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# CCD measurements of visual double stars made with the 74 cm and 50 cm refractors of the Nice Observatory (2nd series)*

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**Abstract.** We present 619 measurements of 606 visual double stars made by CCD imaging from 1996 to 1999 with the 74 cm and 50 cm refractors of the Nice observatory. Angular separation, position angle and magnitude difference are given. Magnitude differences estimated from CCD images are compared with magnitude differences given in the Hipparcos catalog. The residuals in angular separation and position angle are computed for binaries with known orbit.

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

## 1. Introduction

Observations of binary stars are a key source of information on stellar and galactic evolution by the way of fundamental parameters (stellar masses and luminosity) as well as statistical results. The study of double stars largely benefits the development of modern observational techniques such as adaptive optics, speckle interferometry or CCD imaging. The work presented here is the continuation of a large observational program of close visual binaries by CCD imaging undertaken with the 74 cm and 50 cm refractors at the Nice observatory (Gili & Couteau 1997). Binaries with orbital motion, COU double stars and pairs rarely measured are included in this program.

## 2. Observations and image acquisition

The observations were performed using a Hi-SIS22 camera coupled with a CCD sensor KAF 0400 with $768\times 512$ pixels of $9\times9$ $\mu$m size. At the 74 cm refractor, the CCD was directly placed at the focus and the $17890\pm10$ mm focal length giving a scale of $0.104''$ per pixel. At the 50 cm refractor ($F = 7501$ mm), a 2X Barlow lens gives a resulting focal length of $14\,957 \pm 30$ mm and a scale of $0.124''$ per pixel. No filter was used for the observations. From the combination of the sensibility curve of the CCD and of the curve of minimum focus of the refractor, the observations were performed in a medium spectral band with a maximum transmission wavelength at 575 nm and a *FWHM* bandpass of about 32 nm. The Rayleigh resolution limits were $0.195''$ and $0.290''$ for the 74 cm and 50 cm refractors respectively.

Data acquisition was done using a $128 \times 128$ pixels windowing and the QMIPS software (Buil & Thouvenot 1993) with a portable PC (133 MHz). The resulting fields of view were $13''$ and $16''$ for the 74 cm and 50 cm refractors. Images were recorded with exposure times ranging from 0.02 to 1 s depending on the stellar magnitude and quality of seeing. The best images were selected using a maximum intensity threshold to insure the highest signal to noise ratio. At the 74 cm refractor when instantaneous images reach the diffraction limit (nearly perfect Airy pattern), a 0.02 s exposure time was sufficient to record a 9th–9.5th magnitude star and 1 s exposure time reaches a 14th magnitude star.

The detector orientation was checked by recording star trails in right ascension and the resulting error in the position angle calibration is close to $\pm0.5°$.

The selection of the observed stars was done using the catalog of COU doubles stars discovered at Nice by P. Couteau (Couteau 1999) and the WDS (Worley & Douglass 1996) for orbital binaries or pairs rarely measured.

## 3. Data reduction and results

The data reduction was done using a PC (processor Pentium 233 Mz) computer. For each measurement, typically about 10 to 25 images were selected. These images

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* Table 2 is 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/378/954

**Table 1.** CCD imaging measurements of visuals double stars at 74 cm and 50 cm refractors. Comparison with computed positions for pairs with known orbits.

| Coord.2000 | Name | $m_A$ | $m_B$ | Epoch 1990.0+ | θ (°) | ρ ('') | Δm | I | Δθ (°) | Δρ ('') | Q | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00014+3937 | HLD 60 | 9.2 | 9.6 | 96.839 | 172.8 | 1.22 | 0.7 | n | −2.3 | +0.05 | 4 | Hei1963a |
| 00022+2705 | BU 733AB | 5.8 | 11.0 | 96.858 | 162.4 | 0.73 | 2.2 | n | +9.9 | −0.05 | 2 | Sod1999 |
| 00134+2659 | STT 2AB | 6.6 | 8.0 | 97.932 | 173.7 | 0.33 | 1.3 | n | +7.1 | +0.01 | 4 | Hei1979b |
| 00167+3629 | STT 4 | 8.2 | 8.9 | 97.797 | 136.6 | 0.36 | 2.1 | N | −7.2 | +0.00 | 2 | Alz2000a |
| | | | | 99.690 | 137.6 | 0.35 | 1.0 | N | −1.1 | +0.01 | | Alz2000a |
| 00550+2338 | STF 73AB | 6.1 | 6.7 | 96.839 | 300.4 | 0.85 | 0.4 | n | −2.1 | +0.01 | 2 | Doc1990b |
| 02182+3920 | A 207 | 10.1 | 10.2 | 96.839 | 343.4 | 0.51 | 0.4 | n | −6.3 | +0.14 | 5 | Sca1982a |
| 02211+4246 | STF 248 | 9.6 | 9.6 | 97.871 | 250.6 | 0.22 | 0.2 | n | −0.2 | −0.07 | 4 | Pbx2000 |
| 02475+1922 | STF 305AB | 7.4 | 8.3 | 97.871 | 308.4 | 3.64 | 0.7 | n | +1.1 | −0.06 | 5 | Rab1961a |
| 03344+2428 | STF 412AB | 6.6 | 6.7 | 97.088 | 359.4 | 0.65 | 0.1 | N | +3.4 | +0.01 | 4 | Sca1985a |
| 04091+2839 | HO 326 | 8.9 | 9.0 | 97.088 | 281.9 | 0.36 | 0.0 | N | +0.4 | −0.08 | 5 | Hei1997 |
| 04422+3731 | STF 577 | 8.6 | 8.6 | 97.836 | 0.9 | 0.88 | 0.1 | n | −0.6 | −0.03 | 4 | Hei1998 |
| 12108+3953 | STF1606 | 7.3 | 8.0 | 97.274 | 195.5 | 0.28 | 1.1 | N | +5.8 | −0.03 | 4 | Msn1999a |
| 12244+2535 | STF1639AB | 6.8 | 7.9 | 97.370 | 323.6 | 1.68 | 1.2 | n | −1.3 | −0.01 | 4 | Ole2000b |
| 12272+2701 | STF1643 | 8.8 | 9.1 | 97.378 | 7.9 | 2.73 | 0.4 | n | −5.3 | +0.43 | 5 | Hop1964b |
| 13375+3618 | STF1768AB | 5.0 | 6.9 | 97.375 | 100.5 | 1.80 | 1.8 | n | +0.6 | +0.02 | 3 | Sod1999 |
| 14122+4411 | STT 278 | 8.4 | 8.6 | 97.392 | 288.8 | 0.31 | 0.5 | n | −4.2 | +0.01 | 3 | Hei1996c |
| 14131+5520 | STF1820 | 8.8 | 9.1 | 97.329 | 115.2 | 2.51 | 0.4 | n | −1.3 | −0.04 | 5 | Kiy1998 |
| 14203+4830 | STF1834 | 8.0 | 8.2 | 97.329 | 101.3 | 1.51 | 0.3 | n | −1.7 | +0.06 | 3 | Sey2000b |
| 15183+2650 | STF1932Aa-B | 7.1 | 7.6 | 97.411 | 258.0 | 1.57 | 0.0 | N | −0.4 | −0.02 | 2 | Hei1965c |
| 15245+3723 | STF1938BC | 7.2 | 7.8 | 97.411 | 9.5 | 2.25 | 0.6 | N | −0.1 | +0.01 | 2 | Sod1999 |
| 16147+3352 | STF2032AB | 5.8 | 6.7 | 98.504 | 236.2 | 6.89 | 1.0 | N | −0.5 | −0.09 | 4 | Sca1979 |
| 16289+1825 | STF2052AB | 7.8 | 7.8 | 98.490 | 125.5 | 1.99 | 0.2 | N | +0.7 | +0.06 | 2 | Sod1999 |
| 17420+1557 | BU 1251AB | 5.6 | 9.0 | 98.504 | 121.0 | 1.20 | 3.4 | N | +0.9 | −0.02 | 4 | Baz1991a |
| 17457+1743 | STF2205 | 8.5 | 8.9 | 98.504 | 350.0 | 1.24 | 0.1 | N | +0.6 | −0.06 | 5 | Pop1995d |
| 18025+4414 | BU 1127 | 7.4 | 9.3 | 99.540 | 65.5 | 0.85 | 1.7 | N | −2.2 | −0.14 | 5 | Pop1995 |
| 18101+1629 | STF2289 | 6.5 | 7.3 | 98.504 | 219.5 | 1.19 | 1.0 | N | +1.5 | −0.05 | 4 | Hop1964b |
| 18443+3940 | STF2382AB | 5.1 | 6.0 | 98.504 | 351.7 | 2.42 | 1.0 | N | +0.9 | −0.16 | 4 | Gzl1956 |
| 19062+3026 | STF2454AB | 8.5 | 9.7 | 98.504 | 284.5 | 1.28 | 1.6 | N | −1.9 | −0.02 | 5 | Sta1982b |
| 19266+2719 | STF2525 | 8.1 | 8.3 | 97.679 | 291.1 | 2.02 | 0.6 | N | +0.1 | +0.02 | 4 | Hei1984b |
| 20102+4357 | STT 400 | 7.9 | 8.5 | 96.732 | 349.9 | 0.42 | 0.4 | N | −0.1 | −0.01 | 2 | Hei1997 |
| 20210+4437 | A 725 | 9.3 | 10.1 | 96.680 | 7.2 | 0.44 | 0.9 | N | +2.5 | +0.04 | 4 | Hei1995 |
| 20550+2805 | BU 367AB | 8.6 | 9.0 | 99.690 | 135.9 | 0.43 | 0.9 | N | −0.7 | +0.01 | 3 | Hei1962 |
| 21000+4004 | KUI 103 | 10.0 | 11.6 | 96.680 | 101.7 | 1.000 | | N | +8.6 | +0.02 | 4 | Mnt2000c |
| | | | | 97.690 | 104.8 | 0.980 | | N | +8.6 | +0.04 | | |
| | | | | 97.936 | 104.3 | 0.98 | 2.8 | N | orb | | | |
| | | | | 99.690 | 109.3 | 0.88 | 2.3 | N | +6.3 | +0.01 | | |
| 21148+3803 | AGC 13AB | 3.8 | 6.3 | 97.838 | 312.3 | 0.79 | 3.6 | n | −5.6 | −0.02 | 2 | Sod1999 |
| 21355+2427 | HU 371 | 6.7 | 7.0 | 99.636 | 149.5: | 0.29 | 0.7 | N | +17.1 | −0.01 | | Baz1960 |
| 21426+4103 | BU 688AB | 8.3 | 8.3 | 96.781 | 14.6 | 0.36 | 0.2 | N | −8.6 | −0.06 | 3 | Baz1981b |
| 21446+2539 | BU 989AB | 4.7 | 5.1 | 99.693 | 109.0 | 0.22 | 0.3 | N | +0.9 | −0.03 | 1 | Sod1999 |
| 21501+1717 | COU 14 | 5.6 | 6.8 | 96.626 | 226.5 | 0.36 | 1.7 | N | −8.5 | −0.02 | 2 | Hart1989 |
| 21556+3849 | A 1449 | 9.6 | 9.6 | 96.705 | 252.9 | 0.17 | | N | +6.9 | −0.04 | | Baz1993a |
| 22302+2228 | HU 388 | 8.7 | 8.9 | 99.666 | 54.4 | 0.52 | 0.5 | N | −8.9 | +0.04 | 5 | Baz1976 |
| 22402+3732 | HO 188 | 8.7 | 8.7 | 99.690 | 214.0 | 0.42 | 0.2 | N | −3.0 | +0.09 | 3 | Doc1986b |
| 22419+2126 | STF2934Aa-B | 8.6 | 9.4 | 96.839 | 57.5 | 1.31 | 0.9 | n | −6.2 | +0.17 | 5 | Hei1981a |
| 22514+2623 | HO 482AB | 7.7 | 7.7 | 96.705 | 21.9 | 0.41 | 0.2 | N | −2.0 | −0.03 | 3 | Sta1982b |
| 22570+2441 | COU 542Aa | 8.8 | 9.2 | 96.628 | 321.5: | 0.18 | | N | −19.3 | −0.02 | 4 | Cou1993c |
| 23114+3813 | HO 197AB | 8.3 | 8.6 | 99.682 | 300.0 | 0.30 | 0.9 | N | −5.8 | −0.08 | 2 | Doc1990c |
| 23304+3050 | BU 1266AB | 8.0 | 8.0 | 99.677 | 12.5: | 0.32: | 1.2 | N | −11.4 | +0.17 | 2 | Msn1998c |
| | | | | 99.690 | 4.1: | 0.43: | 2.3 | N | −19.7 | +0.28 | | |
| 23340+3120 | BU 720 | 6.0 | 6.0 | 99.693 | 92.2 | 0.52 | 0.7 | N | −3.6 | −0.01 | 3 | Sta1982b |
| 23375+4426 | STT 500AB | 6.3 | 7.0 | 96.732 | 11.8 | 0.41 | 1.1 | N | +5.2 | −0.06 | 4 | Zul981 |
| 23431+1150 | A 1242 | 9.6 | 9.6 | 96.839 | 330.8 | 0.99 | 0.3 | n | −4.0 | +0.25 | 5 | Zul977b |
| 23440+2922 | AGC 14 | 5.0 | 7.8 | 96.858 | 264.8 | 0.80 | 2.2 | n | +0.0 | −0.07 | 5 | Pop1997f |
| 23595+3343 | STF3050AB | 6.5 | 6.6 | 96.858 | 143.7 | 1.98 | 0.1 | n | −1.2 | +0.05 | 4 | Sta1977b |

were shifted and added using the functions of the MIPS software (Buil & Thouvenot 1993) to increase the signal to noise ratio by a factor of 3 to 5. A wavelet filtering (Wavelet function of the MIPS software) was applied to sharpen the image before measurement of the relative position and intensity ratio of the components. The internal incertainty of each astrometric measurement is estimated to be close to 1/10 of pixel i.e. ±0.010″ and ±0.012″ respectively for the 74 cm and 50 cm refractors. The measured positions and the intensity ratio were converted to classical parameters, angular separation, position angle and magnitude difference. The 619 measurements of 606 double stars performed from 1996 to 1999 are presented in Tables 1 and 2.

Columns 1 and 2 list the WDS Catalogue coordinates and the name of the star. Columns 3 and 4 list the magnitude of each component given in the WDS. The epoch in fractional Besselian year, position angle, angular separation and magnitude difference are given in Cols. 5–8. The aperture used is given in Col. 9 ($N$ for 74 cm or $n$ for 50 cm).

The measured angular separations range from 0.17″ to 6.89″. The distribution of the measurements as a function of angular separation (Fig. 1) shows that 35% of the measurements concern pairs closer than 1.0″ and 72% pairs closer than 2.0″.

Measurements achieved for double stars with the primary brighter than magnitude 12 and a well-separated

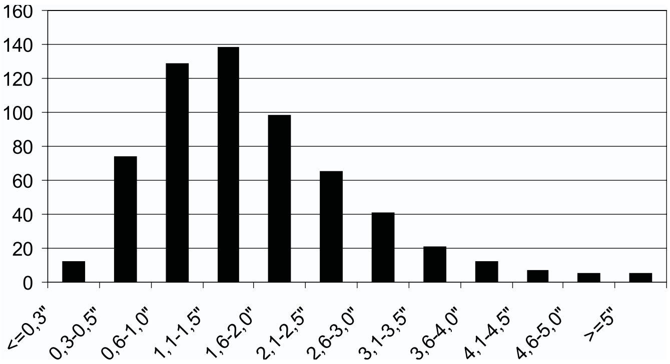


**Fig. 1.** Distribution of the measurements versus angular separation bins.

faint companion have been detected up to a magnitude difference close to 4. The WDS magnitudes given in Tables 1 and 2 provide only a gross estimate of the magnitude difference. Consequently, in order to evaluate the reliability of our measurements of magnitude difference we prefer to use a comparison with the values available in the Hipparcos Catalogue (1997) as shown in Fig. 2.

The strong correlation between $\Delta m$(CCD) and $\Delta m$(HIP) appears in the top plot.

The central plot shows the scatter of the difference ($\Delta m$(CCD)$-\Delta m$(HIP)) decreasing from about $\pm 0.4$ mag to $\pm 0.1$ mag with increasing angular separation. A systematic difference between the CCD and Hipparcos $\Delta m$ appears for small angular separations. This effect decreases from about 0.25 mag for separation under $0.5''$ to less than 0.1 mag for separation above $2''$.

The lower plot shows the difference ($\Delta m$(CCD) $-$ $\Delta m$(HIP)) versus $\Delta m$(HIP). The scatter of ($\Delta m$(CCD)$-$ $\Delta m$(HIP)) is constant up to $\Delta m$(HIP) $= 3.5$.

A detailed analysis reveals that ($\Delta m$(CCD) $-$ $\Delta m$(HIP)) above 0.25 mag is obtained for double stars having a secondary component fainter than 9.5 mag and with a greater incertainty on the $\Delta m$(HIP) determination. When these pairs are not taken into account, the systematic effect disappears and the scatter decreases to $\pm 0.25$ mag for separations under $1''$.

This residual scatter is due mainly to uncertainty in the CCD photometric measurements but also to intrinsic color effects. These effects can result from the color of the stellar components, owing to the difference between our observing bandpass with the Hipparcos spectral bandwidths (350 to 850 nm with a maximum sensitivity close to 475 nm) (Grenon et al. 1992).

Table 1 contains the astrometric measurements of binaries with known orbits. The residuals in position angle and angular separation are given in Cols. 10 and 11. Columns 12 and 13 give the grade of the orbit and reference to the author of the calculation from the Fifth Catalog of Orbits (Hartkopf et al. 2000). Figure 3 displays the residuals in $\theta$ and $\rho$ in the ($\Delta\rho$, $\rho\Delta\theta$) plane. The cloud of points centered on $(0.0, 0.0)$ clearly indicates that no systematic effect appears in the data reduction and calibration procedures.

However we notice some abnormally large differences betweeen our measurements and the expected relative position computed from the published orbits. These measurements have been compared with recent ones by speckle interferometry (epoch 1995–1999), Hipparcos or Tycho (epoch 1995.25) available in the Third Catalog of Interferometric Measurements of binary Stars (Hartkopf et al. 1998) and other CCD measurements at Nice (epoch 1997–1999) from the SIDONIe data base (Le Contel et al. 2001).

- BU 733AB. This observation was performed with the 50 cm refractor. The large magnitude difference and the close separation could explain the poor quality of our measurement as indicated by the large residuals from this good orbit ($Q = 2$) of short period ($P = 26.26y$);
- A 1813AB-C. For this long period pair ($P \approx 330y$), the strong residuals found with measurements by Hipparcos and CCD imaging confirm that the published orbit is only preliminary;
- A 207. For this long period binary ($P \approx 160y$), the strong residuals found with measurements by Hipparcos and CCD imaging confirm that the published orbit is only preliminary;
- STF 1643. In agreement with the speckle interferometric measurements, the strong residual of our observation is due to the poor quality of the computed orbit of very long period ($P \approx 2200y$);
- BU 1127. Our observation as well as measurements by Speckle interferometry and with Hipparcos show systematic residuals with respect to the published orbit of long period ($P \approx 345y$);
- STF 2382AB. For this very long period binary ($P \approx 1166y$), our observation and the measurements by speckle interferometry and by Hipparcos show rather small residuals in position angle but larger and systematic residuals in angular separation;
- KUI 103. For this system of short period ($P \approx 29.5y$), recent measurements by CCD imaging show sytematic residuals relative to the published orbit. New precise measurements are need to determine physical parameters of this interesting system of two red dwarfs, also known as a variable star of DY Draconis type. The lack of speckle interferometric observations should be noted;
- STF 2934Aa-B. For this long period binary ($P \approx 636y$), the measurements by speckle interferometry and by Hipparcos show systematic residuals relative to the published orbit;
- A1242. For this long period binary ($P \approx 409y$), the measurements by speckle interferometry and by Hipparcos and Tycho show systematic residuals relative to the published orbit.

## 4. Conclusions

These observations have confirmed that the use of CCD imaging at the refractors of the Côte d'Azur Observatory

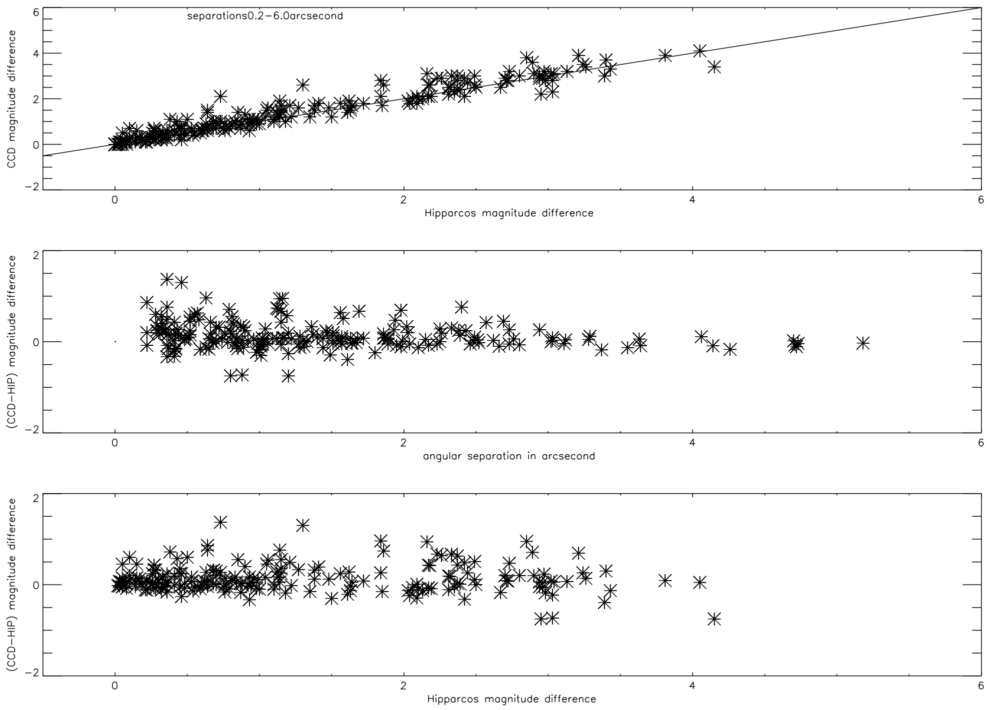


**Fig. 2.** Comparison between CCD and Hipparcos magnitude difference. Top: $\Delta m$(CCD) versus $\Delta m$(HIP). Centre: ($\Delta m$(CCD)−$\Delta m$(HIP)) versus angular separation. Down: ($\Delta m$(CCD)−$\Delta m$(HIP)) versus $\Delta m$(HIP).

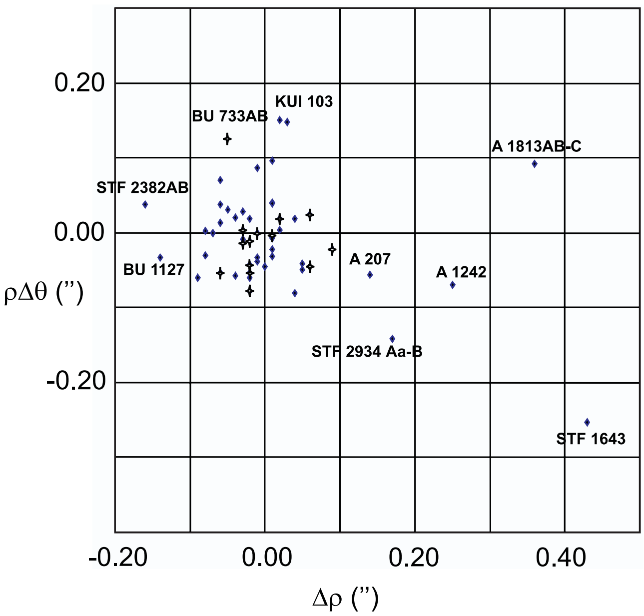


**Fig. 3.** Plot of the residuals in position angle ($\Delta\theta$) and angular separation ($\Delta\rho$). Stars with orbit of grade 2 or better are indicated by crosses.

is well adapted to double star measurements. The comparison between CCD and Hipparcos $\Delta m$ determinations provides an indication of the reliability of magnitude differences obtained from CCD images. The comparison of the position angle and separation measures with published orbits shows the absence of systematic effects in the data reduction and calibration procedure. This is confirmed by the agreement between CCD observations and Speckle or Hipparcos observations for stars with poorly determined orbits.

CCD observations of double stars will continue to improve orbit determinations, and also allow the caculation of new orbits in order to derive fundamental physical parameters of individual stars.

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Worley, C. E., & Douglass, G. G. 1997, A&AS, 125, 523 `http://ad.usno.navy.mil/ad/wds/`