ACCURATE TWO-COLOUR PHOTOMETRY AND ASTROMETRY FOR HIPPARCOS DOUBLE STARS: FIRST STATISTICAL RESULTS FOR A SAMPLE OF INTERMEDIATE BINARIES*

E. Oblak[1], **J. Cuypers**[2], **P. Lampens**[3], **W. Seggewiss**[3], **M. Chareton**[1], **D. Duval**[2]

[1]Observatoire de Besançon, France
[2]Koninklijke Sterrenwacht van België, Belgium
[3]Hoher List Observatorium, Germany

ABSTRACT

A large number of new astrometric and photometric CCD measurements of intermediate visual binaries (angular separation between one and fifteen arcsec), literature values and Hipparcos data are compared. The claimed mean relative position errors (0.02 arcsec for both the CCD and Hipparcos) are confirmed. For 8 per cent of the systems in the sample we had no Hipparcos solution and in about 6 per cent of the cases the CCD and Hipparcos solutions were too different to be used in the comparison. The dispersion between literature values and CCD results for the joint magnitudes of the systems was 0.03 mag. A comparable dispersion is found only for the Hipparcos data when colour corrections for both components (supplied by the CCD observations) are taken into account. In that case the mean errors on individual components from Hipparcos data are about 0.04 mag for the primaries and 0.08 mag for the secondaries.

Key words: double stars, photometry, astrometry.

1. INTRODUCTION

From 1991 on, a photometric observational programme of intermediate visual binaries (angular separation between one and fifteen arcseconds, difference in magnitude less than 4 mag) has been carried out in the framework of a European Network of Laboratories (Oblak et al. 1992a). The stars selected for the programme had no complete component photometry listed in the data base compiled at Besançon (Kundera et al. 1997).

Observations were made at different observatories (La Palma, Teide and Calar Alto, Spain and Haute-Provence, France), but here we report on data obtained solely at the European Southern Observatory (Chile), where several campaigns and a Key Programme (Oblak et al. 1992b) for this purpose were carried out.

*Based on observations obtained at the European Southern Observatory, Chile and on data from the Hipparcos astrometry satellite.

2. OBSERVATIONS, REDUCTION AND CALIBRATION

The observations were gathered at ESO, La Silla in October 1991 (J. Cuypers), in February 1992 (W. Seggewiss), in August 1992, December 1993 and August 1994 (P. Lampens), in November 1992 and November 1994 (E. Oblak). The 91-cm Dutch telescope was used with different CCD camera's with pixel sizes in the range 0.3 to 0.5 arcsec.

The raw CCD images were treated in a standard way, but a specially developed profile fitting procedure (Cuypers 1997) was used for extracting the relative positions and differential magnitudes when the profiles of the components overlap.

Photometric observations were carried out with Bessel V and Gunn i filters. Observations of standard stars from a list compiled by Grenon (1991), based on lists of Landolt (1983) and Menzies (1989), were used to correct for extinction and to transform the data into the standard $V(R)I$ system.

To calibrate the relative astrometry a set of wider pairs taken from the lists of Brosche and Sinachopoulos (1988, 1989) were measured. Stars were trailed over the frames for a first estimate of the orientation of the CCD detector. In some campaigns open clusters could already be used to calibrate the astrometry (Sinachopoulos al. 1993). This resulted in a very accurate scale and orientation calculation as shown below.

3. EVALUATION OF THE CCD DATA

Since each CCD observation consists of a repetitive sequence of frames (up to 15 for large Δm) and because some double stars were measured in different runs, an internal evaluation is possible.

3.1. Astrometry

Internal position errors are smaller than 0.015 arcsec, while the errors on the means are 0.004 arcsec in general. An increase of the error with larger differential magnitudes is obvious. There is also a degradation of the consistency for separations smaller than 3 arcsec (due to seeing limitation) and for separations larger than 9 arcsec (maybe due to loss of isoplanicity).

The mean value of the differences in positions for the 28 systems observed more than once was 0.024 arcsec, but the median was as small as 0.013 arcsec, since 4 systems have differences greater than 0.07 arcsec. The errors due to the calibration of the scale and orientation of the CCD for each campaign are included here and some of the systems were remeasured because the first observation was uncomplete or not satisfactory.

3.2. Photometry

Internal errors on the differential and derived component magnitudes are very small (<0.005 mag). There is some degradation for separations smaller than 3 arcsec. The standard stars measurements show deviations smaller than 0.03 mag after calibration and transformation to the standard system. The blue ($V-I<0.2$ mag) and, as expected, the very red stars ($V-I>1.2$ mag) sometimes deviate more. Only a limited number of double stars (14) was measured more then once. The median deviation of the magnitudes was only 0.007 mag for the primaries, 0.013 mag for the secondaries and 0.012 mag for the difference in magnitude between A and B. The mean and standard deviation of the differences were 0.02 mag, but it is not excluded that some components are variables.

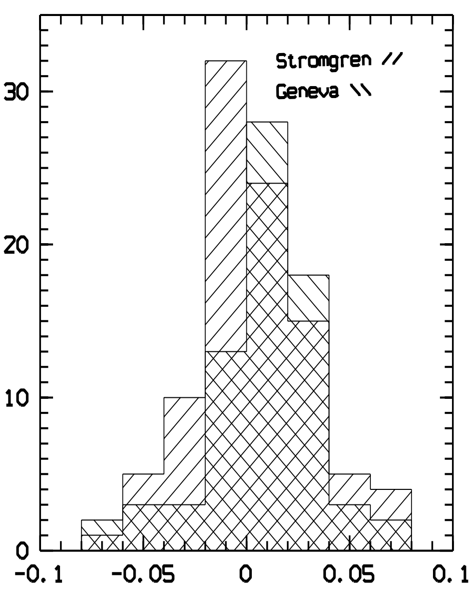

Figure 1. The distribution of the differences between the global V magnitudes in literature and the CCD results.

To evaluate the quality of the photometric observations a comparison was made between the measured and calibrated global V magnitudes of the systems (joint magnitude of component A and B) and the values available in the catalogues (Mermilliod et al. 1996, Kundera et al. 1997). Of 133 double stars of our sample a global V magnitude was available, either from Strömgren (96) or from Geneva photometry (72). The histogram of the differences is given in Figure 1. We do not know whether the slight offset (0.006 mag) between the two sets is significant. The dispersions of the differences are 0.028 mag for the Strömgren and 0.030 mag for the Geneva data. In this dispersion the errors on the literature values are, of course, also included, so 0.03 mag is undoubtedly a very conservative upper limit of the mean error on the CCD magnitudes. No significant dependence of the differences on the system parameters was found. A more detailed error analysis is given in Lampens et al. (1997).

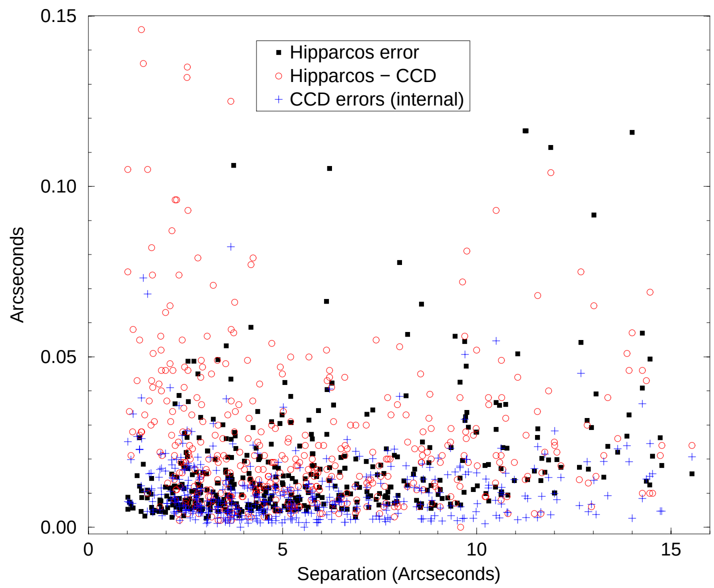

Figure 2. The claimed internal errors on CCD and Hipparcos relative astrometry and the position differences between CCD and Hipparcos results for 416 double stars.

4. COMPARISON WITH HIPPARCOS DATA

4.1. Astrometry

A total of 488 double star systems were used for a detailed comparison between our CCD data and the Hipparcos results (the 28 systems measured twice were considered only once). For 41 systems (8 per cent) we had no Hipparcos solution, while for 31 systems (6 per cent) the positional differences were larger than 0.15 arcsec. The errors on the Hipparcos solutions for the latter cases were well above average. Some of these systems had small separations and, as a consequence, larger errors on the CCD measurements. In other cases a different, wide, usually faint, component was considered as the secondary. In two cases Hipparcos detected a very close companion, not recognized in the CCD images. For 15 other systems we have no explanation for the (large) differences yet.

For the sample of 416 double stars the best match between the CCD and Hipparcos positions was searched in the least-squares sense for each observing campaign separately. For some campaigns no orientation change was necessary, since it was found to be accurate the 0.1° level, due to the well defined star trails or the good calibration with the aid of the astrometric standard fields. A scale correction was usually necessary with a final accuracy at the 0.1 per cent level.

The differences in positions are given in Figure 2, together with the estimated Hipparcos errors and internal CCD errors. Estimates of the errors on the calibration of the CCD data are included in the histogram of the distribution of the errors (Figure 3). The mean error of the Hipparcos sample (0.017 arcsec) and the mean error of the CCD data (0.021 arcsec) are in excellent agreement with the mean value of the position differences (0.026 arcsec). Individual errors depend on the separation and the magnitude differences of the components.

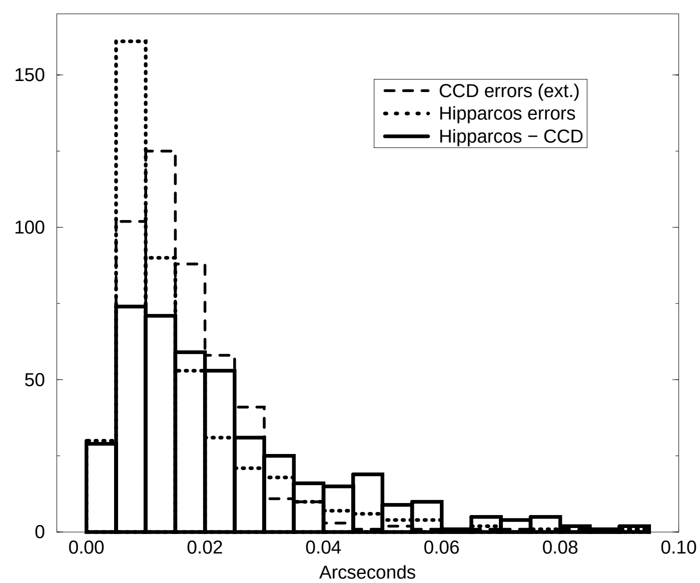

Figure 3. The distribution of the errors on CCD and Hipparcos relative astrometry and the position differences between CCD and Hipparcos results for 416 double stars.

4.2. Photometry

We obtained very reliable V and I magnitudes for 367 double stars of our sample so far. For 19 systems the difference in one of the components was clearly too large (> 0.3 mag) to be included in a detailed comparison (6 per cent). For the remaining sample the component information (V magnitude of component A and B separately) was compared to the Hipparcos magnitudes.

A direct comparison cannot be done: at least some colour information is necessary to compare the Hipparcos magnitudes to the Johnson V magnitudes, otherwise errors could be as large as 0.2 mag (Figures 4a and 5a). We used our measured $V-I$ colour index for the transformation from Hp to V magnitudes following the indications in the Hipparcos catalogue (ESA 1997). The errors after correction are given in Figures 4b and 5b and the distribution of these errors is also shown (Figures 4c and 5c). The rms of the errors for the A components is about 0.05 mag and about 0.09 mag for the B components.

Since we estimated the error of the CCD V magnitudes to be 0.03 mag, in agreement with the comparison to the literature values, a good estimate of the errors on V magnitudes derived from Hipparcos Hp is about 0.04 mag on average for the A components and 0.08 mag for the B components. Individual errors on the V magnitudes are related to the magnitudes of the components.

5. CONCLUSIONS

With the data set presented here excellent possibilities exist to evaluate and complement the Hipparcos measurements of the 'intermediate' double stars. We can already state that the overall accuracy of the majority (85 to 95 per cent) of the double star astrometric solutions by Hipparcos is confirmed for separations from 1 to 15 arcsec. Only in a few cases the errors are much larger, the solutions are not compatible with the system referred to by the HIP number or Hipparcos had no solution for the system. This will be investigated further.

On ground based CCD astrometry we can say that, the level of accuracy with the described instrumentation depends on the possibility of external calibration, while the internal precision on the relative positions can be extremely good (0.007 arcsec). If either a set of reliable Hipparcos measurements or an astrometric field (e.g. a star cluster) is available to do the final calibration, modest instrumentation will reach an accuracy of 0.02 arcsec, which is comparable to the Hipparcos results.

The CCD photometry presented here resulted in a large sample of accurate and well calibrated photometric data for the components, as indicated by the comparison with literature values on the global photometry of the systems. Errors on the magnitudes of the components are in general smaller than 0.03 mag.

To make full use of the Hipparcos double star photometry, the colours of the individual components are necessary. In that case component magnitudes are accurate at the 0.04 to 0.08 mag level, while otherwise errors up to 0.2 mag in V will remain.

ACKNOWLEDGMENTS

We thank ESO for granting a Key Programme for this work and the Hipparcos Science Team (and

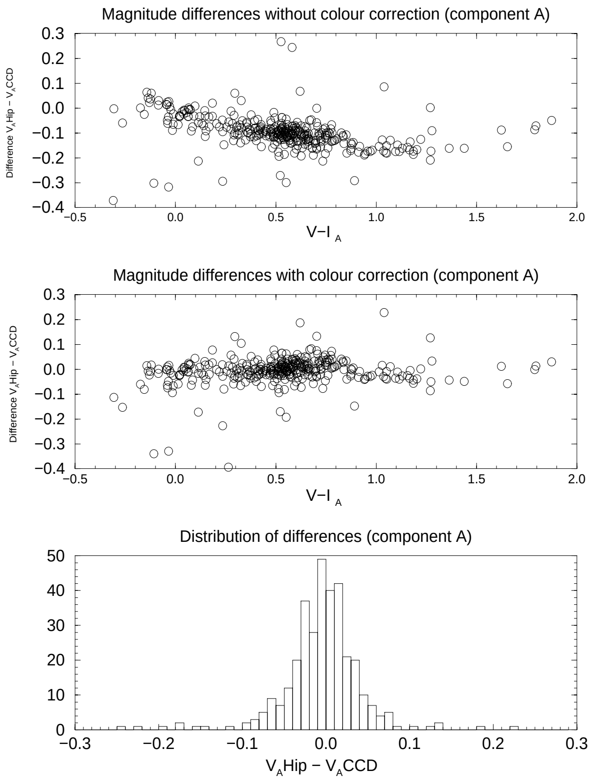

Figure 4. The differences between the Hp and the CCD V magnitude (a), between the from Hp derived V magnitude and the CCD V magnitude of the A components (b) and their distribution (c).

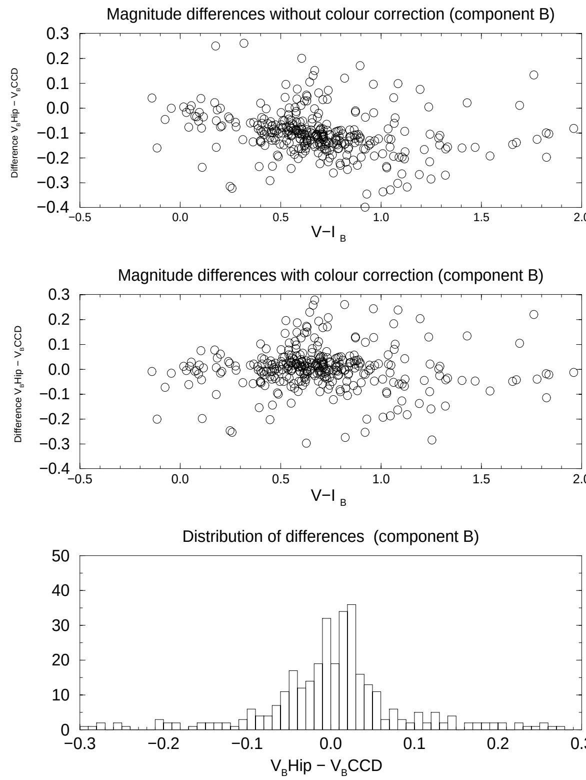

Figure 5. The differences between the Hp and the CCD V magnitude (a), between the from Hp derived V magnitude and the CCD V magnitude of the B components (b) and their distribution (c).

J.L. Falin) for the preliminary data on double stars for which CCD results were previously transmitted to the Reduction Teams. This research has made use of the Besançon Double and Multiple Star data base, operated at Besançon (France), the Lausanne Photometric data base, operated at Geneva (Switzerland) and the Simbad data base, operated at CDS, Strasbourg (France). We also acknowledge financial aid from the French Ministère de la Recherche et de la Technologie at the start of this project in 1992 and of the Research Programme of the Fund for Scientific Research (F.W.O.), Flanders (Belgium).

REFERENCES

Brosche, P., Sinachopoulos D., 1988, Bull. Inf. CDS, 34, 39

Brosche, P., Sinachopoulos D., 1989, Bull. Inf. CDS, 36, 3

Cuypers, J., 1997, Proceedings of the International Workshop Visual Double Stars: Formation, Dynamics and Evolutionary Tracks, eds. J.A. Docobo, A. Elipe, H. McAlister, ASSL series, in press

ESA, 1997, The Hipparcos and Tycho Catalogues, ESA SP–1200

Grenon, M., 1991, private communication.

Kundera, T., Oblak, E., 1997, in preparation

Lampens, P., Cuypers, J., Oblak, E., Seggewiss, W., Duval, D., 1997, Proceedings of the International Workshop Visual Double Stars: Formation, Dynamics and Evolutionary Tracks, eds. J.A. Docobo, A. Elipe, H. McAlister, ASSL series, in press

Landolt A.U., 1983, AJ, 88, 439

Menzies, J. 1989, SAAO Circ., 13, 1-13.

Mermilliod, J.C., Hauck, B. and Mermilliod, M., 1996, 'General Catalogue of Photometric Data'. [*http://obswww.unige.ch/gcpd/gcpd.html*]

Oblak, E., Argue, A.N., Brosche, P., et al., 1992a, IAU Coll. 135, ASP Conference Series 32, eds. H.A. McAlister, W.I. Hartkopf, 454-456.

Oblak, E., Argue, A.N., Brosche, P., et al., 1992b, ESO Messenger, 69,14

Sinachopoulos, D., Oblak, E., Geffert, M., Colin, J., Le Champion, J.F., Hopp, U., 1993, in Astronomy from Wide-field Imaging, IAU Symp. 161, Potsdam, 291.