# Double Star Astrometry with a Simple CCD Camera

Wolfgang Vollmann

Dammäckergasse 28/D1/20, A-1210
Wien, Austria

Email: vollmann@gmx.at

**Abstract:** I show my image acquisition and measurement procedures with a simple CCD camera. The attainable accuracy with a focal length of 1 meter is discussed and a list of about 100 measures of stars is presented. It was found that precise measures are possible for separations larger than 5 or 6 arc seconds. Some useful projects can be tackled with this setup, eg measuring "Neglected Double Stars" or demonstrating proper motion in nearby stars in comparison with older measures.

## A Simple CCD Camera

In March 2006 I acquired a used, relatively cheap CCD camera, an SBIG model ST237A. It is an older model (1999) with a small chip size (4.7 x 3.6 mm) and quite long readout times of around 10 seconds for a full frame over the computer's parallel port. But it is a sensitive camera and well suited as a precise astrometry measuring device – e.g.. see my work on 61 Cygni [1]. The camera pixel size of 7.4 micron is a good match for the 1040 mm focal length of my 130 mm refractor. A pixel subtends an angle of 1.47 arc seconds on the sky. Astrometry of minor planets and comets yielded good measurements with an accuracy of 0.3 arc seconds or better using Astrometrica software [2]. This accuracy is good enough to earn a MPC observatory code, A97 Stammersdorf, for my installation [4].

## Double Star Astrometry with a CCD Camera

I used the camera to try some double star measures with it. At the telescope I take around 20 images with an exposure time of 10 seconds. This captures stars down to about magnitude 14 and the resulting images are almost always solvable with Astrometrica and the UCAC2 star catalog or USNO B1.0 for northern stars. Astrometrica writes the exact measured focal length and camera field orientation to its log file. I found that the measured focal length on different images has a standard deviation of only 0.2 - 0.3 mm on average, so image scale is known to 0.02 % accuracy. The measured field orientation on different images has a standard deviation of usually 0.01 - 0.02 degrees.

If the double stars are bright and close, I take additional images with 1 s, 0.1 s and, in some cases, a 0.01 s exposure time. These images are for measuring the double star and are taken immediately after the 10 s images so image scale and field orientation should be the same. They usually do not have enough reference stars on them to solve them with Astrometrica, except for richer regions near the Milky Way like that of 61 Cygni.

## Measuring CCD Images with Astrometrica

If the components of the double star are well separated and not under or overexposed, they are directly measurable with Astrometrica. Underexposure with a signal-to-noise ratio (SNR) of lower than about 6 delivers increasingly notable position errors approaching an arc second.

Overexposure is shown by Astrometrica in an intensity profile which is cut off on the top when you click on the star. The software is able to deliver the desired 1/10 pixel (0.15 arc second) accuracy easily

and quickly for correctly exposed stars. From the astrometric positions PA and distance can be calculated directly (eg. see [7], formulae (16.1) and (16.2)).

## Measuring CCD images with AIP4WIN

In many cases the components of the double star are close or overexposed on the 10s astrometry images. Then I measure them with the "Distance Tool" of AIP4WIN software [3]. For this I often use images with less exposure time when the components of the double star are sufficiently bright. AIP4WIN does centroid astrometry which is not as precise as the PSF fitting of Astrometrica but produces consistent results with better than ½ pixel accuracy for correctly exposed stars. For close stars I use AIP4WIN's "Resample" function to enlarge the image 10 times to 1000% and then measure distance and angle with the "Distance Tool" function. For the focal length I provide the averaged value taken from the 10 s astrometry images solved by Astrometrica, so distance is given by the software directly in arc seconds. The software calculates a "PA" which must be corrected by the image orientation from Astrometrica: real PA = 360° – "PA" + orientation_angle_from_astrometrica.

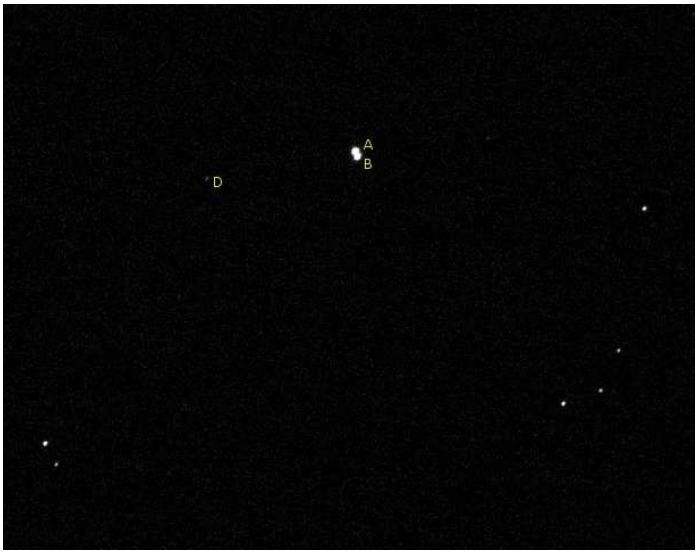


**Figure 1**: CCD image of STF2486, 0.1 s exposure.


**Figure 2**: CCD image of STF2486, 10 s exposure.

### *Example: STF2486 in Cygnus*

A calibration double with a well known slow orbit is STF2486 (WDS 19121+4951). On September 5, 2006, I took 12 images with 10 s exposure time which were solved with Astrometrica and USNO B1.0 star catalog. This gave a focal length of 1039.24 mm with std. dev. 0.17 mm and image orientation of +3.38° with std. dev. 0.01°. For the closer AB components 24 images with 0.1 s exposure time were measured and a PA of 205.62° with a std.dev. 0.87° was found. The distance was measured to 7.34 arcsec std.dev. 0.20 arcsec. The wider and fainter AC and AD components

| | | | | Observation | | Calculation | | | Observation minus Calculation | |
|---|---|---|---|---|---|---|---|---|---|---|
| Epoch | Name | Discoverer Code | WDS | Sep. | PA | Orbit | Sep. | PA | O-C Dist | O-C PA |
| 2006.215 | γ Leo | STF1424 | 10200+1950 | 4.58 | 124.64 | Rab1958 | 4.43 | 125.41 | 0.15 | -0.77 |
| 2006.420 | ξ Boo | STF1888 | 14514+1906 | 6.46 | 311.91 | Sod1999 | 6.28 | 311.97 | 0.18 | -0.06 |
| 2006.516 | | STF2052 | 16289+1825 | 1.91 | 129.27 | Sod1999 | 2.13 | 121.66 | -0.22 | 7.61 |
| 2006.697 | 70 Oph | STF2272 | 18055+0230 | 5.16 | 136.92 | Pbx2000b | 5.19 | 135.81 | -0.03 | 1.11 |
| 2006.683 | | STF2486 | 19121+4951 | 7.34 | 205.62 | Hle1994 | 7.39 | 205.51 | -0.05 | 0.11 |

**Table 1**: comparison of observed and calculated distances and PAs for pairs with well known orbits

were directly measured on the 10 s exposures. The CCD images are shown in figures one and two.

## Accuracy of Measures

Of great interest to every observer is the accuracy of his/her measurement procedure. For 5 stars I measured I was able to find orbits in the WDS [5]. I compared the calculated position with my observed position aided by Brian Workman's spreadsheet ephemeris calculator [6].

The distances have a mean O-C of 0.13 arc seconds. One cannot expect better accuracy with this telescope. PAs have a mean O-C of 1.9 degrees. We must throw out the measure of STF2052AB which is at 1.91 arc seconds. This is really too close, the stars are separated by only 1.3 pixels (10 microns) on the image. The remaining O-C for the PAs is 0.51 degrees. Since this is for a mean separation of only 5.9 arc seconds (4 pixels, 30 microns) at my focal length of one meter the accuracy of the position angles is good. It should be much better for wider separations when components are separated by more pixels!

## Measures of Double Stars 2006

Besides measuring some stars for checking accuracy a variety of interesting objects were measured. These are given in Table 2.

### *Proper motion in nearby stars*

Some faint companions to bright and nearby stars show the proper motion of the bright primary clearly when compared to the first measures in the WDS. A good object is Vega (α Lyrae). Here the naked eye component A travels, due to proper motion, almost exactly towards component E (STFB 9AE) in PA 39°, which is apparently not physically related to A and has apparently no noticeable proper motion.

Comparing the values from the WDS 2006.5 with my own measures I find:

| Year | PA | Distance | Source |
|---|---|---|---|
| 1831 | 40° | 150.0" | WDS 2006.5 |
| 1999 | 39° | 91.7" | WDS 2006.5 |
| 2006.48 | 39.0° | 89.1" | Average of my measures, see table 2 |

In the 175.5 years since 1831 component A traveled 60.9 arc seconds towards E, which corresponds to 0.347 arc seconds per year. The ARI Catalog of Nearby Stars [9] gives for Vega a proper motion of 0.348" in PA 35.2°.

### *Neglected stars*

Besides several well known stars I measured a few stars on the "Neglected Doubles List" from the WDS and tried to improve positions for the components where they were given to only 1 arc second accuracy in WDS or found to be off by more than one arc second. This is noted in Table 2.

### *Magnitudes and magnitude differences*

Some effort was made to determine the magnitude of the stars if they were not over- or underexposed and well separated so Astrometrica [2] was able to determine a magnitude from the UCAC2 reference star catalog. Since this is not a precise photometric catalog and the images were taken unfiltered with the color sensitivity of the CCD camera they are only an approximation to the real visual or V magnitudes.

## Conclusion

It was found that precise measures are possible for separations larger than 5 or 6 arc seconds. Some useful projects can be tackled with this setup, e.g. measuring "Neglected Double Stars" or demonstrating proper motion in nearby stars in comparison with older measures.

## References


1. Vollmann, Wolfgang: Measurements of 61 Cygni (STF2758AB, WDS 21069+3845). JDSO Vol.4, No.2, p74 (Spring 2008).
2. Raab, Herbert: Astrometrica. http://www.astrometrica.at
3. Berry, Richard and Burnell, Jim: Handbook of Astronomical Image Processing. Contains AIP4WIN software. Willmann-Bell, Richmond 2004.
4. IAU Minor Planet Center (MPC): http://www.cfa.harvard.edu/iau/mpc.html
5. William I. Hartkopf & Brian D. Mason: Sixth Catalog of Orbits of Visual Binary Stars. http://ad.usno.navy.mil/wds/orb6.html
6. Workman, Brian: The Binary Star Calculator. http://www.saguaroastro.org/content/db/binaries_6th_Excel97.zip
7. Argyle, R. (ed.): Observing and Measuring Visual Double Stars. Springer, Cambridge 2004.
8. Brian D. Mason, Gary L. Wycoff, and William I. Hartkopf: The Washington Double Star Catalog

**Double Star Astrometry with a Simple CCD Camera**

http://ad.usno.navy.mil/wds/wds2006.5.html

9. ARI Catalog of Nearby Stars: http://www.ari.uni-heidelberg.de/datenbanken/aricns/ with the entry for Vega at http://www.ari.uni-heidelberg.de/datenbanken/aricns/cnspages/4c01497.htm

| Epoch | Designation | WDS | Mag1 | Mag2 | Sep. (as) | stdev | PA | stdev | Images | Method | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006.812 | STF3055AB | 00040+1209 | | | 5.52 | 0.21 | 359.08 | 0.88 | 12 | AIP2 | |
| 2006.812 | STF3055AC | 00040+1209 | 7.80 | 12.55 | 122.74 | | 31.55 | | 8 | Astro. | 1 |
| 2006.812 | STF3056AB-C | 00047+3416 | 7.16 | 9.58 | 25.74 | | 3.31 | | 17 | Astro. | 2 |
| 2006.812 | STF3056AB-D | 00047+3416 | 7.16 | 10.66 | 95.84 | | 238.07 | | 17 | Astro. | |
| 2006.812 | STF3056C-D | 00047+3416 | 9.58 | 10.66 | 112.67 | | 227.31 | | 17 | Astro. | 3 |
| 2006.823 | STF3061 | 00057+1750 | | | 7.71 | 0.07 | 148.55 | 0.66 | 30 | AIP2 | |
| 2006.921 | STF3064 | 00076+4009 | 7.28 | 10.82 | 25.83 | 0.31 | 7.84 | 0.84 | 12 | Astro. | 4 |
| 2006.938 | STF 8 | 00116-0305 | | | 7.87 | 0.17 | 291.48 | 0.97 | 18 | AIP2 | |
| 2006.938 | STF 12 | 00150+0849 | | | 11.43 | 0.17 | 147.20 | 0.52 | 18 | AIP2 | 5 |
| 2006.938 | STT 10AB | 00275+1602 | 7.30 | 10.08 | 113.24 | 0.05 | 239.83 | 0.04 | 18 | AIP2 | 6 |
| 2006.938 | STT 10AC | 00275+1602 | 7.30 | 9.28 | 274.30 | 0.03 | 155.94 | 0.01 | 18 | AIP2 | |
| 2006.938 | STT 10BD | 00275+1602 | 10.08 | 13.97 | 152.78 | 0.15 | 155.77 | 0.06 | 18 | AIP2 | 7 |
| 2006.938 | STF 32 | 00308+1602 | 7.34 | 10.75 | 27.46 | 0.18 | 100.61 | 0.33 | 18 | AIP2 | |
| 2006.215 | LAM 4AB | 07282+0856 | | | 26.42 | 1.00 | 234.37 | 1.76 | 12 | AIP2 | 8 |
| 2006.215 | LAM 4AC | 07282+0856 | | | 114.25 | 0.71 | 261.48 | 0.24 | 12 | AIP2 | 8 |
| 2006.215 | WAL 52AD | 07282+0856 | | | 138.21 | 0.52 | 290.21 | 0.19 | 12 | AIP2 | 8 |
| 2006.215 | S 570AB | 08391+1941 | | | 57.25 | 0.10 | 84.11 | 0.08 | 6 | Astro. | |
| 2006.215 | S 570AC | 08391+1941 | | | 178.75 | 0.14 | 344.89 | 0.11 | 6 | Astro. | |
| 2006.215 | S 571AC | 08399+1933 | | | 45.16 | 0.09 | 156.32 | 0.10 | 7 | AIP2 | |
| 2006.215 | S 571AD | 08399+1933 | | | 92.73 | 0.14 | 241.78 | 0.19 | 7 | AIP2 | |
| 2006.215 | BU 584DC | 08399+1933 | | | 99.90 | 0.08 | 88.63 | 0.04 | 7 | AIP2 | |
| 2006.215 | BKO 34DE | 08399+1933 | | | 35.34 | 0.37 | 3.34 | 1.52 | 7 | AIP2 | |
| 2006.215 | STF1254AB | 08404+1940 | | | 20.53 | 0.38 | 53.95 | 0.87 | 7 | AIP2 | |
| 2006.215 | STF1254AC | 08404+1940 | | | 63.35 | 0.11 | 342.74 | 0.08 | 7 | AIP2 | |
| 2006.215 | STF1254AD | 08404+1940 | | | 82.64 | 0.11 | 43.87 | 0.06 | 7 | AIP2 | |
| 2006.215 | S 572CD | 08404+1940 | | | 76.13 | 0.22 | 90.65 | 0.10 | 7 | AIP2 | |
| 2006.215 | S 574 | 08405+1933 | | | 134.22 | 0.12 | 249.88 | 0.04 | 7 | AIP2 | 9 |
| 2006.420 | STFB 6AB | 10084+1158 | | | 176.42 | 0.19 | 307.35 | 0.05 | 6 | AIP2 | 10 |
| 2006.420 | HDO 127AD | 10084+1158 | | | 198.48 | 0.18 | 273.99 | 0.07 | 6 | AIP2 | 10 |
| 2006.420 | HDO 127BD | 10084+1158 | | | 109.69 | 0.21 | 211.77 | 0.07 | 6 | AIP2 | 11 |

**Table 2**: measures of double stars 2006. *Table 2 continued on next page.*

## Double Star Astrometry with a Simple CCD Camera

| Epoch | Designation | WDS | Mag1 | Mag2 | Sep. (as) | stdev | PA | stdev | Images | Method | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006.215 | STF1424AB | 10200+1950 | | | 4.58 | 0.39 | 124.64 | 4.52 | 11 | AIP2 | 12 |
| 2006.218 | STF1424AC | 10200+1950 | | | 334.64 | 0.19 | 288.19 | 0.02 | 8 | AIP2 | 12 |
| 2006.218 | STF1424AD | 10200+1950 | | | 369.29 | 0.22 | 301.80 | 0.01 | 8 | AIP2 | 12 |
| 2006.218 | STF1424CD | 10200+1950 | | | 90.21 | 0.06 | 2.57 | 0.09 | 8 | AIP2 | 12 |
| 2006.420 | BU 604AC | 11491+1434 | | | 98.50 | 1.62 | 23.20 | 0.96 | 4 | AIP2 | 13 |
| 2006.420 | BU 604AD | 11491+1434 | | | 238.43 | 0.69 | 194.74 | 0.20 | 13 | AIP2 | 13 |
| 2006.420 | SHJ 169 | 13547+1824 | | | 113.29 | 0.68 | 86.96 | 0.11 | 6 | AIP2 | 14 |
| 2006.420 | STF1888AB | 14514+1906 | | | 6.46 | 0.24 | 311.91 | 1.18 | 18 | AIP2 | 15 |
| 2006.420 | STF1888AC | 14514+1906 | | | 69.72 | 0.19 | 341.37 | 0.18 | 6 | AIP2 | 15 |
| 2006.420 | STF1888AD | 14514+1906 | | | 159.28 | 1.23 | 286.31 | 0.15 | 12 | AIP2 | 15 |
| 2006.420 | ARN 11AE | 14514+1906 | | | 269.42 | 1.14 | 98.58 | 0.16 | 18 | AIP2 | 15 |
| 2006.420 | ARN 12AF | 14514+1906 | | | 333.80 | 0.37 | 38.25 | 0.24 | 18 | AIP2 | 15 |
| 2006.571 | STF1918 | 15078+6307 | | | 17.77 | 0.23 | 19.32 | 0.63 | 20 | AIP2 | 16 |
| 2006.571 | STF1918 | 15078+6307 | 7.01 | 10.25 | 17.71 | | 20.30 | | 20 | Astro. | 16 |
| 2006.571 | STF1927AB | 15118+6151 | 7.59 | 8.33 | 16.02 | | 353.41 | | 13 | Astro. | 17 |
| 2006.571 | STF1927AB | 15118+6151 | | | 16.03 | 0.10 | 353.17 | 0.81 | 13 | AIP2 | 17 |
| 2006.571 | STF1927AC | 15118+6151 | 7.59 | 12.26 | 32.97 | | 14.97 | | 13 | Astro. | 18 |
| 2006.571 | STF1927BC | 15118+6151 | 8.33 | 12.26 | 19.01 | | 33.01 | | 13 | Astro. | 18 |
| 2006.571 | STF1937AB-C | 15232+3017 | | | 73.74 | 0.16 | 358.68 | 0.25 | 2 | AIP2 | 19 |
| 2006.571 | STF1937AB-D | 15232+3017 | | | 217.66 | 0.29 | 40.97 | 0.14 | 2 | AIP2 | 19 |
| 2006.571 | STFA 28Aa-BC | 15245+3723 | | | 107.94 | 0.09 | 170.90 | 0.08 | 6 | Astro. | 20 |
| 2006.516 | STF1964AB-CD | 15382+3615 | | | 14.76 | | 84.72 | | 2 | AIP2 | |
| 2006.543 | STF1964AB-CD | 15382+3615 | | | 15.04 | 0.22 | 84.25 | 0.71 | 12 | AIP2 | |
| 2006.543 | STF1965 | 15394+3638 | | | 6.22 | 0.16 | 305.79 | 1.74 | 18 | AIP2 | 21 |
| 2006.516 | STF2052AB | 16289+1825 | | | 1.91 | 0.14 | 129.27 | 6.96 | 10 | AIP2 | 22 |
| 2006.516 | STF2052AC | 16289+1825 | | | 135.77 | 0.08 | 45.45 | 0.06 | 6 | AIP2 | |
| 2006.516 | STF2051 | 16294+1036 | | | 13.91 | 0.20 | 18.77 | 0.37 | 8 | AIP2 | |
| 2006.516 | STF2069 | 16364+3349 | | | 35.24 | 0.12 | 81.58 | 0.37 | 12 | AIP2 | |
| 2006.516 | STF2070 | 16377+1933 | | | 28.59 | 0.21 | 141.84 | 0.48 | 18 | AIP2 | |
| 2006.571 | STF2093 | 16429+3855 | | | 116.31 | 0.13 | 265.64 | 0.03 | 5 | AIP2 | 23 |
| 2006.571 | STF2093 | 16429+3855 | | | 82.65 | 0.39 | 283.25 | 0.26 | 5 | AIP2 | 24 |
| 2006.571 | STF2090AC | 16449+0957 | | | 69.00 | 0.15 | 24.80 | 0.18 | 6 | AIP2 | |
| 2006.571 | STF2090AD | 16449+0957 | | | 90.46 | 0.17 | 27.99 | 0.07 | 6 | AIP2 | |
| 2006.571 | STF2090CD | 16449+0957 | | | 21.91 | 0.18 | 38.13 | 0.37 | 6 | AIP2 | |
| 2006.571 | STF2098AB | 16457+3000 | | | 14.29 | 0.07 | 145.48 | 0.22 | 10 | AIP2 | |
| 2006.571 | STF2098AC | 16457+3000 | | | 65.74 | 0.07 | 128.92 | 0.07 | 10 | AIP2 | |

*Table continued on next page.*

## Double Star Astrometry with a Simple CCD Camera

| Epoch | Designation | WDS | Mag1 | Mag2 | Sep. (as) | stdev | PA | stdev | Images | Method | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006.571 | STF2098AD | 16457+3000 | | | 66.94 | 0.09 | 17.27 | 0.08 | 10 | AIP2 | |
| 2006.571 | STF2098BC | 16457+3000 | | | 52.38 | 0.55 | 124.52 | 0.25 | 10 | AIP2 | |
| 2006.571 | STF2110 | 16550+2544 | | | 18.08 | 0.47 | 91.81 | 0.77 | 12 | AIP2 | 25 |
| 2006.571 | STF3127Aa-B | 17150+2450 | | | 11.79 | 0.62 | 283.41 | 1.83 | 19 | AIP2 | 26 |
| 2006.571 | STF3127Aa-C | 17150+2450 | | | 173.19 | 0.10 | 353.16 | 0.09 | 7 | AIP2 | 26 |
| 2006.571 | STF3127Aa-D | 17150+2450 | | | 191.67 | 0.21 | 90.83 | 0.06 | 7 | AIP2 | 26 |
| 2006.697 | STF2272AB | 18055+0230 | | | 5.16 | 0.22 | 136.92 | 1.72 | 36 | AIP2 | 27 |
| 2006.368 | H 5 39AB | 18369+3846 | | | 80.09 | | 183.28 | | 9 | AIP2+ Astro. | 28 |
| 2006.590 | H 5 39AB | 18369+3846 | | | 80.09 | | 183.02 | | 4 | AIP2+ Astro. | 28 |
| 2006.590 | STFB 9AC | 18369+3846 | | | 74.16 | | 255.38 | | 4 | AIP2+ Astro. | 28 |
| 2006.368 | STFB 9AE | 18369+3846 | | | 88.87 | | 39.00 | | 9 | AIP2+ Astro. | 28 |
| 2006.590 | STFB 9AE | 18369+3846 | | | 89.34 | | 39.01 | | 4 | AIP2+ Astro. | 28 |
| 2006.590 | STF3136BC | 18369+3846 | | | 91.27 | | 312.11 | | 4 | AIP2+ Astro. | 28 |
| 2006.773 | BU 1204AB-C | 19121+0237 | | | 12.47 | 0.33 | 195.20 | 1.16 | 24 | AIP2 | |
| 2006.773 | BU 1204AB-D | 19121+0237 | 7.94 | 11.41 | 20.39 | 0.18 | 158.19 | 0.73 | 24 | AIP2 | |
| 2006.773 | BU 1204AB-E | 19121+0237 | 7.94 | 14.43 | 26.50 | 0.08 | 316.89 | 0.50 | 24 | AIP2 | |
| 2006.773 | BU 1204AB-F | 19121+0237 | 7.94 | 14.42 | 26.80 | 0.15 | 292.11 | 0.31 | 24 | AIP2 | |
| 2006.773 | STF2476AB-G | 19121+0237 | 7.94 | 11.18 | 29.88 | 0.11 | 211.26 | 0.28 | 24 | AIP2 | |
| 2006.683 | STF2486AB | 19121+4951 | | | 7.34 | 0.20 | 205.62 | 0.87 | 24 | AIP2 | |
| 2006.683 | STF2486AC | 19121+4951 | | | 27.19 | 0.58 | 96.06 | 1.29 | 12 | AIP2 | |
| 2006.683 | STF2486AD | 19121+4951 | | | 195.82 | 0.31 | 102.33 | 0.34 | 12 | AIP2 | |
| 2006.773 | HJ 879AB | 19137+0218 | 7.80 | 12.80 | 36.73 | 1.59 | 288.77 | 0.95 | 4 | Astro. | 29 |
| 2006.773 | BUP 190Aa-B | 19255+0307 | | 12.54 | 133.55 | 1.73 | 267.06 | 0.65 | 9 | Astro. | 30 |
| 2006.773 | Aa-C | 19255+0307 | | 13.31 | 34.26 | 1.24 | 338.29 | 3.33 | 9 | Astro. | 31 |
| 2006.516 | STFB 10AB | 19508+0852 | | | 193.05 | 0.95 | 286.47 | 0.32 | 12 | AIP2 | 32 |
| 2006.516 | STFB 10AC | 19508+0852 | | | 190.06 | 0.88 | 106.47 | 0.39 | 12 | AIP2 | 32 |
| 2006.516 | DAL 27AD | 19508+0852 | | | 32.81 | 1.53 | 96.11 | 1.76 | 4 | AIP2 | 32 |
| 2006.697 | STF2594 | 19546-0814 | | | 35.69 | 0.10 | 170.24 | 0.19 | 18 | AIP2 | 33 |
| 2006.765 | HJ 1507 | 20247+1438 | 11.00 | 12.03 | 10.29 | 0.12 | 63.87 | 0.52 | 12 | Astro. | 34 |
| 2006.765 | HJ 1508AB | 20247+1443 | 11.11 | 13.65 | 13.57 | 0.22 | 58.72 | 0.91 | 12 | Astro. | 35 |
| 2006.765 | HJ 1508AC | 20247+1443 | 11.11 | 13.83 | 17.63 | 0.28 | 153.31 | 1.90 | 12 | Astro. | 35 |

*Table continued on next page.*

**Double Star Astrometry with a Simple CCD Camera**

| Epoch | Designation | WDS | Mag1 | Mag2 | Sep. (as) | stdev | PA | stdev | Images | Method | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006.765 | STF2680 | 20248+1452 | 9.34 | 9.63 | 16.16 | 0.04 | 287.82 | 0.20 | 9 | Astro. | |
| 2006.921 | ES 2704AB | 21036+5358 | 8.56 | 8.97 | 54.51 | 0.09 | 96.78 | 0.05 | 15 | Astro. | |
| 2006.921 | | 21040+5354 | 11.68 | 12.79 | 8.01 | 0.10 | 188.00 | 1.39 | 9 | Astro. | 36 |
| 2006.921 | | 21040+5354 | | | 8.02 | 0.25 | 186.79 | 3.00 | 15 | AIP2 | 36 |
| 2006.921 | BU 680AC | 21055+5340 | 8.49 | 10.49 | 20.81 | 0.07 | 32.63 | 0.34 | 10 | Astro. | |
| 2006.921 | HJ 1615 | 21075+4515 | 11.30 | 11.75 | 14.31 | | 96.92 | | 18 | Astro. | 37 |
| 2006.773 | HJ 3061 | 21512+0546 | 11.73 | 11.74 | 17.04 | 0.21 | 105.41 | 0.39 | 11 | Astro. | 38 |

Table Notes

1. A = 00 04 00.25 +12 08 44.7 (2000.0)
2. AB = 00 04 40.09 +34 15 53.9 (2000.0)
3. C = 00 04 40.21 +34 16 19.6 (2000.0)
4. A = 00 07 37.89 +40 08 52.5 (2000.0)
5. 35 Psc. could not identify Che 2 at 0 15 06 +08 50 (2000.0)
6. A = 00 27 31.03 +16 01 31.7 (2000.0)
7. "B = 00 27 24.30 +16 00 34.6 (2000.0). In line with measure 1907, but not 1988 in WDS2006.5"
8. Gamma CMi
9. Epsilon Cnc
10. Alpha Leo
11. Alpha Leo. Magnitude difference 4.00mag
12. Gamma Leo
13. Beta Leo
14. Eta Boo. Only 4 reference stars in poor field
15. Xi Boo
16. A = 15 07 50.14 +63 07 01.8 (2000.0)
17. A = 15 11 50.20 +61 51 26.0 (2000.0)
18. new component C
19. Eta CrB
20. Mu Boo
21. Zeta CrB
22. too close for f.l. 1040mm
23. Eta Her
24. "Eta Her. Faint companion, closer than B"
25. 56 Her
26. Delta Her
27. 70 Oph
28. Alpha Lyr (Vega)
29. 21 Aql. Scatter due to brightness of A

*(Continued on page 135)*

**Double Star Astrometry with a Simple CCD Camera**

*(Continued from page 134)*

30. Delta Aql
31. "Delta Aql. New? star. Faint and close, large scatter"
32. Alpha Aql
33. 57 Aql
34. A = 20 24 39.15 +14 38 05.6 (2000.0)
35. A = 20 24 40.27 +14 42 52.5 (2000.0)
36. "pair in field of ES 2704. 21 03 58.43 +53 53 57.7"" (2000.0)"
37. A = 21 07 33.95 +45 14 24.7 (2000.0) -- position in WDS 2006.5 is near
38. A = 21 51 16.30 +05 44 59.8 (2000.0)