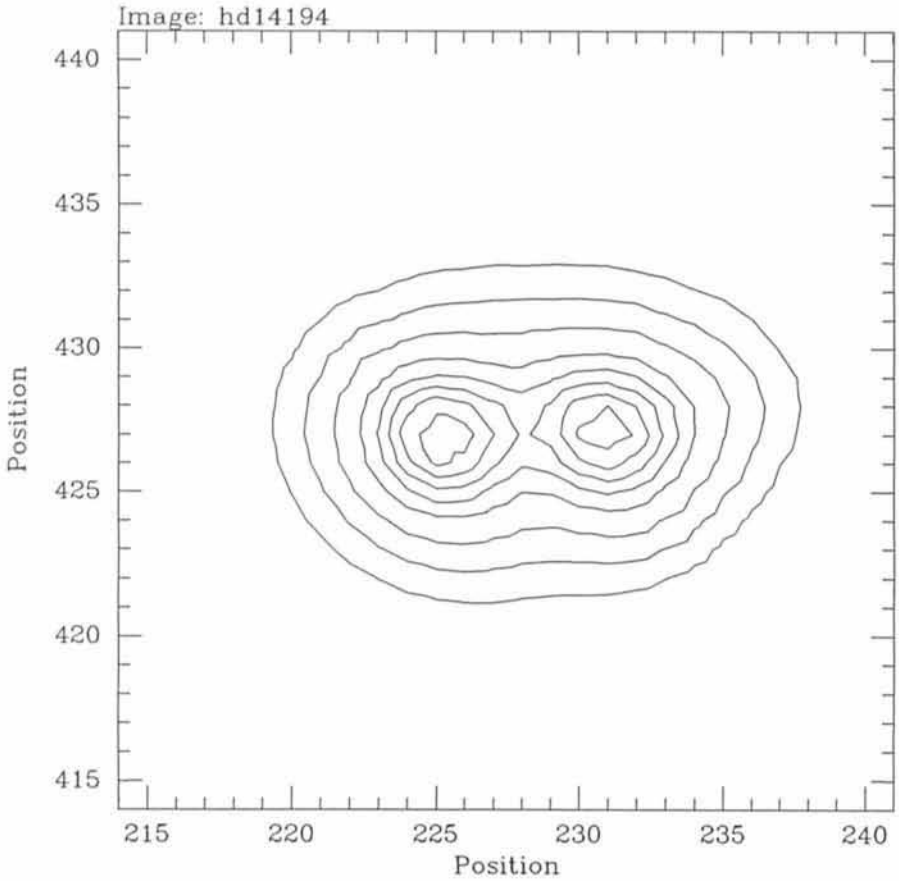

Figure 3: *CCD image of the double star HD 14194 observed with the 90-cm Dutch telescope at ESO: date: 17/10/91; exposure time: 15s; mag A: 9.6; dm = .1, ϱ=2″.1, seeing=1″.3. The preliminary reduction gives: dm = 0.054, ϱ. = 2″.15.*

4. Reduction of the Observations

While the conventional photometry will be reduced in a standard way, a preliminary reduction can only be done with the known packages for the photometric reduction of CCD frames. Crowded-field-photometry routines cannot be applied without modifications to most of the frames obtained, since no reference star images are available (Fig. 2). Therefore, individual profile fittings are necessary. Accurate profiles are needed to separate the closest pairs in the programme (Fig. 3).

In one of the techniques in use for the reductions, a row and a column projection is applied on each CCD frame and a Franz's profile is fitted on the data according to the least-square method supported by an expert system routine (Sinachopoulos, 1992). Other techniques are in use in Geneva and Cambridge (Irwin, 1985). A further one is still under development at Bonn. All these techniques will be compared and the most appropriate for the stellar images on the CCD frames will be accepted for the final data reduction.

Differential magnitudes and relative positions will be obtained with high precision. Efforts are also made in writing and testing additional software for extraction of individual magnitudes and colour indices with an accuracy at the 1% level.

Standard star measurements allow to correct for extinction and to transform the magnitudes to the standard VRI system. Extinction coefficients derived from photometric observations at nearby telescopes will be used when available. Finally, all observations will be processed as homogeneously as possible with a well-defined adopted "standard" procedure.

5. Forthcoming Extensions

In order to have a less biased observational programme and to supplement in a useful way the photometric data, we intend to introduce the double stars not yet included in the Input Catalogue but listed in more recent double star catalogues (Couteau (1992), Worley and Douglas (1984; or its new version)). By arrangement with ESA, we will also be able to include the new double stars with separations greater than one arcsecond detected in the Hipparcos mission. This limit could eventually be decreased in the future, with the use of larger telescopes.

For a better evaluation of the multiplicity on our samples, the information of spectroscopic and speckle interferometric duplicity will be introduced as well. A double star photometric data base, to be integrated in the "Centre de Données Astronomiques de Strasbourg", will be established at the Observatory of Besançon.

We gratefully thank ESO for the allocation time to the Key Programme and are confident that accurate basic data for astrophysically well-defined samples of visual double stars will be within reach during the next few years.

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THE 3rd ESO/OHP SUMMER SCHOOL:

Provençal Summer, Hard Work and Warm Hospitality

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Introduction

Counting the observatories that on the territories of the ESO member countries still operate several telescopes with up-to-date instrumentation, requires the fingers not even of one hand. Accordingly scarce are the opportunities for students to get practical observing experience before this experience is really needed. The scope of the ESO/OHP Summer Schools is to help alleviating this deficiency. For obvious practical reasons neither La Silla and certainly not Garching are suitable sites for this purpose.

One of the few remaining observatories in Europe is the Observatoire de Haute-Provence (OHP). It is named after one of the most attractive regions in the south of France. However, between July 15 and 25 the focus of the attention of 18 graduate students from nine different countries was not on tourism but on the OHP where the third ESO/OHP Summer School took place. Their aim was to partly fill in the observational void in the standard university curriculum.

Practical Work

The layout of the School followed the scheme that had proved useful already in 1988 and 1990 (cf. *The Messenger* No. **53**, p. 11, and No. **61**, p. 8). Seven tutors (Claude Chevalier, Denis Gillet, Sergio Ilovaisky, and Philippe Prugniel from the OHP, Alain Jorissen, Werner Zeilinger and D.B. from Garching) had designed six small observing programmes for as many groups of three students each. The preparation started already the first afternoon, only interrupted by a small reception and the subsequent dinner, because the first observations were to be done the following night.

Each group had one night at the 1.2-m telescope for direct imaging with a CCD camera. For the spectroscopic part, three groups worked at the 1.93-m telescope with its Cassegrain spectrograph Carelec, and the other three used the high-resolution coudé spectrograph Aurelie of the 1.5-m telescope. These two instruments, too, deploy a CCD as the detector.

The director of the OHP, Philippe Véron, had in his welcoming address emphasized the observatory's efforts in the previous weeks to save some good weather for the Summer School. These efforts proved, in fact, quite successful. Only one group had to depend on one of the spare nights for a second attempt to obtain a useful set of direct images. The amount of observations kept the students more than busy with the reduction of their data, using either MIDAS or IHAP or both. The prediction by the organizers that during the School sleep would at best be optional was amply confirmed, especially in the night before the last day in the morning of which each group had to present its results to the other participants.

The diversity of scientific subjects was quite considerable: rotation curves of spiral galaxies and triaxiality of their bulges, a search for inhomogeneities in the internal extinction of a planetary nebula, the optical identification of ROSAT X-ray sources, photometry of an open star cluster in search for δ Scuti stars and the detection of the spectros-

Figure 1: *In the break of Hans Dekker's talk, students, tutors, and organizers assembled in the shadow of a tree for a group photograph. First row (from left to right): Mathias Kunz, Hans Dekker, Nadine Rons, Jesús Gallego, Iordanka Borissova, Christian Surace, Simon Portegies-Zwart; sitting: Lutz Wisotzki; second row: Jean-Philippe Beaulieu, Sandro Bardelli, Helmut Jerjen, Salvatore Scuderi, Susanne Vogel, Mira Véron: third and fourth row: Dietrich Baade, Roland Reiss, Richard Dallier, Eugenio Carretta, Nancy Ageorges, Mikael Sahrling, Volker Ossenkopf, Werner Zeilinger, Alain Jorissen, Marc Ferrari, Karine Bocchialini.*