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# CCD astrometry and components instrumental magnitude difference of 432 Hipparcos wide visual double stars⋆,⋆⋆

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**ABSTRACT**

*Context.* We measured the angular separations, position angles, $\Delta V$, $\Delta y$ and $\Delta I$ of wide visual double stars during the period 2003–2005. At least one component of the double stars in our sample has an entry in the Hipparcos catalogue.
*Aims.* Our measurements are a contribution to the study of the nature of these double stars.
*Methods.* The northern double stars of the project were observed with the 1.2 m telescope of the Kryonerion observatory and the southern with the 1.0 m SAAO. We performed multiple-exposure CCD imaging of our targets and used the standard procedure of data reduction and astrometric CCD calibrations.
*Results.* We present measurements of 213 northern and 219 southern wide binaries.

**Key words.** stars: binaries: visual – astrometry

## 1. Introduction

We obtained new CCD observations of visual double stars, which led to astrometric positions of 213 northern and of 219 southern pairs and usually to magnitude differences in their components. About 30% of the double stars in our sample have both components measured by the Hipparcos, satellite. The rest of them have one component included in this space mission.

Our new measurements are a continuation of the observing program initiated in 1988 (Sinachopoulos et al. 1988). Later on, several additional major contributions were made in the field, such as the work by Argue et al. (1992) and the ESO key project by Oblak et al. (1999).

## 2. The observations

We used the 1.2 m Kryonerion telescope in the northern hemisphere in the period of about 2.5 years starting in the summer months of 2003. The telescope has a Photometrics CCD camera attached to the Cassegrain focus. The camera chip has $516 \times 516$ square pixels of 24 $\mu$ size. Details on the 1.2 m telescope and the performance of its CCD camera can be found in Sinachopoulos et al. (1999). The average seeing was $1\farcs8$ and no systematic seasonal seeing variations could be determined. This seeing was mainly caused by the telescope dome, since some simultaneous measurements, made outside the telescope building using the DIMM method, found seeing values around $1\farcs1$. Sixteen exposures per visual double star were taken mainly in the Bessel $V$ filter. About thirty percent of the targets were observed in the Bessel $I$ filter in an attempt to detect close low-mass companions.

In addition, we used the 1.0 m telescope of SAAO, Sutherland, in the southern hemisphere in December 2003, May and September 2004. Its CCD camera has $1024 \times 1024$ square pixels of 24 $\mu$ size.

About 60% of the nights were photometric and seeing varied around a median value of $1\farcs2$ with often measured minimum values around $0\farcs9$. Maximum was 3.2 arcsec. Nine exposures per visual double star were taken with the Strømgren "$y$" filter. This intermediate pass band filter was chosen because it corresponds to the $V$ one of the $UBVRI$ system. Both of these telescopes had equatorial mountings. Reliable magnitude difference of the double star components could usually be measured. Transformation to the standard photometric system was not undertaken.

## 3. Data reduction

Standard cleaning of the CCD frames (BIAS, flat-field etc) was done. During the observations performed at Kryonerion we

⋆ Based on observations made at Kryonerion Observatory of the National Observatory of Athens, Greece, and the South African Astronomical Observatory.

⋆⋆ Full Table 1 and Tables 2, 3 are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/472/1055

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**Table 1.** A part of our measurements. It shows angular separations, positions angles, as well as instrumental $V$ magnitude differences of visual double stars.

| $\alpha_{2000}$ | | | $\delta_{2000}$ | | | WDS | $\rho$ | $\sigma_\rho$ | $\theta$ | $\sigma_\theta$ | $\Delta V$ | $\sigma_{\Delta V}$ | Epoch | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| h | m | s | ° | ′ | ″ | | ″ | | ° | | magnitudes | | year | |
| 1 | 52 | 10.1 | +66 | 26 | 56 | 01522+6627 | 29.515 | 0.016 | 315.83 | 0.03 | 2.695 | 0.003 | 2003.60 | 15 |
| 2 | 42 | 21.3 | +38 | 37 | 07 | 02424+3837 | 14.562 | 0.008 | 343.41 | 0.05 | 1.521 | 0.002 | 2004.91 | 16 |
| 2 | 55 | 47.1 | +34 | 28 | 40 | 02558+3429 | 21.519 | 0.012 | 148.78 | 0.02 | 1.421 | 0.001 | 2004.91 | 16 |
| 3 | 02 | 16.8 | +41 | 23 | 46 | 03023+4124 | 17.602 | 0.010 | 162.88 | 0.05 | 1.822 | 0.002 | 2004.91 | 16 |
| 3 | 22 | 51.8 | +29 | 49 | 06 | 03229+2949 | 10.438 | 0.006 | 101.38 | 0.02 | 0.176 | 0.001 | 2004.91 | 16 |

checked the linearity of the CCD camera once a year. It was found to be linear.

Most of double stars in our sample are very wide pairs and the images of their components do not overlap. In these cases, we fitted two separate two-dimensional Gaussians to the images for deriving the instrumental photocenter positions of the components. Aperture photometry of the components was performed afterwards to derive their magnitude difference.

For the reduction of the closer double stars, showing overlapping profiles of their components, we used the FORTRAN program developed by Sinachopoulos (1999), which fits two 2D MOFFAT profiles to the stellar images simultaneously. A description of this method can be found in Shatsky et al. (1999).

The $x$-axis of the CCD detector of the cameras of the equatorial telescopes is never perfectly aligned in the celestial East-West direction. Several stellar traces on the CCD were taken every night in order to determine the deviation. During the long exposures needed to get them, the telescopes were parked at positions near equator and meridian. The deviation was determined nightly, using the traces, with an accuracy of a few hundredths of a degree, depending on seeing conditions and the size of the CCD chip used. Correction due to this deviation was applied to the measured instrumental position angle of each double star.

There is sometimes a minor misalignment between the axis of the rotation of the telescope and the axis of the rotation of the Earth. We investigated whether this misalignment introduces significant systematic errors to the position angles of our measurements, especially to the position angles of double stars closer to the celestial pole, where this error becomes prominent. We checked both telescopes by taking more than thousand additional stellar traces. During these exposures the telescopes were parked at positions pointing to different declinations and hour angles. These positions were chosen to systematically cover the surface of a well-defined grid in hour angle and declination. No measurable misalignment of the 1.0 m SAAO telescope was detected, but it was detected at the Kryonerion 1.2 m telescope and found to introduce systematic error into the position angles of double stars with declinations larger than 35°. We have recently presented (Sinachopoulos et al. 2006) an empirical formula that let us determine the size of this systematic error in dependence on hour angle and declination and also let us correct it. The formula works accurately up to declinations of 66°. There is a relatively small amount of double stars in our sample northern to 66°. We usually took stellar traces of the components of these binaries as a part of their observation.

The scale of the 1.2 m telescope was first determined by Sinachopoulos et al. (1999), who found 0.30118 ± 0.00056 arcseconds/pixel (pixel size is 24 × 24 microns) by using ten Hipparcos stars that were components of five visual double stars. The CCD camera is the same, but at that point we used the Hipparcos catalogue data for both components of 63 double stars in order to improve the previous value. The new scale estimation is 0.30033 ± 0.00015 arcsec/pixel. The scale of the 1.0 m SAAO telescope CCD camera was found to be 0.30990 ± 0.00046 arcsec/pixel (pixel size is 24×24 microns) using 46 Hipparcos pairs.

## 4. Astrometric and photometric results

Using the calibrations we calculated astrometric results of 213 northern and 219 southern wide, visual double stars. Usually, instrumental mean magnitude difference in the components has also been determined.

Table 1 shows a small part of the new measurements. The first two columns contain the 2000 coordinates of the double star, taken from the 2006.5 version of the WDS (Mason et al. 2001). which is based on the 2001 one (Mason et al. 2001). The third column is the identifier of the WDS catalogue. Column four shows the measured angular separation of the components and its accuracy in arcseconds. Column five contains the position angle and its accuracy in degrees and column six the corresponding instrumental magnitude difference of the components and its accuracy. In the part shown the filter is always the $V$. Column seven shows the epoch of the observation and last column the number of the exposures used.

Fifty-five northern double stars of the sample were observed in the Bessel $I$ filter as well in order to search for low-mass companions. These results are given in a separate table. Another table of the same format contains the measurements of the southern double stars. The three tables have the same format and are available at the CDS.

## 5. Discussion

We present new CCD observations of visual double stars. One northern and one southern telescope were used. The two telescope scales were determined using a large number of Hipparcos double stars at each instrument. We consider the present scale values accurate enough for the needs of similar projects in the future.

We searched for misalignments between the rotation axes of the used telescopes and the axis of the earth. We found that there is a measurable deviation for the 1.2 m Kryonerion telescope. Additional needed corrections of the measured position angles have been applied therefore to the double stars observed northern of 35°. Such a deviation was not detected at the SAAO 1.0 m.

We were not able to detect low-mass companions in the northern double stars, which were observed in $I$ also. The astrometric results of these binaries are statistically the same in both $V$ and $I$ filters.

A few binaries were observed with both telescopes from the two hemispheres in order to check for systematic errors in the astrometric results between the northern and the southern samples. Such errors were not found at the level of the accuracy of the present observations.

Some binaries were observed twice in different epochs. The differences in these astrometric results are minor and expected. The component magnitude differences measured in the two epochs often deviate more than the photometric error for each measurement. We think that this is expected since our magnitude differences are instrumental values.

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