

# 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

### Double Star Astrometry with a Simple CCD Camera

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

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:  $\text{real PA} = 360^\circ - \text{"PA"} + \text{orientation\_angle\_from\_astrometrica}$ .

#### 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

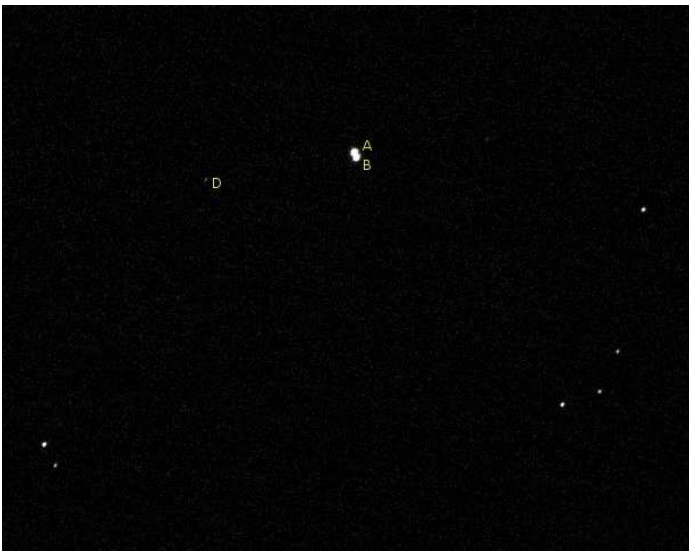


Figure 1: CCD image of STF2486, 0.1 s exposure.



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

fitting of Astrometrica but produces consistent results with better than 1/2 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

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

Epoch	Name	Discoverer Code	WDS	Observation		Calculation			Observation minus Calculation	
				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

## Double Star Astrometry with a Simple CCD Camera

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 ( $\alpha$  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](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>

for Vega at <http://www.ari.uni-heidelberg.de/datenbanken/aricns/cnspages/4c01497.htm>

9. ARI Catalog of Nearby Stars: <http://www.ari.uni-heidelberg.de/datenbanken/aricns/> with the entry

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)

