University of South Alabama

Journal of Double Star Observations

VOLUME 4 NUMBER 4 FALL 2008

Inside this issue:

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

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)

Divinus Lux Observatory: Report #15

Dave Arnold

Program Manager for Double Star Research
2728 North Fox Fun Drive
Flagstaff, AZ 86004

E-Mail: dvdarnl@aol.com

Abstract: This report contains theta/rho measurements from 96 different double star systems. The time period spans from 2008.221 to 2008.402. Measurements were obtained using a 20-cm Schmidt-Cassegrain telescope and an illuminated reticle micrometer. This report represents a portion of the work that is currently being conducted in double star astronomy at Divinus Lux Observatory in Flagstaff, Arizona.

While in the process of reviewing several papers over the past several months, in conjunction with my own research, it seems that a particular inference may be drawn regarding the neglected doubles list that comprises part of the Washington Double Star (WDS) Catalog data base. It appears that the majority of double stars that I have measured from this list are optical doubles, especially if the last published measurements are at least 50 years old. Perhaps since many of these pairs are widely separated, or have been discovered to have divergent proper motions, such double stars have become ignored because of only having a slight possibility of being physically connected. If these pairs happen to be faint, or have poorly known coordinates, this would also contribute to these double stars appearing on the neglected doubles list.

As a result of my experience with the neglected double star data base, it has occurred to me that it might be useful if a list of double stars could be generated from the WDS catalog that identified all known optical doubles, so that they could be eliminated from further study when one is attempting to conduct a binary star research project. It has since come to my attention that the Washington Multiplicity Catalog (WMC), which is currently being developed by the U. S. Naval Observatory, could fill this need. Not only could known optical systems be identified, but the WMC would combine the WDS catalog data with those of other existing catalogs, in order to formulate a complete listing of all known double and/or multiple stars. This could provide a list of pairs that would show theta/rho shifts that are more likely to be caused by orbital motion, rather than divergent proper motions. The existence of such a catalog could provide greater efficiency in identifying pairs that might merit an orbital motion study.

I simply mention the emergence of the WMC as an upcoming valuable tool for bringing efficiency to binary star research, especially when sifting through known optical pairs becomes burdensome. If more time could be devoted to common proper motion pairs, or pairs that are known to be physically related, it might become more likely that additional visual binaries could be identified in less time. My understanding is that the WMC will, hopefully, be completed in about two years. More information about this upcoming catalog can be obtained by visiting the website of the US Naval Observatory. I would also like to thank Bill Hartkopf for his input as I composed these above paragraphs.

As has been done in previous articles, the selected double star systems, which appear in this report, have been taken from the 2001.0 version of the Washington Double Star Catalog, with published measurements that are no more recent than ten years ago. Several systems are included from the 2006.5 version of the WDS Catalog as well. There are also some noteworthy items that are discussed pertaining to the following table.

Divinus Lux Observatory: Report #15

As is often the case, proper motion by one or both of the components of a double star has caused some shifts in reported theta/rho values. In regards to STF 2120 AB, proper motion by the "B" component has caused a 3.5% increase in the rho value since 1998. A significant rho value increase is also being noted for AG 214. Since 1998, proper motion by the reference point star has caused a 10% shift to occur. Another rho value increase is being cited for HJ 4923. Since 1998, proper motions by both components have caused an increase of 4%. Additionally, proper motion by the reference point star, for HU 946, has resulted in a 5% increase in the rho value during the past 10 years. However, the most noteworthy rho value increase, which is being highlighted in this article, pertains to LV 20 AB. Since 1998, an increase of 36" has occurred because of a large proper motion by the "A" component.

A possible additional component is being submitted for A 281 (20106+3452). Labeled as ARN 100 AC, this star, with a magnitude of +9.7, appears to share a common proper motion with the (AB) components. This proposed "C" component does not appear to have been previously cataloged.

Regarding double stars that are currently listed in the WDS catalog, it is being noted that SEI 630 (19335+3611) appears to be a duplicate entry for HJ 1414 (19335+3610) because the coordinates and parameters for these two entries are very similar. It has been visually confirmed that only one double star appears in this part of the sky near the coordinates listed above.

NAME	RA DEC	MAGS	PA	SEP	DATE	NOTES
STF1779	14048-0633	8.1 9.0	297.5	4.44	2008.279	1
STF1818	14143+3356	8.9 10.2	330.0	5.43	2008.221	2
STF1826AB	14152+4658	8.9 9.6	310.0	3.95	2008.279	3
BU 116	14195-1343	8.0 8.2	275.0	3.95	2008.279	4
STF1858AB	14336+3535	8.0 8.5	38.5	2.96	2008.221	5
SHJ 191	14596+5352	6.8 7.5	341.7	40.49	2008.257	6
LV 20AB	15103-1616	9.1 10.1	10.6	478.94	2008.358	7
BUP 161AC	15103-1616	9.1 9.5	180.3	301.19	2008.358	7
STT 137	15158+5056	6.5 8.8	101.2	67.64	2008.257	8
HDS2150	15177-1712	9.4 10.7	193.6	20.74	2008.221	9
HJ 2779	15206+5520	8.0 10.7	347.2	10.86	2008.257	10
AOT 60	15306-1217	10.1 10.6	356.6	39.37	2008.221	11
STF1961AB	15346+4331	9.9 10.1	20.7	28.14	2008.279	12
STF1963AB	15379+3006	8.5 8.8	298.2	5.43	2008.279	13

Table continued on next page.

Divinus Lux Observatory: Report #15

NAME	RA DEC	MAGS	PA	SEP	DATE	NOTES
STF1965	15394+3638	5.0 5.9	305.2	6.42	2008.257	14
STT 300	15402+1203	6.2 10.0	260.7	14.81	2008.257	15
STF1982	15499+4247	9.9 10.1	298.0	4.94	2008.257	16
STT 302AB	15549+3422	7.1 10.4	50.8	29.63	2008.279	17
STF2010AB	16081+1703	5.0 6.1	13.3	27.16	2008.279	18
SHJ 227AB	16219+1909	3.7 9.9	227.2	42.46	2008.358	19
STF2053Aa-B	16284+3108	9.9 10.7	350.9	21.73	2008.265	20
STF2068	16339+4717	8.9 9.0	251.7	4.94	2008.265	21
STF2072	16355+4741	9.7 10.5	179.7	4.94	2008.265	22
STF2087AB	16426+2340	8.8 8.8	287.0	4.94	2008.358	23
STF2101AB	16458+3538	7.5 9.3	48.5	4.44	2008.265	24
KPR 3AC	16458+3538	7.5 10.2	87.5	235.03	2008.265	24
STF2120AB	17048+2805	7.3 9.2	231.0	23.21	2008.298	25
STF2120AC	17048+2805	7.3 10.2	174.2	145.16	2008.298	25
HJ 4923	17091-1815	8.5 10.6	147.8	15.80	2008.358	26
TOB 137	17108+3211	7.3 10.6	260.5	39.99	2008.358	27
POP1234AC	17167+3504	9.5 10.6	320.8	56.78	2008.284	28
STN 34	17167-1709	9.4 10.6	289.0	17.28	2008.284	29
BU 45	17179+3229	9.9 10.5	291.2	4.94	2008.279	30
STF2161Aa-B	17237+3709	4.5 5.4	318.5	3.95	2008.298	31
STF2167	17244+4931	8.1 10.7	209.1	20.74	2008.284	32
STF2180	17290+5052	7.8 7.9	261.0	2.96	2008.298	33
STF2175	17294+3243	8.8 10.6	7.0	13.33	2008.358	34
AG 210	17378+2257	9.9 10.2	187.0	4.44	2008.284	35
B 2413	17424-1924	9.6 10.6	198.1	11.36	2008.284	36
STF2209	17428+4310	8.3 10.5	126.7	29.63	2008.284	37

Table continued on next page.

Divinus Lux Observatory: Report #15

NAME	RA DEC	MAGS	PA	SEP	DATE	NOTES
STT 334	17436+3446	7.8 9.8	355.5	15.31	2008.284	38
AG 213	17457+3452	9.1 10.6	175.7	22.22	2008.284	39
STT 336AD	17479+3417	6.6 10.6	163.4	41.48	2008.284	40
AG 214	17495+3436	9.0 9.9	203.5	4.94	2008.298	41
A 698AB	17505+4112	9.6 10.1	256.5	4.44	2008.284	42
STF3129	18011+4521	7.6 10.6	167.8	31.11	2008.342	43
STF2264	18015+2136	4.8 5.1	257.4	6.42	2008.342	44
STF2323AC	18239+5848	5.1 7.9	19.6	88.88	2008.342	45
STF2318	18255+2600	8.4 9.9	249.2	20.74	2008.342	46
STF2352AC	18370+3452	7.9 10.2	160.7	210.34	2008.339	47
SLE 218AD	18381-1400	6.6 10.5	337.9	120.48	2008.339	48
STF2259AC	18386+3046	9.0 9.8	182.5	137.26	2008.339	49
STF2259AE	18386+3046	9.0 10.1	148.0	225.15	2008.339	49
STT 361	18437+0539	8.2 9.4	171.5	22.71	2008.377	50
STF 38AD	18448+3736	4.3 5.6	149.8	43.94	2008.342	51
ES 1425	18467+4303	9.8 10.3	230.5	4.44	2008.339	52
H 40AC	18498+3249	5.9 10.3	120.6	57.28	2008.339	53
SRT 1	18501-1317	8.9 9.4	251.2	29.13	2008.339	54
TAR 3AB	18506+3313	10.5 10.7	305.3	14.81	2008.342	55
STF2436AB	19022+0845	8.5 9.2	314.4	30.12	2008.377	56
STF2436AC	19022+0845	8.5 10.6	300.3	134.30	2008.377	56
STF2453	19051+4008	8.5 10.5	86.0	13.33	2008.374	57
STF2479AB-C	19083+5520	7.5 9.6	29.7	6.42	2008.377	58
MRG 3	19118+2443	10.0 10.3	144.7	5.43	2008.374	59
LDS5873	19151-0428	9.9 10.3	99.9	85.42	2008.374	60
HJ 1395AC	19252+3708	9.5 10.7	13.2	53.82	2008.374	61

Table continued on next page.

Divinus Lux Observatory: Report #15

NAME	RA DEC	MAGS	PA	SEP	DATE	NOTES
STF2531AC	19295+0305	8.1 10.1	28.2	31.60	2008.377	62
STF 43Aa-B	19307+2758	3.1 4.7	54.2	34.56	2008.377	63
HU 946	19323+3417	8.1 9.9	215.4	8.39	2008.374	64
HJ 1414	19335+3610	9.3 10.7	32.6	14.32	2008.374	65
A 598AC	19365+4124	9.9 10.7	92.7	47.40	2008.374	66
STF2545AB	19387-1009	6.8 8.5	326.0	3.95	2008.377	67
STT 190AC	19434+4715	7.7 9.7	316.1	67.15	2008.374	68
AG 236	19435+3450	9.8 10.1	148.6	4.44	2008.377	69
STT 384AC	19438+3819	7.6 9.8	296.8	59.25	2008.374	70
STF2605AB	19556+5226	5.0 7.5	178.4	2.96	2008.377	71
GUI 29AC	19585+3317	7.7 9.5	273.7	167.88	2008.377	72
STT 196AB	20019+4052	7.3 9.2	168.8	53.82	2008.402	73
STF2624Aa-C	20035+3601	7.1 9.3	327.4	42.96	2008.402	74
SEI 830	20037+3626	8.2 10.2	359.5	29.63	2008.399	75
HDS2861	20042+4645	9.7 10.7	108.9	16.79	2008.399	76
HJ 1471	20046+3213	5.6 10.4	8.4	32.59	2008.399	77
STF 314AD	20060+3547	6.8 9.5	300.6	11.36	2008.402	78
STF 314AF	20060+3547	6.8 7.3	28.0	36.04	2008.402	78
HJ 1485	20096+3325	8.3 8.9	276.5	4.94	2008.402	79
A 281(AB)	20106+3452	9.0 9.4	172.0	4.44	2008.402	80
ARN 100AC*	20106+3452	9.0 9.7	313.5	63.20	2008.402	80
S 738AB	20106+3338	7.8 8.4	106.4	41.97	2008.402	81
AG 249	20123+3451	7.8 10.7	132.4	33.08	2008.402	82
ES 1674	20181+4122	9.5 10.2	125.8	4.94	2008.399	83
STF2661	20199-0215	7.9 9.2	340.3	24.19	2008.399	84
BU 662AB	20209-1939	8.7 10.7	4.1	124.92	2008.399	85

Table continued on next page.

Divinus Lux Observatory: Report #15

NAME	RA DEC	MAGS	PA	SEP	DATE	NOTES
SEI1103	20215+3950	9.0 10.7	223.0	16.79	2008.399	86
ES 206	20288+3810	9.8 10.5	124.4	3.95	2008.399	87
WEI 35AB	20293+3731	8.2 8.8	215.5	4.44	2008.402	88
WEI 35AC	20293+3731	8.2 9.4	99.9	87.39	2008.402	88
SEI1160AB	20327+3916	8.2 10.3	49.9	14.32	2008.399	89
STF2713	20409+1035	9.8 9.8	63.0	4.94	2008.402	90
HJ 612Aa-B	20410+3905	6.5 10.5	9.4	48.88	2008.399	91
SEI1222	20419+3953	10.4 10.7	77.3	25.18	2008.399	92
AG 265	20457+3647	9.9 9.9	207.5	6.91	2008.399	93
HJ 1582AC	20498+3833	8.2 10.5	326.0	28.64	2008.402	94
SEI1268	20501+3714	10.6 10.7	123.3	27.16	2008.402	95
STF2797	21267+1341	7.4 8.8	218.0	3.46	2008.402	96

* Not listed in the WDS Catalog.

Table Notes

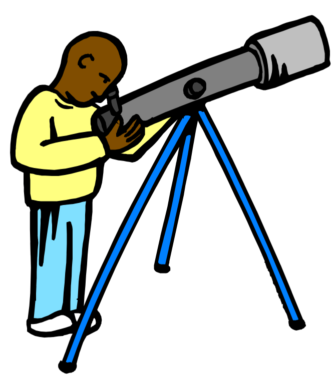
1. In Virgo. Sep. & p.a. increasing. Spect. F0, F0.
2. In Bootes. Common proper motion; sep. increasing. Spect. G2III, G2III.
3. In Bootes. Common proper motion; p.a. decreasing. Spect. F8, F8.
4. In Virgo. Common proper motion; sep. inc; p.a. dec. Spect. F8V, G0.
5. In Bootes. Sep. & p.a. increasing. Spect. G5.
6. In Bootes. Relatively fixed. Common proper motion. Spect. F1V, F1V.
7. In Libra. AB = sep. inc. AC = relfix; common proper motion. Spect. K0.
8. In Bootes. Sep. & p.a. decreasing. Spect. G5, G5.
9. In Libra. Relatively fixed. Common proper motion. Spect. F8, F2.
10. In Draco. Common proper motion; p.a. decreasing. Spect. F5, F5.
11. In Libra. Sep. increasing; p.a. decreasing. Spect. G5.
12. In Bootes. Sep. increasing; p.a. decreasing. Spect. K2, F8.
13. In Corona Borealis. Sep. & p.a. increasing. Spect. F8, F8.
14. Zeta or 7 Coronae Borealis. Cpm; sep. & p.a. inc. Spect. B7V, B9V.
15. In Serpens. Separation slightly increasing. Spect. G2.5III.
16. In Hercules. Common proper motion; p.a. decreasing. Spect. F8, F8.
17. In Corona Borealis. Sep. increasing; p.a. decreasing. Spect. A3V.
18. Kappa or 7 Herculis. Sep. decreasing; p.a. increasing. Spect. G7III, G5.
19. Gamma or 20 Herculis. Position angle decreasing. Spect. A9III.
20. In Hercules. Relatively fixed. Common proper motion. Spect. G0.

Divinus Lux Observatory: Report #15

21. In Hercules. Sep. & p.a. decreasing. Spect. F5, F5.
22. In Hercules. Common proper motion; p.a. decreasing. Spect. G0, G0.
23. In Hercules. Common proper motion; sep. & p.a. dec. Spect. G5IV, G5IV.
24. In Hercules. AB = cpm; p.a. dec. AC = sep. inc. Spect. AB = F6V, G0.
25. In Hercules. AB = sep. increasing. AC = relfixed. Spect. AB = K0III, K1III.
26. In Ophiuchus. Sep. increasing; p.a. decreasing. Spect. A7III.
27. In Hercules. Position angle increasing. Spect. K2.
28. In Hercules. Separation decreasing. Spect. G0, G.
29. In Ophiuchus. Separation slightly increasing. Spect. F5.
30. In Hercules. Common proper motion; p.a. increasing.
31. Rho or 75 Herculis. Common proper motion; p.a. inc. Spect. B9.5III, B9.5III.
32. In Hercules. Common proper motion; p.a. decreasing. Spect. F5, F5.
33. In Draco. Common proper motion; sep. & p.a. decreasing. Spect. A7IV.
34. In Hercules. Common proper motion; p.a. decreasing. Spect. F5.
35. In Hercules. Common proper motion; p.a. increasing. Spect. M0, M0.
36. In Ophiuchus. Relatively fixed. Common proper motion. Spect. F6V.
37. In Hercules. Relatively fixed. Common proper motion. Spect. F0.
38. In Hercules. Position angle slightly increasing. Spect. G5, G5.
39. In Hercules. Sep. increasing; p.a. decreasing. Spect. K0.
40. In Hercules. Separation slightly decreasing. Spect. B3V.
41. In Hercules. Sep. increasing; p.a. decreasing. Spect. F5.
42. In Hercules. Common proper motion; sep. increasing. Spect. F5, F5.
43. In Hercules. Separation increasing. Spect. B9.
44. 95 Herculis. Common proper motion; p.a. decreasing. Spect. A5III, G5.
45. 39 Draconis. Common proper motion; p.a. decreasing. Spect. A1V, F5.
46. In Hercules. Separation increasing. Spect. K2III.
47. In Lyra. Relatively fixed. Spect. K0.
48. In Scutum. Separation slightly decreasing. Spect. B9IV.
49. In Lyra. AC & AE = relatively fixed. Spect. A5.
50. In Serpens. Relatively fixed. Common proper motion. Spect. A2.
51. Zeta or 7 Lyrae. Common proper motion; sep. inc.; p.a. dec. Spect. F0IV, F0IV.
52. In Lyra. Relatively fixed. Common proper motion.
53. 8 Lyrae. Sep. & p.a. slightly decreasing. Spect. B3IV.
54. In Scutum. Relatively fixed. Common proper motion. Spect. G5V, G0.
55. In Lyra near STF 39. Sep. & p.a. increasing.
56. In Aquila. AB = sep. dec.; p.a. inc. AC = sep. inc; p.a. dec. Spect. K0, F8, A0.
57. In Lyra. Sep. & p.a. decreasing. Spect. A2, A2.
58. In Cygnus. Position angle decreasing. Spect. A5IV, A3.
59. In Vulpecula. Separation slightly increasing. Spect. A2.
60. In Aquila. Relatively fixed. Common proper motion.
61. In Lyra. Separation slightly decreasing. Spect. A0.
62. In Aquila. Position angle decreasing. Spect. B5V, A1V.
63. Albireo, Beta, or 6 Cygni. Relatively fixed. Spect. K3II, B8V.
64. In Cygnus. Sep. increasing; p.a. decreasing. Spect. G0.
65. In Cygnus. Sep. decreasing; p.a. increasing.

Divinus Lux Observatory: Report #15

66. In Cygnus. Position angle decreasing. Spect. F5.
67. In Aquila. Sep. & p.a. increasing. Spect. A9III, A5.
68. In Cygnus. Relatively fixed. Spect. B0V, A2.
69. In Cygnus. Sep. & p.a. decreasing. Spect. A0, A0.
70. In Cygnus. Sep. slightly increasing; p.a. slightly decreasing. Spect. B5V.
71. Psi or 24 Cygni. Sep. & p.a. dec. Common proper motion. Spect. A4V, A4V.
72. In Cygnus. Sep. increasing; p.a. decreasing. Spect. F5IV, G0.
73. In Cygnus. Sep. slightly decreasing; p.a. slightly increasing; Spect. A0.
74. In Cygnus. Relatively fixed. Spect. B1III, B2.
75. In Cygnus. Sep. & p.a. slightly increasing. Spect. B5II.
76. In Cygnus. Relatively fixed. Common proper motion. Spect. A, A.
77. In Cygnus. Sep. & p.a. slightly increasing. Spect. B1.5I.
78. In NGC 6871 in Cygnus. AD & AF = relatively fixed. Spect. O9.5I, B2, B.
79. In Cygnus. Position angle slightly decreasing. Spect. A2V, A2V.
80. In Cygnus. (AB) = sep. inc.; common proper motion. AC = cpm. Spect. F7V.
81. In Cygnus. Position angle decreasing. Spect. B9V, B9V.
82. In Cygnus. Separation decreasing. Spect. K2V.
83. In Cygnus. Position angle increasing. Spect. B0, G.
84. In Aquila. Relatively fixed. Common proper motion. Spect. A0.
85. In Capricornus. Separation increasing. Spect. K2III, G.
86. In Cygnus. Relatively fixed. Common proper motion. Spect. B2I, B2I.
87. In Cygnus. Position angle increasing.
88. In Cygnus. AB = sep. & p.a. inc. AC = relatively fixed. Spect. F5, F5, B8.
89. In Cygnus. Common proper motion; p.a. decreasing. Spect. B9, B9.
90. In Delphinus. Relatively fixed. Spect. B9.
91. In Cygnus. Relatively fixed. Spect. B6III.
92. In Cygnus. Sep. increasing; p.a. decreasing.
93. In Cygnus. Common proper motion; sep. slightly increasing.
94. In Cygnus. Separation increasing. Spect. M.
95. In Cygnus. Position angle decreasing.
96. In Pegasus. Position angle increasing. Spect. A2V, A2.



Double Star Measures Using a DSLR Camera

Ernõ Berkó

3188-Ludányhalászi,
Bercsényi u. 3.
Hungary

E-mail: berko@is.hu

Abstract: This publication presents double star measures made with a DSLR camera. The images used for the measures were taken in the period between 2007.197 - 2007.205. The result is 124 positive and 4 negative measures.

Instead of the earlier CCD camera, since 2007 I have been using a digital one (Canon EOS 350D) for photographing the images to be measured. I mounted the camera on my Newton telescope of 35.5 cm diameter and 2100 mm focal length. For the sake of precision, I enlarged the camera's focus 2X with the help of a photographic teleconverter. The focus thus increased to 4200 mm gives a 0.3089"/pixel resolution.

For the later photo-processing and the measures, I took several dozen images of each sky area that I had previously chosen.

The exposure times are 10 - 60 seconds, depending on the brightness of the stars to be recorded. In the case of fainter stars, I added up more photos, while for closer doubles I took the average of the images. With this method, it has become possible to record a larger field of view, which is of great help in identifying the doubles.

I measured the pictures with Florent Losse's program (Reduc), and I would like to express my gratitude to the developers. The photos had to be prepared for the measurements (Gray-scale, BMP, adding up, average). For the orientation of the pictures, I employed the Drift Analysis function of the program.

Cross-checking the system and the program has proved that they are capable of performing the planned measures. With thorough work, we can achieve a standard deviation under 0.1", by measuring 6-10 images independently.

I used approximately 1157 photos for the present publication. It contains the data of 1165 independent measures of 128 pairs.

Regarding the measurement data, the identification of the doubles happened according to the Washing Double Star catalog (WDS) codes. I marked the pairs and components not appearing in WDS as Anon. Whenever possible, I wrote down the Guide Star Catalog (GSC) code of at least one of the components of the doubles measured by me. I described the brightness of the components on the basis of WDS, although it seems contradictory sometimes. When there is an Anon. component, I gave the GSC or USNO "R" brightness, if not available I provided the brightness that I estimated on the basis of the photo.

I found the greatest problem with the 10-character identification coordinates of WDS. In many cases it is different from the real position of the double. Although WDS contains more precise coordinates for most of the pairs, at times the double cannot be found at these locations. This certainly makes the identification of some (especially the neglected) doubles troublesome, mostly in sky areas rich in stars, pairs. This is true for computer imaging, as well. Several astronomical programs use the fixed identification coordinates of WDS, so it would be practical if these data were changed into the value closest to the precise position of the double.

Double Star Measures Using a DSLR Camera

For the doubles measured by me, I give suggestions regarding these closest coordinates in the form of (xxxxx+xxxx!). In the RA and Dec columns of the table, the abbreviated coordinates of the doubles can be found, as used by WDS.

The table contains the position angle (PA) and separation (S) values that I measured, and the standard deviations values in (+/-) format. The time when the images were taken is also indicated, together with the number of photos used for the measures of the doubles (n), and finally - where it was needed - the reference to the separate notes. The last column of the table shows the number of the picture in which the double can be found.

I have made a picture for every measured pair with subtitles added, this way the double of a multiple system is readily apparent.

I would specially like to thank the work of Ágnes Kiricsi, who has helped a lot in this publication with the English translations and the correspondence.

RA + Dec	Discoverer	Mags		PA	+/-	Sep	+/-	Epoch	N	Notes	Img
05138+3520	SEI 112	11.0	11.0	62.59	0.17	17.42	0.05	2007.202	8	1	1
05139+3517	TOB 24	11.7	13.4	243.52	0.15	13.85	0.04	2007.202	7	2	1
05159+3425	ES 170AB	7.8	11.1	11.81	0.25	22.9	0.07	2007.202	10	3	2
05159+3425	WAL 36AC	7.79	12.13	302.93	0.12	59.25	0.07	2007.202	14	3	2
05163+3419	SEI 136AB	6.03	9.1					2007.202		4	3
05163+3419	WAL 37AC	6.03	10.73					2007.202		4	3
05197+3526	SEI 186	10.74	12.26	245.59	0.07	21.24	0.03	2007.202	10	5	4
05202+3528	Anon. 1	12.2	13.0	153.61	0.23	11.61	0.06	2007.202	7	6	4
05218+3639	SEI 208	9.0	11.0	108.05	0.26	23.01	0.07	2007.202	10	7	5
05220+3627	SEI 209	11.78	12.01	181.6	0.09	26.34	0.06	2007.202	12	8	6
05221+3610	SEI 211	10.5	11.0	292.12	0.27	8.97	0.05	2007.205	12	9	7
05226+3642	SEI 216AB	11.0	11.0	146.9	0.33	17.8	0.03	2007.202	5	10	8
05226+3642	Anon. 2Bx	11.0	14.0	322.84		6.35		2007.202	1	10	8
05226+3627	SEI 218	10.0	11.0	240.73	0.23	16.56	0.06	2007.202	12	11	6
05229+3642	SEI 223	10.06	11.43	106.21	0.1	22.61	0.01	2007.202	9	12	8
05233+3445	SEI 229	12.61	12.44	27.11		5.16		2007.202	1	111	9
05234+3446	FOX 140	10.8	10.9	179.41	0.24	6.57	0.07	2007.202	9	13	9
05236+3607	SEI 232	10.2	11.0	4.86	0.1	8.21	0.01	2007.205	3	14	10
05237+3606	SEI 233AB	10.8	11.0	83.42	0.09	29.05	0.04	2007.205	18	15	10
05237+3606	Anon. 3Bx	11.0	13.9	133.16	0.37	13.11	0.03	2007.205	8	16	10

Table 1: Double star measurements made with DSLR camera. *Table continued on next page.*

RA + Dec	Discoverer	Mags	PA	+/-	Sep	+/-	Epoch	N	Notes	Img
05252+3451	STF 698	6.65 8.33	347.11	0.19	31.22	0.05	2007.202	8	17	11
05253+3527	SEI 242	10.7 10.8	256.49	0.11	25.07	0.06	2007.197	12	18	12
05255+3431	Anon. 4	12.5 12.5	153.1		4.68		2007.202	1	19	13
05259+3648	SEI 248	12.53 12.53	159.25	0.24	20.24	0.07	2007.202	9	20	14
05260+3522	SEI 249	9.9 12.1	19.43	0.11	26.85	0.04	2007.197	15	21	12
05262+3647	SEI 251	11.71 12.51	273.35	0.29	17.02	0.05	2007.202	8	22	14
05262+3558	Anon. 5	12.2 13.2	305.61	0.34	24.04	0.07	2007.197	7	23	15
05264+3658	SEI 256	10.8 13.1	33.41	0.25	26.48	0.07	2007.202	7	24	16
05266+3524	STF 705	10.22 10.83	12.39	0.11	18.46	0.04	2007.197	14	25	17
05268+3559	Anon. 6	12.4 14.0	188.93	0.21	17.47	0.08	2007.197	9	26	15
05268+3557	Anon. 7	12.5 15.0	65.94	0.2	21.49	0.03	2007.197	8	27	15
05271+3558	Anon. 8	13.2 13.8	14.99	0.16	21.91	0.1	2007.197	7	28	15
05273+3602	SEI 260	10.0 10.3	347.36	0.12	22.64	0.04	2007.197	12	29	18
05274+3551	SEI 262	11.0 11.0	35.71	0.24	16.32	0.05	2007.197	12	30	19
05280+3800	Anon. 9	12.5 13.0	79.78	0.41	2.98	0.03	2007.197	3	31	20
05281+3811	ALI 800	10.6 12.0	88.26	0.14	10.92	0.05	2007.197	15	32	21
05282+3800	PTT 10	10.2 10.2	146.25	0.56	4.43	0.08	2007.197	12	33	20
05290+3629	SEI 292	11.0 11.0	128.53	0.32	14.35	0.06	2007.197	10	34	22
05294+3505	SEI 299	10.3 11.0	160.47	0.31	9.07	0.05	2007.205	11	35	23
05295+3502	Anon.10AB	13.0 13.0	250.28	0.24	9.98	0.04	2007.205	12	36	23
05295+3502	Anon.10BC	13.0 14.0	140.35	0.35	7.16	0.01	2007.205	2	36	23
05296+3503	Anon.11	12.4 12.7	97.69	0.17	10.47	0.04	2007.205	13	37	23
05298+3731	SEI 304	9.9 10.8	175.72	0.22	8.84	0.06	2007.205	15	38	24
05299+3807	SEI 306AB	10.0 11.0	257.28	0.31	13.14	0.06	2007.2	6	39	25
05299+3807	Anon.12Ax	10.0 12.0	340.28	0.13	14.68	0.07	2007.2	6	39	25
05299+3513	SEI 307	13.23 13.53	259.27	0.13	28.99	0.06	2007.205	14	40	26
05302+3525	SEI 309	9.0 11.0	221.17	0.2	7.44	0.1	2007.205	5	41	27
05307+3725	SEI 311AB	11.1 12.1	356.65	0.06	22.87	0.04	2007.205	12	42	28
05307+3725	ES 2340BC	12.1 12.6	188.05		2.67		2007.205	1		28
05312+3627	SEI 314	10.78 15.1	13.48		18.98		2007.205	1	43	29
05268+3557	Anon. 7	12.5 15.0	65.94	0.2	21.49	0.03	2007.197	8	27	15
05271+3558	Anon. 8	13.2 13.8	14.99	0.16	21.91	0.1	2007.197	7	28	15
05273+3602	SEI 260	10.0 10.3	347.36	0.12	22.64	0.04	2007.197	12	29	18

Table continued on next page.

Double Star Measures Using a DSLR Camera

RA + Dec	Discoverer	Mags		PA	+/-	Sep	+/-	Epoch	N	Notes	Img
05274+3551	SEI 262	11.0	11.0	35.71	0.24	16.32	0.05	2007.197	12	30	19
05280+3800	Anon. 9	12.5	13.0	79.78	0.41	2.98	0.03	2007.197	3	31	20
05281+3811	ALI 800	10.6	12.0	88.26	0.14	10.92	0.05	2007.197	15	32	21
05282+3800	PTT 10	10.2	10.2	146.25	0.56	4.43	0.08	2007.197	12	33	20
05290+3629	SEI 292	11.0	11.0	128.53	0.32	14.35	0.06	2007.197	10	34	22
05294+3505	SEI 299	10.3	11.0	160.47	0.31	9.07	0.05	2007.205	11	35	23
05295+3502	Anon.10AB	13.0	13.0	250.28	0.24	9.98	0.04	2007.205	12	36	23
05295+3502	Anon.10BC	13.0	14.0	140.35	0.35	7.16	0.01	2007.205	2	36	23
05296+3503	Anon.11	12.4	12.7	97.69	0.17	10.47	0.04	2007.205	13	37	23
05298+3731	SEI 304	9.9	10.8	175.72	0.22	8.84	0.06	2007.205	15	38	24
05299+3807	SEI 306AB	10.0	11.0	257.28	0.31	13.14	0.06	2007.2	6	39	25
05299+3807	Anon.12Ax	10.0	12.0	340.28	0.13	14.68	0.07	2007.2	6	39	25
05299+3513	SEI 307	13.23	13.53	259.27	0.13	28.99	0.06	2007.205	14	40	26
05302+3525	SEI 309	9.0	11.0	221.17	0.2	7.44	0.1	2007.205	5	41	27
05307+3725	SEI 311AB	11.1	12.1	356.65	0.06	22.87	0.04	2007.205	12	42	28
05307+3725	ES 2340BC	12.1	12.6	188.05		2.67		2007.205	1		28
05312+3627	SEI 314	10.78	15.1	13.48		18.98		2007.205	1	43	29
05312+3626	Anon.13	13.5	15.0	198.94		6.42		2007.205	1	44	29
05317+3702	SEI 315	11.0	11.0	61.33	0.29	15.22	0.04	2007.205	13	45	30
05318+3604	SEI 316	10.8	11.0	330.59	0.29	15.99	0.06	2007.2	7	46	31
05321+3636	SEI 317AB	9.3	11.0	184.35	0.4	10.37	0.01	2007.2	7	47	32
05321+3636	Anon.14Ax	9.3	12.0	299.42	0.48	8.74	0.08	2007.2	8	47	32
05324+3858	ALI 803	11.1	12.0	34.73	0.14	13.86	0.07	2007.2	14	48	33
05324+3532	SEI 319	9.0	10.6	91.13	0.3	10.52	0.05	2007.2	9	49	34
05325+3628	SEI 318	10.5	11.0	59.11	0.23	9.03	0.07	2007.2	10	50	35
05325+3602	SEI 320	11.59	11.61	152.1	0.19	22.89	0.07	2007.2	14	51	31
05329+3915	ALI1055	11.1	12.6	119.25	0.18	8.54	0.04	2007.2	14	52	36
05329+3606	SEI 321	11.0	11.0	349.25	0.21	20.03	0.06	2007.2	4	53	37
05332+3644	SEI 322	9.2	11.0	233.16	0.11	18.58	0.05	2007.2	14	54	38
05342+3600	Anon.15	13.0	14.5	85.97		7.41		2007.205	1	55	39
05343+3752	SEI 325	11.47	11.65	223.97	0.16	11.87	0.02	2007.197	18	56	40
05343+3603	SEI 326	11.4	11.6	159.39	0.18	18.86	0.06	2007.205	13	57	39
05344+3658	Anon.16	13.8	13.9	123.61	0.02	11.01	0.04	2007.197	2	58	41
05344+3549	AG 95	9.40	10.30	17.35	0.06	24.33	0.05	2007.205	12	59	44

Table continued on next page.

Double Star Measures Using a DSLR Camera

RA + Dec	Discoverer	Mags		PA	+/-	Sep	+/-	Epoch	N	Notes	Img
05345+3733	SEI 329	11.0	11.0	176.89	0.24	16.17	0.07	2007.197	16	60	45
05345+3727	SEI 330	9.5	11.0	139.08	0.26	7.87	0.06	2007.197	10	61	45
05345+3727	SEI 332	10.7	11.8	197.31	0.29	8.54	0.04	2007.197	15	62	45
05345+3651	SEI 331	11.0	11.0	320.26	0.2	21.54	0.05	2007.197	14	63	42
05345+3537	SEI 333	10.9	12.4	330.77	0.31	12.6	0.08	2007.205	9	64	46
05346+3656	SEI 334	10.0	10.5	225.59	0.16	18.5	0.07	2007.197	12	65	41
05347+3651	SEI 335	10.5	10.7	315.62	0.13	23.21	0.05	2007.197	16	66	42
05348+3648	Anon.17	14.6	14.7	63.3	0.23	12.31	0.06	2007.197	13	67	42
05350+3652	Anon.18	13.9	13.9	73.09	0.27	14.13	0.06	2007.197	7	68	43
05350+3648	SEI 338	11.0	11.0	62.86	0.36	7.02	0.04	2007.197	8	69	47
05352+3654	ES 2563	10.8	13.3	137.8		3.27		2007.197	1	70	48
05353+3653	Anon.19	12.5	14.0	259.29	0.2	8.06	0.08	2007.197	7	71	48
05353+3646	SEI 341	10.0	11.0	111.74	0.18	10.89	0.09	2007.197	8	72	47
05354+3721	SEI 342AB	10.5	10.7	348.36	0.12	28.89	0.04	2007.197	14	73	49
05354+3721	Anon.20Bx	10.7	15.0	193.22	0.59	6.45	0.04	2007.197	6	74	49
05354+3721	Anon.20By	10.7	14.6	260.84	0.18	13.92	0.06	2007.197	13	75	49
05354+3608	SEI 344	10.2	11.0	96.94	0.31	17.02	0.07	2007.205	11	76	50
05355+3552	SEI 346	10.0	11.0	145.47	0.12	19.87	0.04	2007.205	14	77	51
05355+3550	Anon.21	13.5	13.7	112.66	0.18	15.92	0.03	2007.205	11	78	51
05356+3651	SEI 345AB	10.93	11.80	349.33	0.14	28.21	0.06	2007.197	13	79	52
05356+3651	Anon.22Bx	11.80	13.5	18.29		2.98		2007.197	1	80	52
05356+3651	Anon.22By	11.80	14.0	255.24		10.15		2007.197	1	81	52
05358+3745	SEI 347	10.5	11.0	165.97	0.24	11	0.04	2007.197	10	82	53
05359+3702	SEI 348	11.0	11.0	84.5	0.26	20.87	0.06	2007.197	12	83	54
05360+3614	SEI 349	9.8	11.97	52.29	0.26	14.15	0.08	2007.205	11	84	50
05368+3735	ALI 545	10.8	13.2	79.98	0.11	13.42	0.03	2007.197	16	85	55
05380+3643	SEI 358	10.5	10.5	196.44	0.13	17.44	0.05	2007.197	11	86	56
05382+3726	Anon.23	12.5	13.0	247.9	0.21	14.08	0.04	2007.197	6	87	58
05384+3729	Anon.24	10.8	11.1	171.59	0.27	20.35	0.05	2007.197	7	88	58
05386+3607	Anon.25	11.2	13.0	259.72	0.19	16.29	0.04	2007.205	11	89	61
05387+3729	Anon.26AB	14.5	15.0	315.56	0.17	5.23	0.07	2007.197	2	90	57
05387+3729	Anon.26BC	15.0	15.2	17.36	0.1	1.47	0.07	2007.197	2	90	57
05388+3704	SEI 361	11.21	10.60	29.97	0.09	29.03	0.05	2007.205	16	91	60
05388+3609	SEI 363	9.82	12.25	244.84	0.11	30.02	0.06	2007.205	9	92	61

Table continued on next page.

Double Star Measures Using a DSLR Camera

RA + Dec	Discoverer	Mags	PA	+/-	Sep	+/-	Epoch	N	Notes	Img
05389+3728	SEI 362	11.0 11.0	141.62	0.12	22.84	0.03	2007.197	14	93	59
05390+3729	Anon.27	14.0 15.0	316.61	0.16	7.96	0.08	2007.197	8	94	59
05393+3740	SEI 364	11.0 11.0	143.7	0.2	18.44	0.04	2007.197	10	95	62
05394+3736	Anon.28	13.8 13.8	86.27	0.16	15.95	0.04	2007.197	7	96	63
05394+3735	Anon.29	14.0 14.5	354.18	0.32	6.72	0.1	2007.197	7	97	63
07540+1457	WEI 17	9.01 9.28	96.04	0.22	6.94	0.07	2007.200	11	98	64
07586+1628	STF1167	9.5 11.5	228.77	0.14	12.26	0.03	2007.200	17	99	65
08014+1657	STF1173	8.47 9.93	50.88	0.34	10.38	0.1	2007.200	14	100	66
08019+1702	HJ 3307	9.7 11.2	349.39	0.14	18.1	0.04	2007.200	14	101	67
08100+1701	SLE 467AB	7.56 11.54	187.08	0.06	73.41	0.1	2007.200	8	102	68
08100+1701	SLE 467AC	8.5 10.5	199.42	0.09	61.49	0.15	2007.200	8		68
08100+1701	SLE 467BC	10.2 10.5	322.43	0.1	18.7	0.07	2007.200	9		68
08103+1650	SLE 468AB	9.9 11.8	174.4	0.13	32.47	0.08	2007.200	8	103	69
08103+1650	SLE 468AC	9.9 11.8	159.87	0.1	34.41	0.06	2007.200	8		69
08103+1650	SLE 468BC	11.8 11.8	90.3	0.16	8.68	0.05	2007.200	7		69
08115+1636	SLE 469	9.8 11.7	292.22	0.12	21.39	0.05	2007.200	17	104	70
08122+1739	STF1196AB	5.30 6.25					2007.200		105	71
08122+1739	STF1196AB-C	5.05 6.20	71.1	0.57	5.8	0.13	2007.200	13		71
08122+1739	STF1196AB-D	5.31 8.89	106.63	0.06	278.81	0.18	2007.200	13		72
08122+1739	ENH 1AB-E	5.31 10.08	25.82	0.05	562.21	0.1	2007.2	6		72
08122+1739	ENH 1AB-F	5.05 10.26	45.72	0.02	638.06	0.08	2007.2	6		72
08122+1739	ENH 1AB-G	5.31 10.15	331.53	0.03	672.25	0.07	2007.2	7		72
08146+1711	SLE 470	10.9 12.0	133.29	0.26	14.81	0.08	2007.2	7	106	73
08160+1842	HO 524AaB	7.70 10.51					2007.2		107	74
08160+1842	OPI 13AaC	7.70 9.78	77.45	0.07	65.62	0.07	2007.2	11	108	74
08185+1937	HJ 444	8.53 10.27	96.07	0.1	37.12	0.04	2007.2	15	109	75
08189+1940	Anon.30	11.2 13.3	184.36	0.22	9.35	0.04	2007.2	3	110	75

Table Notes

1. A=GSC 2397 765 (05138+3519!).
2. A=GSC 2397 725
3. A=GSC 2398 384. The difference is significant compared to the previous measure/measures.
4. A=GSC 2398 894. The primary star according to WDS is AE Aur. In the photos that I took, and in the DSS image, no appropriate companions can be seen.
5. A=GSC 2398 26
6. A=GSC 2398 1076
7. A=GSC 2402 1436 (05217+3639!).
8. A=GSC 2402 394
9. AB=GSC 2402 554

10. Bx=GSC 2402 1041 non star.
11. A=GSC 2402 446 (05227+3627!).
12. A=GSC 2402 1033 (05228+3642!).
13. AB=GSC 2398 581 non star (05234+3445!).
14. A,B do appear in USNO.
15. A,B do appear in USNO.
16. x does not appear in USNO.
17. A=GSC 2411 1617
18. A=GSC 2411 985 (05252+3526!).
19. AB=GSC 2411 1940 non star.
20. A,B do appear in USNO (05258+3648!).
21. A=GSC 2411 911
22. A=GSC 2415 207 (05261+3647!), very different parameters.
23. A=GSC 2415 974. To the west of the specified location of SEI 258. Similar parameters but with 180˚ difference.
24. A=GSC 2415 417
25. A=GSC 2411 1303
26. A=GSC 2415 1076. The double to the north of the specified location of SEI 258, but the parameters are very different.
27. A=GSC 2415 996. The double closest to the specified location of SEI 258, but the parameters are very different.
28. A=GSC 2415 610. To the east of the specified location of SEI 258. Similar parameters but with 100˚ difference.
29. A=GSC 2415 1106.
30. A=GSC 2415 190.
31. AB=GSC 2909 1834 non star.
32. A=GSC 2909 1236.
33. AB=GSC 2909 1338.
34. B=GSC 2415 805, A does appear in USNO (05291+3628!).
35. AB=GSC 2411 1307 non star.
36. A=GSC 2411 1171
37. A=GSC 2411 925
38. A=GSC 2909 1732
39. Abx=GSC 2909 1672 non star (05300+3807!).
40. A=GSC 2411 1473
41. A=GSC 2411 89 1
42. A=GSC 2415 167
43. A=GSC 2415 609 (05312+3626!).
44. AB=GSC 2415 917 non star.
45. A=GSC 2415 605 non star.
46. A=GSC 2415 476 (05319+3604!)
47. Ax=GSC 2415 1001 (05320+3635!)
48. A=GSC 2910 259 (05324+3857!).
49. AB=GSC 2411 345
50. A=GSC 2415 795 (05324+3628!)
51. A=GSC 2415 1400
52. AB=GSC 2910 195 non star.
53. A=GSC 2415 670 (05329+3607!)
54. A=GSC 2416 8
55. AB=GSC 2416 433 non star.
56. A=GSC 2910 1278.
57. A=GSC 2416 167
58. (053424+365808), A,B do appear in USNO.
59. A=GSC 2416 885
60. B=GSC 2910 1398, A does appear in USNO.
61. A=GSC 2416 806.
62. AB=GSC 2416 1255 non star.
63. A=GSC 2416 1215.
64. A=GSC 2412 448
65. A=GSC 2416 1285.
66. A=GSC 2416 858.
67. A=GSC 2416 276.
68. (053459+365225), A,B do appear in USNO.
69. 150AB=GSC 2416 1034 blended object.
70. AB=GSC 2416 706 (05352+3653!)
71. AB=GSC 2416 832 non star.
72. A=GSC 2416 634.
73. A=GSC 2416 574.
74. Bx=GSC 2416 1219 non star.
75. y=GSC 2416 102.
76. A=GSC 2416 805
77. A=GSC 2416 509
78. A=GSC 2416 881
79. A=GSC 2416 1173 (05355+3650!).
80. Bx=GSC 2416 250 non star.
81. y=GSC 2416 700 non star.
82. A=GSC 2910 1024.
83. B=GSC 2416 1186
84. A=GSC 2416 523
85. A=GSC 2910 914.
86. A=GSC 2416 1239
87. A=GSC 2416 356.
88. A=GSC 2416 182.
89. A=GSC 2416 843
90. ABC=GSC 2416 1190 non star.

Double Star Measures Using a DSLR Camera

91. A=GSC 2416 494
92. A=GSC 2416 323
93. A=GSC 2416 134 (05389+3727!).
94. AB=GSC 2416 504 non star.
95. A=GSC 2910 814
96. (053925+373532), A,B do appear in USNO.
97. AB=GSC 2910 1354 non star.
98. A=GSC 791 1441 1
99. A=GSC 1363 2210
100. A=GSC 1380 1831
101. A=GSC 1380 1655
102. A=GSC 1381 916
103. A=GSC 1377 214
104. A=GSC 1377 301
105. ABC=GSC 1381 1638, AB are not separated.
106. A=GSC 1381 881
107. B is visible but cannot be measured.
108. Aa=GSC 1381 586
109. A=GSC 1386 1163
110. A=GSC 1386 1000
111. AB=GSC 2398 511 non star (05239+3451!). Far from the specified location.

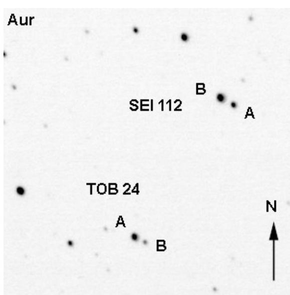


Image 1

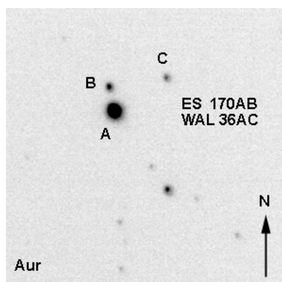


Image 2

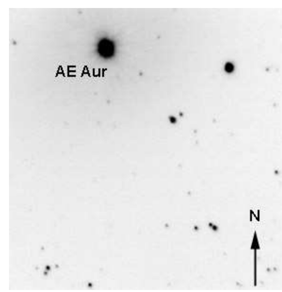


Image 3

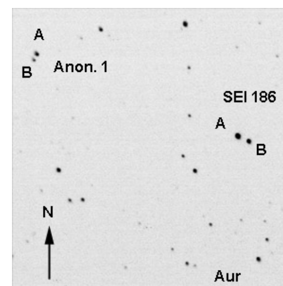


Image 4

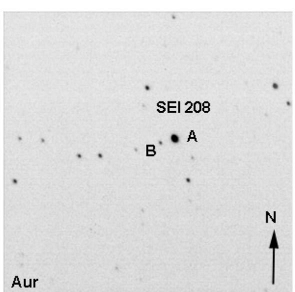


Image 5

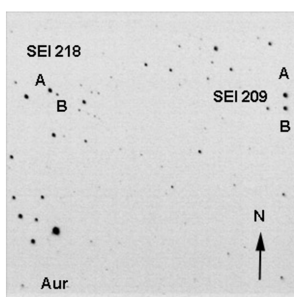


Image 6

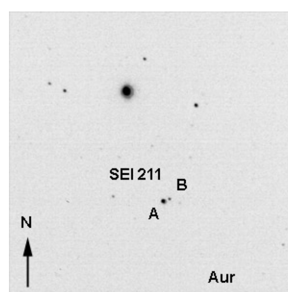


Image 7

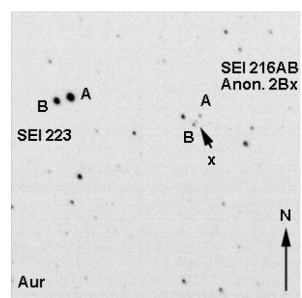


Image 8

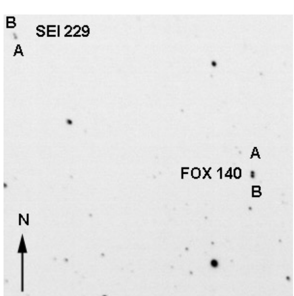


Image 9

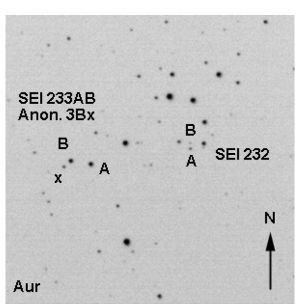


Image 10

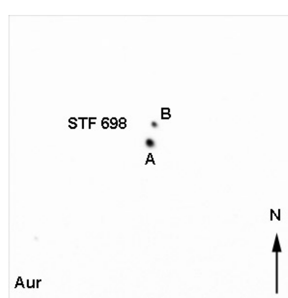


Image 11

Image 12

Double Star Measures Using a DSLR Camera

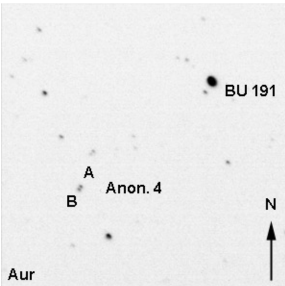


Image 13

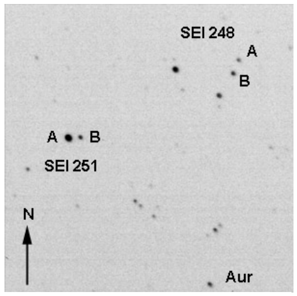


Image 14

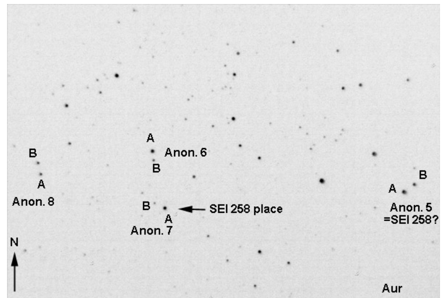


Image 15

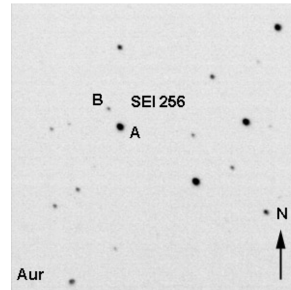


Image 16

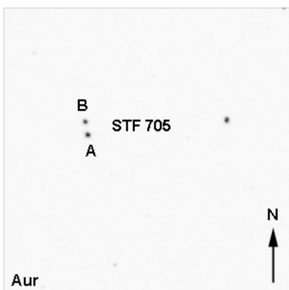


Image 17

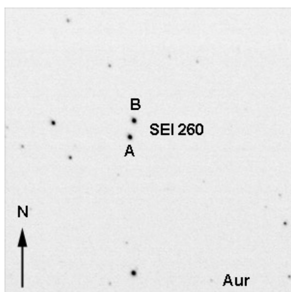


Image 18

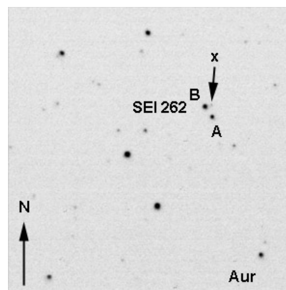


Image 19

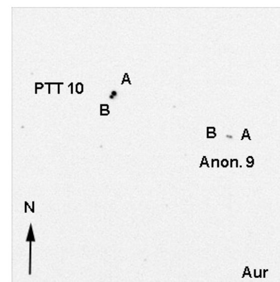


Image 20

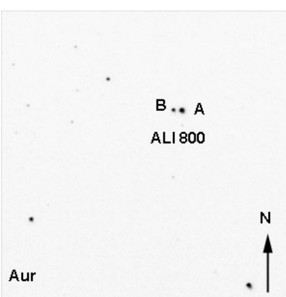


Image 21

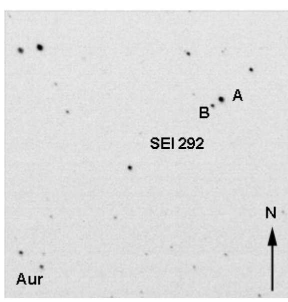


Image 22

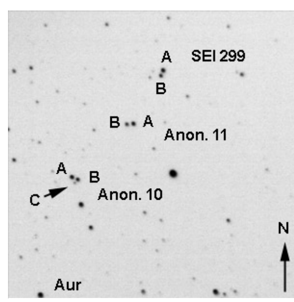


Image 23

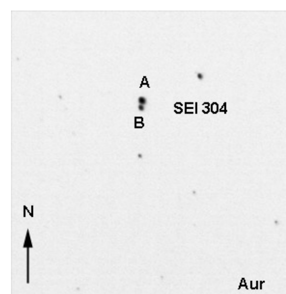


Image 24

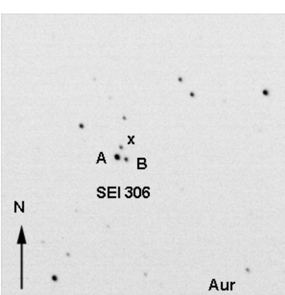


Image 25

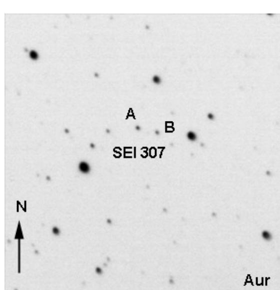


Image 26

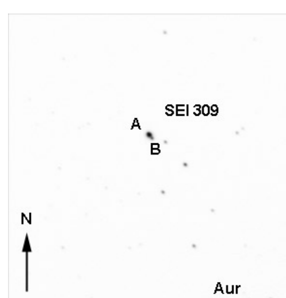


Image 27

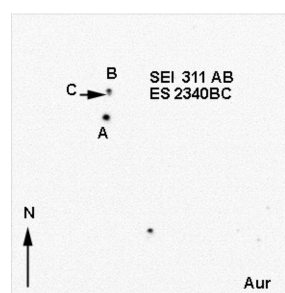


Image 28

Double Star Measures Using a DSLR Camera

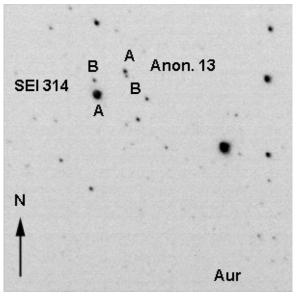


Image 29

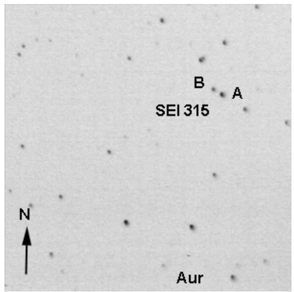


Image 30

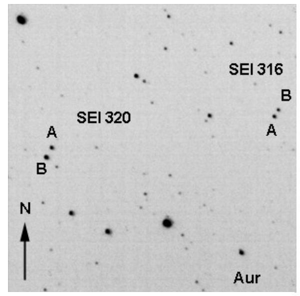


Image 31

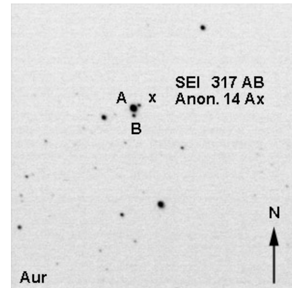


Image 32

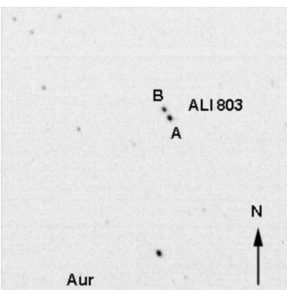


Image 33

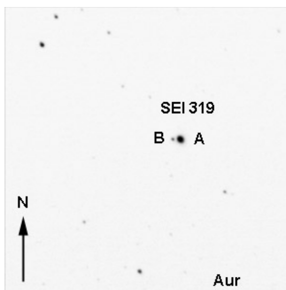


Image 34

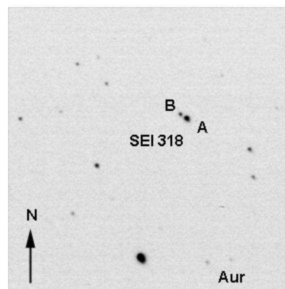


Image 35

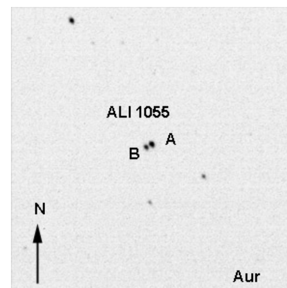


Image 36

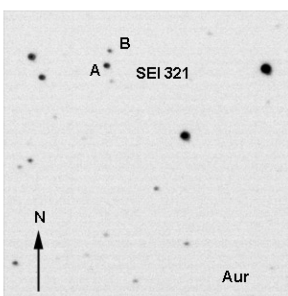


Image 37

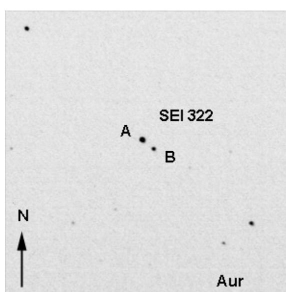


Image 38

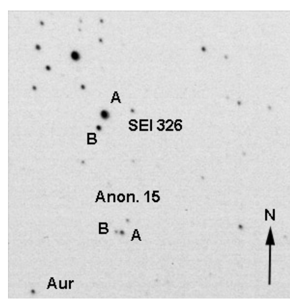


Image 39

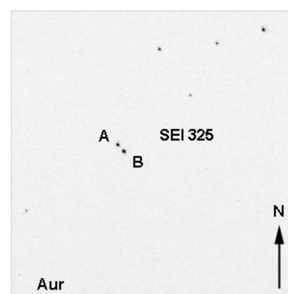


Image 40

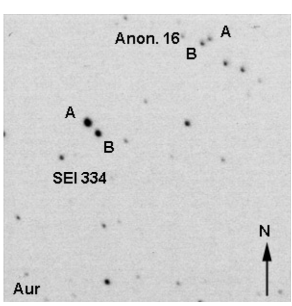


Image 41

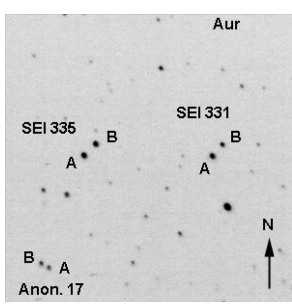


Image 42

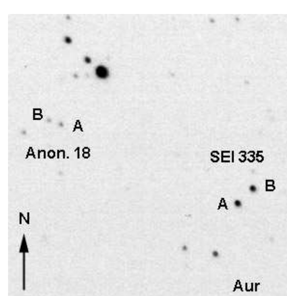


Image 43

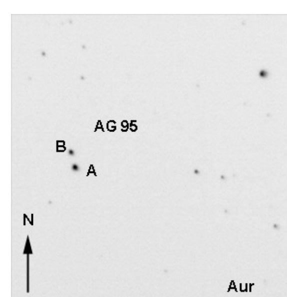


Image 44

Double Star Measures Using a DSLR Camera

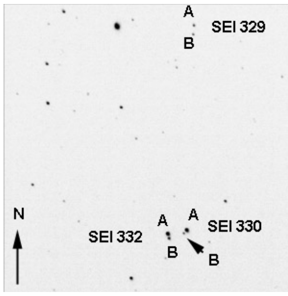


Image 45

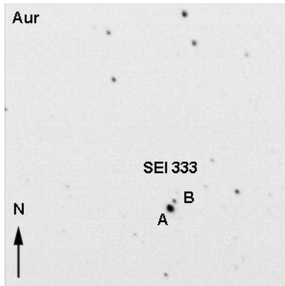


Image 46

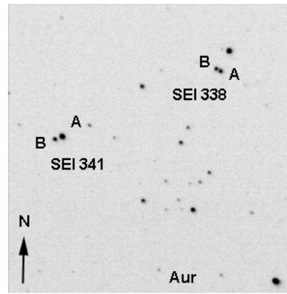


Image 47

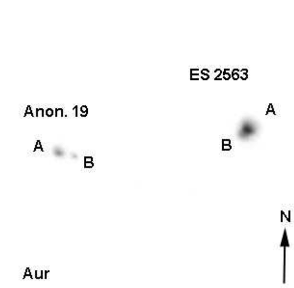


Image 48

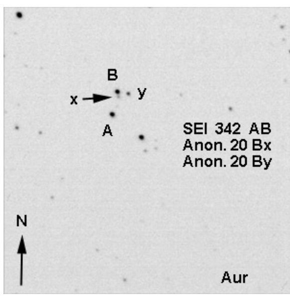


Image 49

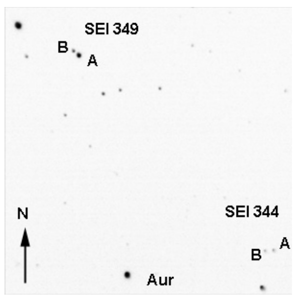


Image 50

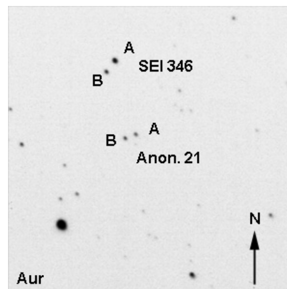


Image 51

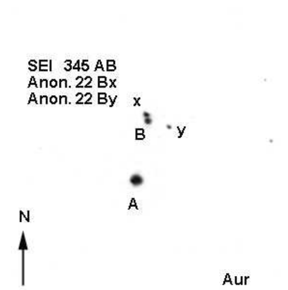


Image 52

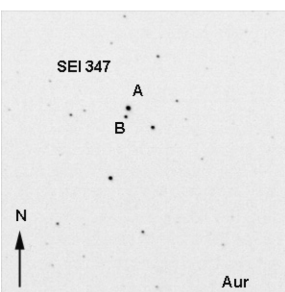


Image 53

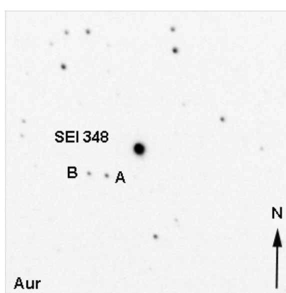


Image 54

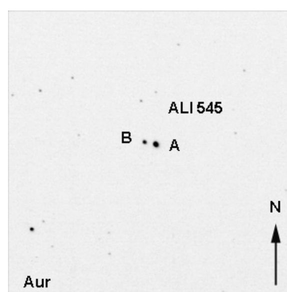


Image 55

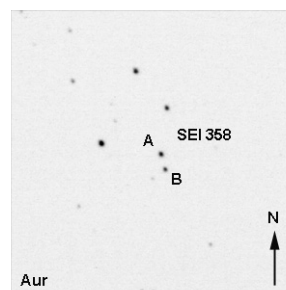


Image 56

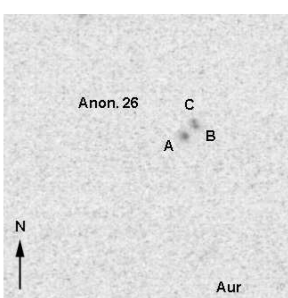


Image 57

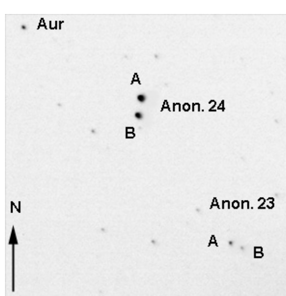


Image 58

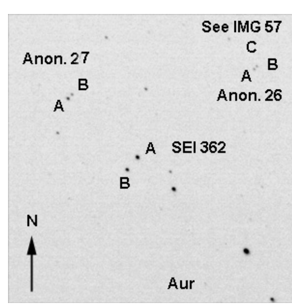


Image 59

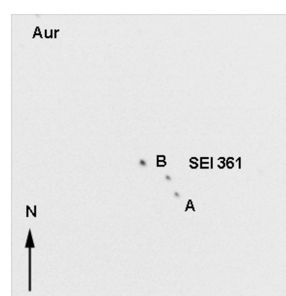


Image 60

Double Star Measures Using a DSLR Camera

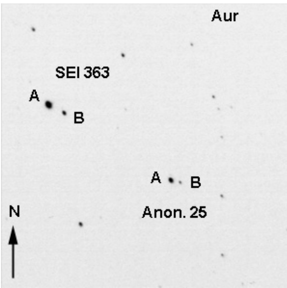


Image 61

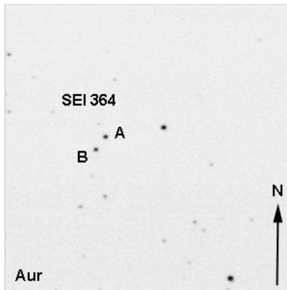


Image 62

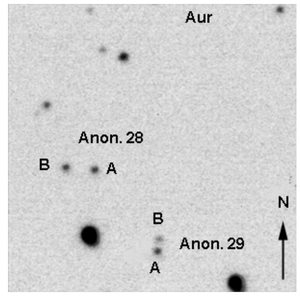


Image 63

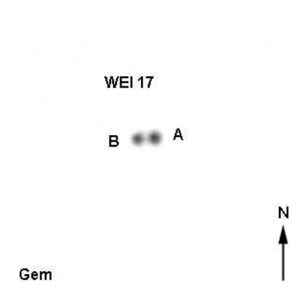


Image 64

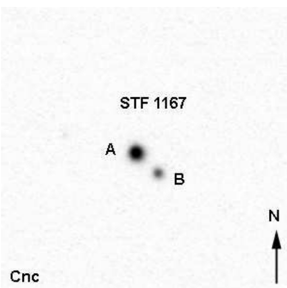


Image 65

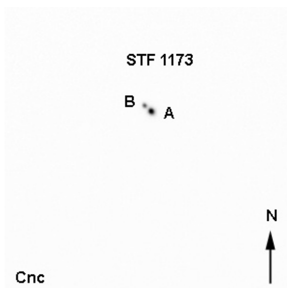


Image 66

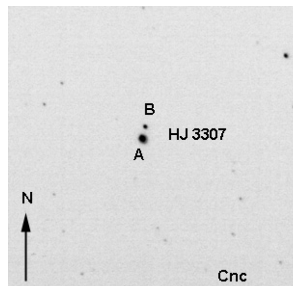


Image 67

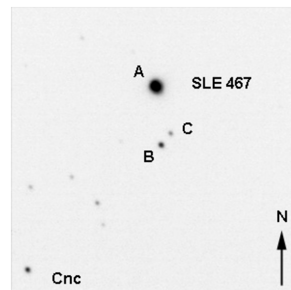


Image 68

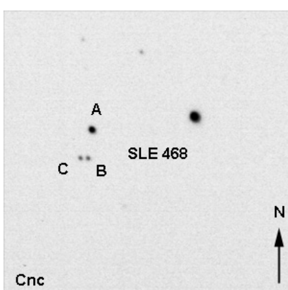


Image 69

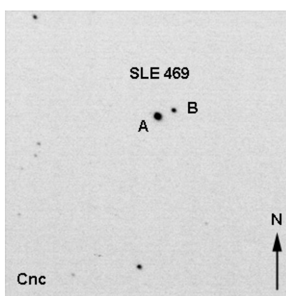


Image 70

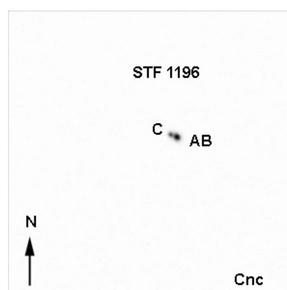


Image 71

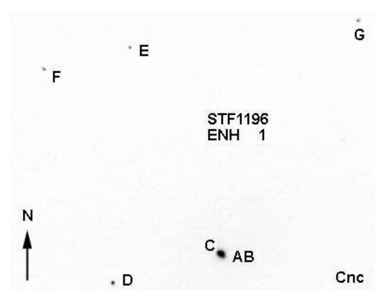


Image 72

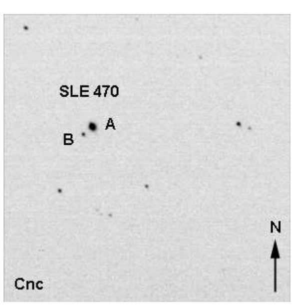


Image 73

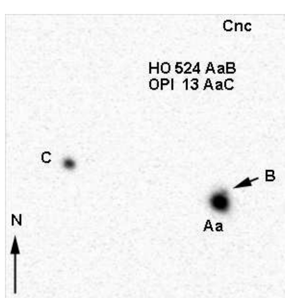


Image 74

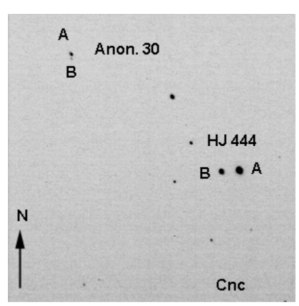


Image 75

A Mathematical Model to Predict the Resolution of Double Stars by Amateurs and Their Telescopes

Tim Napier-Munn

Astronomical Association of Queensland,
Queensland, Australia

Abstract: This paper reports the development of a new statistical model for predicting whether a given double star will be resolved by a particular telescope. The model predicts the effect of the magnitudes of the pair, their separation, the telescope aperture and a quantitative estimate of seeing on the probability of resolving the pair. It is based on a database of observations made by members of the Astronomical Association of Queensland, Australia. The paper reviews the phenomenon of resolution, and summarises the literature on the development of criteria for predicting whether a given pair will be resolved, from the 19th century Dawes' criterion to modern attempts to include factors other than just telescope aperture. The development of the new model is then described, including the collection of the data, a statement of the model equations, an assessment of model quality, and demonstrations of its use to show the effects of magnitude difference and seeing on the resolution limit of a range of telescope apertures. Some future work is suggested. The model has been implemented in an Excel spreadsheet which is available from the author at tgn-m@bigpond.net.au.

Introduction and Objectives

There are many reasons why you might want to split or separate close double stars in your telescope, for example:

1. To challenge the telescope and observer.
2. To establish, in a formal measurement, the capability of the telescope and observer.
3. To train the eye through regular observation of difficult doubles.
4. To measure the separation and position angle of close pairs.

However an observer new to the pleasures of observing double stars, or indeed new to amateur astronomy in general, has no real idea of what to expect when trying to separate or "resolve" a close or otherwise difficult double. There are several well-known theoretical and empirical resolution limits but these have generally been developed by and for expert observers with high quality instruments in good seeing conditions, and therefore may not apply to the average amateur. They are also based only on telescope aperture. Other more recent correlations have been reported which include additional factors, but none are based exclusively on amateur observations nor do they treat the problem as one in statistical probability which may offer a more practical and robust prediction for amateur observers.

Resolution

The ability to split a double star depends on the resolution which the combination of telescope, observer and conditions is capable of. Resolution is the capacity to see detail in an astronomical image, and the resolution of a telescope is generally formally defined as the angular separation of the closest pair of stars of equal magnitude which the instrument (and observer) can separate. Argyle (2004) and Mullaney (2005) give helpful discussions of the issue.

Resolution is dominated by the optical phenomenon of diffraction. When a point source of light such as a star is observed through a circular light collector such as a lens or mirror, the image is not a point of light but a diffraction pattern comprising a bright central disk surrounded by concentric fainter rings. The properties of this pattern were worked out by Sir

A Mathematical Model to Predict the Resolution of Double Stars by Amateurs and Their Telescopes

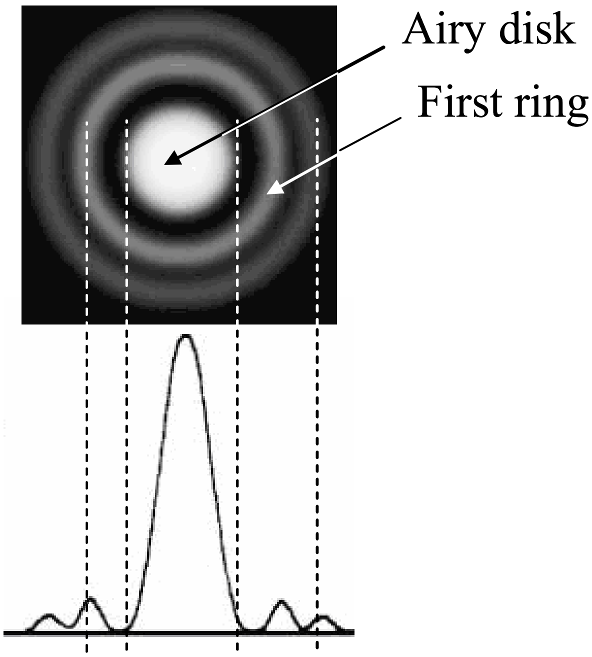


Figure 1: The light intensities of the Airy diffraction pattern

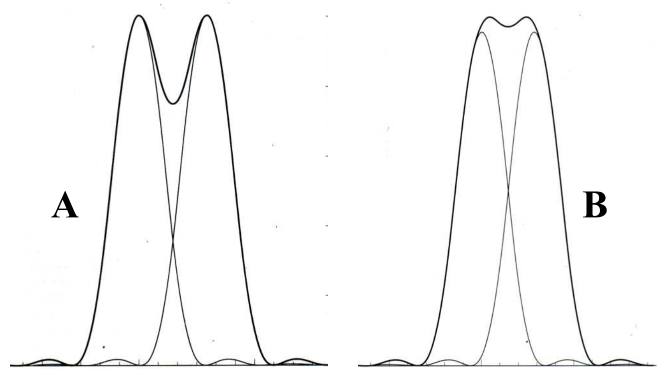


Figure 2: Diffraction limited light profiles of two close doubles. A - the Rayleigh Limit. B - the Dawes Limit. (*from Argyle, 2004)*

George Airy in 1835. In particular he showed that the central disk (called the Airy disk in his honor) contained 84% of the light, the remaining 16% being distributed amongst the rings. The pattern and the intensities of the disk and rings are shown in Figure 1.

The pure diffraction pattern is rarely observed in practice. The "disk" of light which most of us view as a star is in fact a distorted image due to atmospheric seeing. Good seeing and high magnification are needed to observe the pure pattern, and small telescopes are better for this purpose than large because they are less susceptible to the seeing.

When a close double is observed the two diffraction patterns will overlap, making it difficult to distinguish the separate images of the two stars, and this is the main (though not only) factor which limits an observer's ability to split a double. Lord Rayleigh suggested that the two images could just be distinguished if the peak of one Airy disk just fell on the center of the first dark ring of the other, as shown in Figure 2A. The drop in the light intensity between the two peaks is about 25% which is sufficient to distinguish the two centers and so "split" the pair. Figure 3 illustrates the notch effect seen at the Rayleigh Limit. Airy's theory shows that at the Rayleigh Limit the resolution of a telescope is $1.22\lambda/D$ radians where λ is the wavelength of the light and D is the telescope aperture. Taking λ = 550 nm (usually regarded as the peak response of the eye), resolution in arc seconds is then given by 138/D where D is the aperture in mm. This suggests that a 200 mm telescope can resolve a pair separated by only 0.69".

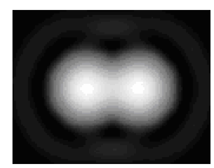


Figure 3: appearance of a double separated by the Rayleigh limit.

In 1867 Rev. W.R. "Eagle Eye" Dawes reported a program of observation with a range of refractors from which he deduced that the separation of a pair of sixth magnitude stars which could just be separated in "moderately favorable seeing" was 116/D arc seconds, somewhat less than the Rayleigh Limit. Figure 2B shows that drop in the peak intensity for the Dawes Limit is only about 3%, but this is enough for an expert observer to deduce duplicity, and the literature has references to observations which exceed even this. A more modest limit is that of Markowitz = 152/D. (Mullaney, 2005).

The Rayleigh Limit is essentially an arbitrary though plausible definition of resolution based on Airy's diffraction theory. The Dawes and Markowitz Limits are empirical, based on observation.

A Mathematical Model to Predict the Resolution of Double Stars by Amateurs and Their Telescopes

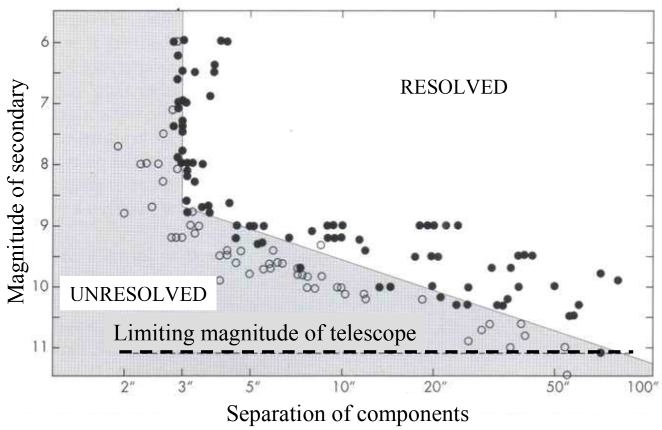


Figure 4: Peterson Diagram for 3" refractor at 45X. (*from Mullaney, 2005)*

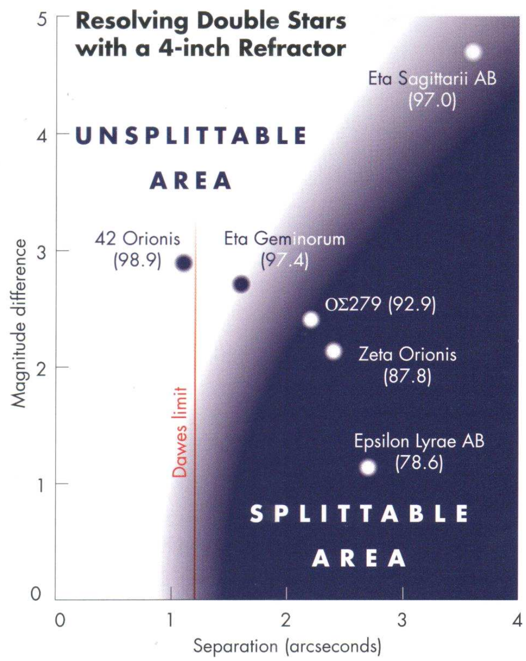


Figure 5: Arguelles diagram for 4: refractor (*from Mullaney, 2005*)

Others Factors Determining the Resolution of Close Doubles

In splitting difficult doubles, it is obvious to anyone who has attempted the task that although telescope aperture is important, as shown by the Rayleigh, Dawes and Markowitz Limits, it is not the only factor which determines whether a given double can be separated. Faint stars are more difficult to distinguish than bright ones, stars of differing magnitude are difficult to split because the glare of the primary can obscure the secondary, seeing can make all the difference between whether a particular double is easy or impossible, and there is evidence that different telescope types can have different resolving performance depending on conditions. And of course the skill, experience and visual acuity of the observer are also important. In predicting whether a particular double can be split by a particular telescope and observer, these factors must also be taken into account.

Several workers have reported methods of incorporating some of these elements into predictive tools. Fisher (2006) gives an excellent review of some of these. Lewis (1914) collected published data from 43 observers with a variety of telescopes, selected the “most difficult objects”, divided them into four groups based on the pairs’ magnitude differences, and reduced the number of stars in each group to about 5. He then deduced the following resolution limits in arc seconds for the four groups: Equal bright pairs (mean mags.5.7 & 6.4): 122/D. Equal faint pairs (means 8.5 & 9.1): 216/D. Unequal (means 6.2&9.5): 419/D. Very unequal (means 4.7 & 10.4): 914/D. (D in mm). Thus the resolution declines radically with the difference in magnitudes. For equal pairs the limit is very similar to Dawes, but for “very unequal” pairs it is more than 7 times greater.

Treanor (1946) used Lewis’ data to draw a continuous curve separating split and no-split regions as a function of magnitude difference. Others have followed. Perhaps the simplest graphical method is that developed by Harold Peterson in the 1950s (Mullaney, 2005), which defines by observation the splittable range for a given telescope in terms of the separation and the magnitude of the secondary (dimmer) star. Figure 4 shows a constant resolution of 3² until a secondary magnitude of about 9, below which resolution declines. Arguelles (see website reference) took this a step further, plotting resolution against the magnitude difference between primary and secondary and suggesting a range of uncertainty between resolved and unresolved (Figure 5). It is well known that larger apertures become seeing-limited rather than diffraction-limited and this leads to different resolution limits for different ranges of aperture, the smaller instruments sometimes having an advantage (Fisher, 2006).

Some authors have developed numerical algorithms to predict double star splits. Arguelles used fuzzy logic to define a “Difficulty Index” based on the difference in the component magnitudes and the

A Mathematical Model to Predict the Resolution of Double Stars by Amateurs and Their Telescopes

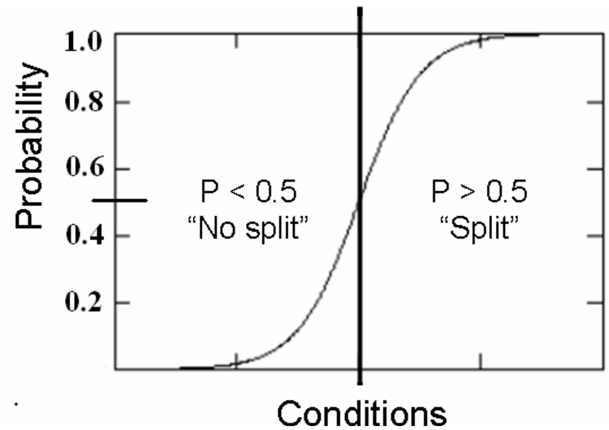


Figure 6: Probability distribution function

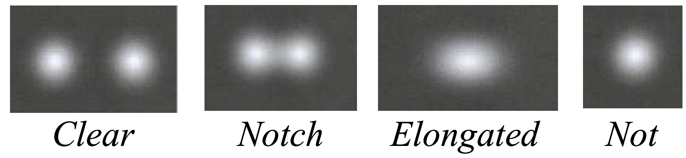


Figure 7: Definitions of separation

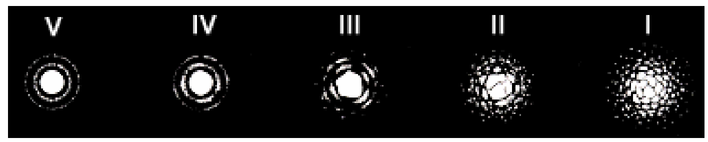


Figure 8: The Danjon scale for atmospheric turbulence.

separation, which is available in a downloadable program called LADIC (see web reference.), and is also estimated in the AstroPlanner program when listing double stars from catalogues. The number in brackets for each pair in Figure 5 is Arguelles' index. Barbour (web ref.) has put together an algorithm based on observations, which also attempts to show visually how the double will look in the eyepiece (though it is not described). Lord produced a mathematical analysis of the problem including a nomogram to help predict whether a given double can be split, based on aperture, obstruction (for reflectors), seeing and magnitude difference, though this is difficult to use (web ref.). Both Haas (2002) and Fisher (2006) have provided more accessible accounts of the use of the nomogram; Fisher also includes an on-line calculator. In a second paper, Lord (1979) provided another algorithm based on aperture and the contrast between primary and secondary.

All of these approaches are either simple criteria based on telescope aperture and observational data, or algorithms based on diffraction theory. They do provide useful benchmarks against which individual observations by amateurs can be judged. Arguably, however, none give an amateur the *probability* with which a pair of given separation and magnitudes can be split by amateurs and their telescopes on a night of given seeing. This is a statistical problem which can only be explored by an appropriate analysis of observational data collected by a group of observers that meets an arbitrary definition of "amateur", over a range of telescopes and conditions. The rest of this paper describes a project to collect and analyze just such an observational database.

The AAQ Model

The Project

Predicting whether a double is resolvable can be thought of in terms of a statistical probability, defined by a cumulative distribution function (Figure 6). A probability close to one indicates that the double is very likely to be splittable, and a probability close to zero suggests the reverse. Intermediate probabilities suggest a corresponding uncertainty (which reflects reality!). Statistical modeling can be used to estimate the probability function in terms of measurable factors such as telescope aperture, magnitudes and seeing, using a database of real observations.

The Astronomical Association of Queensland embarked on a project to collect the observational data needed to fit such a model. 15 observers using 25 different telescopes[1] observed 46 selected doubles over 10 months between February 2007 and January 2008. 315[2] valid observations were made in all. Observers were asked to inspect each pair with what they considered an appropriate magnification (they were encouraged to use higher magnifications than for regular observing). They reported the observation as one of four outcomes, illustrated in Figure 7. To reduce the outcomes to two possible conditions appro-

[1] The telescopes were: Newtonians – 2x508mm, 1x305mm, 3x254mm, 1x250mm, 1x203mm, 1x150mm. SCTs - 1x356mm, 1x235mm, 5x203mm. Refractors – 1x150mm, 2x128mm, 1x120mm, 4x80mm. Maksutov – 1x127mm.

[2] 334 observations were made originally, but 17 were "no-splits" of faint secondaries in small telescopes which were eliminated because the secondary was probably not observed due to its faintness in suburban skies rather than a real failure to resolve the pair. A further two observations were rejected as outliers in the development of the model.

priate for applying the binary modeling procedure, "clear" and "notch" were defined as a split, and the other two as no-split.

Observers were also asked to report the seeing in terms of the Danjon scale which assesses the quality of the observed diffraction pattern, 5 being good and 1 bad (Figure 8).

The distribution of observations across observer/telescope combinations is obviously important in determining the scope and robustness of the resulting model. An even distribution is desirable but practicalities precluded this. The number of observations per observer varied widely, but the most prolific observer/telescope combination contributed no more than 14% of the total.

The Model

The purpose of the model is to predict whether or not a given pair can be split by a given observer and telescope under the prevailing seeing. Binary logistic regression (BLR) using a logit link function was used to develop the model from the observational data. (The term "binary" here means that there are only two possible outcomes of any prediction: split vs no-split. In this application the term is a happy coincidence!). The usual statistical criteria were used to evaluate the validity and efficacy of the model. BLR estimates the coefficients in the term X in the equation for the probability of a split, P:

$$P = \frac{e^x}{1 + e^x} \tag{1}$$

which describes the curve in Figure 6. $0 < P < 1$, and x is a function of the observational variables such as the characteristics of the double, the telescope and the conditions. The variables available for inclusion in the model were: separation , magnitudes of the two components, telescope aperture and type, obstruction diameter (reflectors and compound telescopes), magnification used, age of observer (a possible proxy for visual acuity), and seeing expressed in terms of the Danjon scale (Figure 8). Information was also available on the altitude of the pair at the time of observation, and the presence (or otherwise) and phase of the moon, though this was not used in modeling.

Because of the complexity of the system being studied, single variables often have less influence on prediction than appropriate combinations of variables. Accordingly many models were explored comprising both single (uncombined) variables and plausible combinations of variables. Two observations (both involving the failure to split pairs with large apertures) were eliminated from the database as various models consistently showed them to be outliers, ie they behaved quite differently from the rest of the dataset. Eliminating them improved slightly the predictive power of the model. The best model obtained was as follows:

$$x = 1.6225 - 1.2026\frac{(M_2 - M_1)}{S} - 0.5765\frac{M_2}{S} + 1.9348\frac{A^2 Z}{10^5} \tag{2}$$

where M_1 = magnitude of primary, M_2 = magnitude of secondary, S = separation (arcseconds), A = telescope aperture (mm), and Z = seeing (Danjon scale, 1-5: see Figure 8).

Given the values of the variables, equation 2 is computed to give x which is then inserted into equation 1 to predict the probability with which the double can be split under those conditions. The model is easily implemented in a spreadsheet.

How good is the model ?

The simplest interpretation of the probability P is to assume that the pair can be split when $P>0.5$ and cannot be split when $P<0.5$. On this basis the model correctly predicts the outcome in 84.1% of the cases in the database used in its development, and fails in 15.9% of cases. This does not necessarily imply that the model is 84% accurate all the time. It will depend for example on the conditions. Very difficult and very easy splits are more likely to be correctly predicted than intermediate ones. A more sophisticated interpretation of P can be obtained by dividing the predictions into 3 equal ranges, for which low probabilities ($P<0.333$) are defined as no-split, high probabilities ($P>0.667$) defined as split, and intermediate values (around $P=0.5$) defined as uncertain. On this basis 60 of the predictions (19%) fall into the "uncertain" category, and of the remaining 255 observations, 91.0% are correctly predicted as split or no-split.

The success of the simple "split – no split" interpretation can be illustrated in the histograms shown in Figure 9.

In order to validate the model, four of the original observers made a further 55 observations of 10 new close pairs with 6 telescopes: 80mm and 150mm refractors, a 203mm SCT, a 203mm reflector, a 356mm SCT and a 508mm reflector. In choosing the validation pairs it was realised that it would be easy to give a false impression of model efficacy by choosing

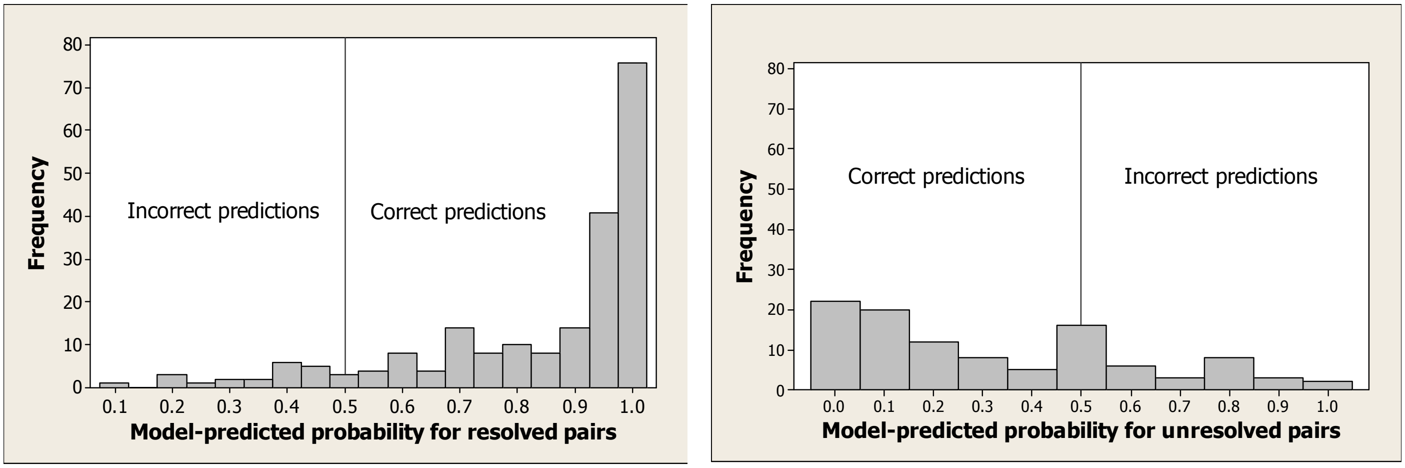


Figure 9: Distribution of correct and incorrect predictions for resolved and unresolved pairs

very wide and very close pairs because the model would nearly always correctly predict such splits. Accordingly the pairs were chosen to cover an intermediate range more difficult to predict. They varied in separation from 0.5" to 2.8" (with one pair at 5.3"), and magnitude differences from 0.8 to 3.7.

Based on the simple criterion of P > 0.5 indicating a split and P < 0.5 indicating no split, 47 of the 55 new observations were correctly predicted by the model, or 85.5%, almost exactly the same as the original database. Interestingly, 7 of the 8 mistakes had P-values in the "uncertain" regime ($0.333 > P > 0.667$), as one might expect. In addition, two of these were no-splits on nights of a bright moon which may have made the detection of the secondary more difficult. Taking just the more certain values, for which $P < 0.333$ or $P > 0.667$, raised the success rate to 97.8%, *i.e.* only one incorrect prediction in 45 observations. Interestingly this was a failure to resolve a 0.5" separation by the largest aperture (a 508 mm Newtonian); it will be recalled that the two outlier values in the original database, which were excluded during model development, were of a similar nature.

The model can therefore be accepted as useful. No model is perfect however. Imperfections are due both to inadequate model form and natural error or noise in the variables used to formulate the model. These may include the following:

- Several factors likely to influence prediction have not been included (yet) in the model, including reflector obstruction, observer experience and visual acuity, instrument type, and quality of optics. Reflector obstruction and observer age (as a possible proxy for visual acuity) were tried as variables in the model but were found to be not statistically significant. These factors need further investigation. As noted above, the moon may have interfered with the detection of faint secondaries.
- Larger telescopes are generally seeing-limited and smaller instruments diffraction-limited. This is not explicitly allowed for in the model.
- Observers themselves may have made observational errors such as incorrectly assigning the split/no-split, using inadequate magnification, incorrect estimate of seeing (which is somewhat subjective), and possible misidentification of the pair.
- The magnitudes and separations of the test pairs were taken from the WDS database. As far as possible pairs were chosen which had been recently observed and/or for which there was some evidence that changes in separation were slow. However it is possible that there are errors in these values, either due to real changes since the last observation, or mistakes.
- Assuming a large enough magnification is used (within the limits of the available focal length) then magnification should play no role *per se* in whether a double is split or not. However it is a complex issue as there was no consistent protocol in choosing magnification, other than an exhortation to user higher values than usual, so some no-splits may be due to inadequate magni-

A Mathematical Model to Predict the Resolution of Double Stars by Amateurs and Their Telescopes

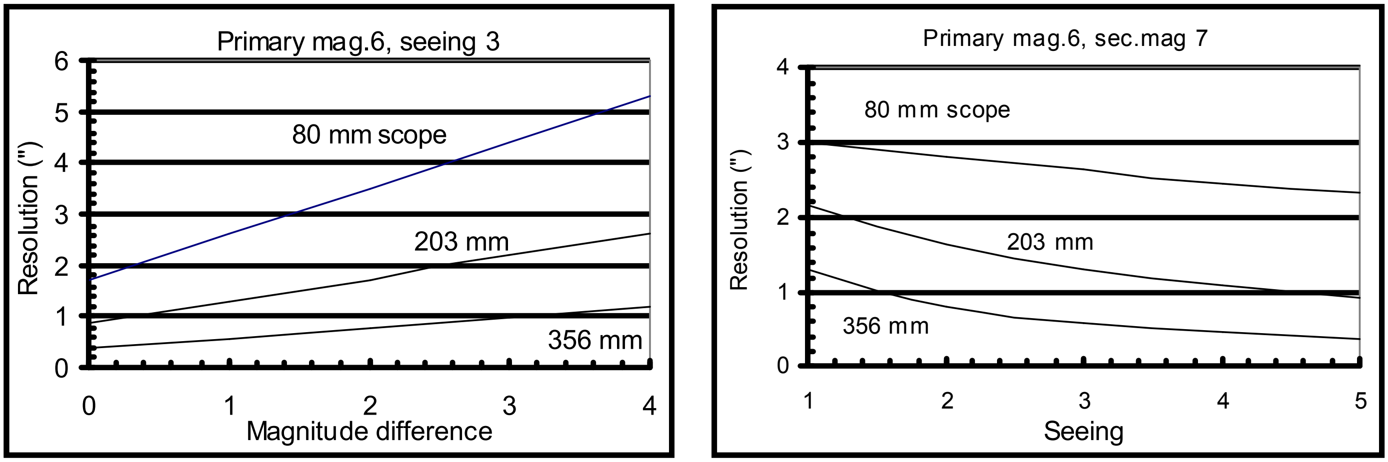


Figure 10: Effects of magnitude difference (left) and seeing (right) on 3 telescope apertures

fication rather than other issues. In fact a negative *magnification x separation* term was found to be statistically significant in the model, though was not included for practical reasons.

Using the model

The model is intended mainly to provide amateur observers with an indication of how likely they are to be able to split a given pair on a night of given seeing with a telescope of particular aperture. This then provides a baseline for testing both their optics and their own skills. However the model also shows quantitatively how the magnitudes, aperture and seeing interact, and the scale of their effects, which may be helpful in future analyses of the problem of resolution.

Figure 10 shows the effects of telescope aperture, magnitude difference and seeing predicted by the model. It is clear that the effects are strong. Interestingly the change ratio (largest/smallest resolution) is similar for the three telescopes in the effect of magnitude difference, but is much greater for larger than smaller telescopes in the effect of seeing, as we might expect.

The model can also be used to calculate the separation having a 50:50 chance of being split ($P = 0.5$) for a particular telescope and seeing. This value can be interpreted as the resolution limit under those conditions and can therefore be compared to other published limits such as Dawes'. Table 1 shows the prediction of the model for a pair of 6th magnitude stars and seeing 4 for five typical telescope apertures (3, 5, 8, 10 and 14 inches), compared with the corresponding predictions of the Dawes and Rayleigh Limits (which depend only on aperture). The Dawes and Rayleigh "factors" are the ratios of the AAQ predictions to the Dawes and Rayleigh Limits respectively.

From 80 to 254 mm the AAQ prediction is similar to the Rayleigh Limit and thus about 20% higher than the Dawes Limit. For the 356 mm (14") telescope however the AAQ model predicts a limiting resolution

'Scope aperture (mm)	AAQ predicted resolution (")	Dawes Limit		Rayleigh Limit	
		Arcseconds	Factor	Arcseconds	Factor
80	1.63	1.45	1.12	1.73	0.94
125	1.22	0.93	1.32	1.10	1.11
203	0.72	0.57	1.25	0.68	1.05
254	0.52	0.46	1.14	0.54	0.96
356	0.30	0.33	0.92	0.39	0.77

Table 1: Resolution Limits: AAQ (seeing 4), Dawes, Rayleigh

less than both the Dawes and Rayleigh Limits. This is outside the range of separations in the database (the smallest was 0.5") and is likely to be optimistic. However it is interesting to note that the model predicts strong effects of seeing in the larger apertures (Figure 10); for the 356 mm aperture the predicted resolution declines from 0.25" at a seeing of 5 to 0.85" at a seeing of 1. At an "average" seeing of 3, the predicted resolution is 0.39", exactly the same as the Rayleigh Limit.

The model predictions have also been compared with the Lewis limits for "unequal" and "very unequal" pairs. With the exception of the 356 mm aperture, which is again probably over-optimistic, the model predictions for the unequal pairs are about the same as Lewis' Limit. For the very unequal pairs however the model predicts a better resolution limit than Lewis. This may be due to the relative lack of close pairs of this extreme characteristic included in the AAQ database, and the model should therefore probably not be used to predict separation for close pairs with a magnitude difference greater than about 4.5. This could be remedied with further observations.

Future Work

The following enhancements to the model are worth considering:

1. More analysis could be done of the effects of magnification, obstruction and observer acuity, optics design, and the characteristics of the incorrect predictions.
2. Different models could be tried for different ranges of telescope aperture to account for the contrast between diffraction-limited and seeing-limited observations.
3. Ordinal logistic regression could be used to incorporate all four of the outcomes illustrated in Figure 7, rather than just two.

Statistical models of this kind always benefit from more data. A particular need is for records of non-splits, which are less well represented in the database and less well predicted by the model (Figure 9). If any reader would like to contribute observations, full details of how to do so with lists of the test doubles (many of which are southern pairs) can be found at the AAQ website at http://www.aaq.org.au/; follow the links to Sections > Double Stars > AAQ Resolution Survey.

Acknowledgements

This project would not have been possible without the dedicated band of AAQ observers who provided the data over a period of a year. Many thanks to Dave Allan, Roy Axelsen, Geoff Biggs, Jonathan Bradshaw, Rodney Burgess, Cheryl Capra, Allan Cooney, Peter Culshaw, Tony Dutton, Graeme Jenkinson, Steve Kerr, Max Kilmister, Bill Oliver, and John Salini. Des Janke and Tony Dutton assisted in placing material relating to the project on the AAQ website.

References

Arguelles, L. http://www.carbonar.es/s33/Fuzzy-splitting/Fuzzy-Splitting.pdf

Argyle, Bob, 2004. Observing and measuring visual double stars. Springer

Barbour, J. http://earth.ihwy.com/~barbour/jeff/software/c++/dblCalc.html

Dawes WR, 1867. Introduction to catalogue of micrometrical measurements of double stars. Monthly Notices of the Royal Astronomical Society, Vol. 27, pp. 217-238

Fisher KA, 2006. Rules-of-thumb for splitting double stars with Peterson and Lord algorithm split calculators. http://members.csolutions.net/fisherka/astronote/astromath/ueb/Unequalbinaries.html

Haas, Sissy, 2002. Enjoying unequal double stars. Sky and Telescope, January, pp 118-121.

Lewis T, 1914. On the class of double stars which can be observed with refractors of various apertures. The Observatory, No.37, pp. 372-379.

Lord CJR, 1979. Contrast and definition. http://www.brayebrookobservatory.org/BrayObsWebSite/HOMEPAGE/BRAYOBS %20PUBLICATIONS.html

Lord CJR. A report upon the analysis of the telescopic resolution of double stars of unequal brightness. http://www.brayebrookobservatory.org/BrayObsWebSite/HOMEPAGE/BRAYOBS %20PUBLICATIONS.html

Mullaney, James, 2005. Double and multiple stars. Springer.

Treanor SJ, 1946. On the telescopic resolution of unequal binaries. The Observatory, No. 831, pp. 255-258.

HJ 1853: Old Companion Lost, New Companion Found

Rafael Caballero

Agrupación Astronómica Complutense
Alcala de Henares
Madrid, Spain

Email: rafa@sip.ucm.es

Abstract: The double star HJ 1853 is a neglected double with only one measurement dated in 1905. The large proper motion of the A component allows checking that the pair registered in 1905 was optical. However, inspection of the photographic plates shows a new component which could constitute a physical pair with the A component of the old pair.

A Missing Old Companion

Located in Andromeda, the double star HJ 1853 should be an easy target for small telescopes: according to the *Washington Double Star Catalog* (WDS, Mason *et al.* 2003) it consists of two components of magnitudes 7 and 7.7 separated by 33".2. However, pointing the telescope to the corresponding coordinates (23108 +4531) shows only a seventh magnitude star, with no noticeable companion nearby. Checking the WDS again, we find that this is a pair with only one recorded measure in 1905. The plates of the 2MASS, POSSI and POSSII surveys confirm that the A star is surrounded only by a few faint stars (magnitude 12 and below). As an example, Figure 1 shows the corresponding J plate of the 2MASS survey.

Finding a missing component in the WDS is not always easy, but in this case the catalog provides additional information suggesting a solution: the proper motion of the A component is quite large (-81 mas in RA, -285 mas in DEC), and this could mean that the B component registered originally was an optical companion which is now far away.

Mystery (almost) Solved

Tracing back the position of the star to the year 1905, leads us to an area where, again, there is no star of magnitude 7.7. At this point I asked for help in the binary-stars-uncensored Yahoo group and W.I. Hartkopf kindly browsed the WDS data and found that the 1905 measurement was obtained by S.W. Burnham. The original observations from J. F. W. Herschel were dated in 1828 with PA 265.4º, sep. 15", and mags. 8-9 and 12.

The position of the A star in 1828 was such that there was a 12 magnitude star roughly at the position angle and separation recorded by Herschel. This star is now at PA 325.0 deg., sep. 40".14, mags. 7.07 and 12.3 (see Figure 1). The very small proper motion of the B component implies that it was an optical pair.

Burnham observed the star 77 years after Herschel and, due to the effect of the large proper motion, could not find the companion. Although he suspected that the Herschel measurement corresponded to the A and B star indicated above, he also thought that the double star could be another nearby pair (later designated BU 1528), and the data of this pair (PA: 191 deg, sep: 33".2) ended up as the WDS record for HJ 1835 (Hartkopf, 2008).

This explains most of the story, although some details are not completely clear, as the origin of the magnitude attributed to the B component, 7.7, which is mentioned neither by Herschel nor by Burnham.

The New Companion

Using the RGB facility of Aladin (Bonnarel, 2000) for color composition, I observed the large proper motion of the A star combining the plate of the POSSI

HJ 1853: Old Companion Lost, New Companion Found

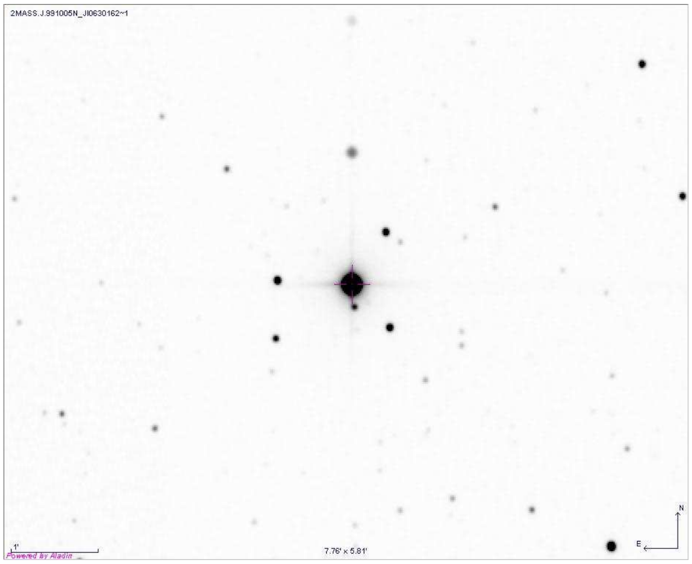


Figure 1: Photographic J plate of HJ 1853 from the 2MASS survey with zoom 2x in Aladin. The A component is the brightest star. The star pointed by the arrow corresponds to the B component observed by Herschel.

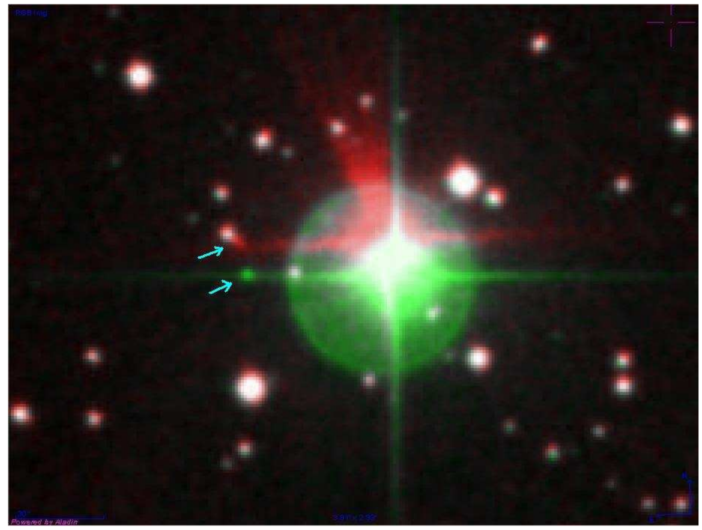


Figure 2: Color composition in Aladin of two plates from 1953 (red) and 1993 (green). Zoom 4x. The positions of the new component C are pointed by arrows.

survey (year 1953) in the red channel and one of the plates of the POSSII survey (year 1993) in the green channel. The result can be seen in Figure 2. The stars with small proper motion appear almost white, while the large proper motion stars as HJ 1853 A show two different images, one in red and another one in green.

Apart from the movement of the A component, the image shows that another star seems to be moving at the same pace as A. It is a new component not known before, which will be denoted by C in the rest of this paper. A rough measurement using the dist feature of Aladin shows that the C component is at about 90 degrees and about 50” from the primary.

Table 1 shows the proper motion data for both stars at the USNO-B1.0 catalog (Monet et al., 2003). The numbers after the ± symbol represent the mean error of the measure. Using these data we can check the Halbwachs (Halbwachs, 1983) selection criteria for distinguishing physical and optical pairs from its proper motion:

(1) $(\mu 1 - \mu 2)\ 2 < -2\ (\sigma 12 + \sigma 22)\ \ln(0.05)$

(2) $\mu \geq 50\text{x}10\text{-}3$ “/yr

(3) (3) $\rho/\mu < 1000$ yr

With $\mu 1$, $\mu 2$ the two proper motion vectors, σi, the mean error of the projections on the coordinate axes of μi, μ the smaller proper motion vector module between $\mu 1$ and $\mu 2$, and ρ the angular separation of the two stars. In the A-C system the three criteria hold, indicating that the two stars are probably physically attached.

USNO-B1.0	HJ 1853 A	HJ 1853 C
Id.	1355-0521782	1355-0521821
Epoch	2000.0	1992.3
pm RA	-86 ± 0	-50 ± 14
pm DE	-288 ± 0	-322 ± 75

Table 1: Proper motion data for HJ 1853 A-C

Old and New Measurements of the HJ 1853 A-C System

In order to obtain more precise data for the separation and position angle, it is convenient to look for the coordinates of both components in the available catalogs and also to obtain new images if possible. Unfortunately, the C component is not in the UCAC2 catalog (Zacharias *et al.*, 2004), and the data for the two stars in the other catalogs such as the USNO-B1 correspond to different epochs. An exception is the 2MASS catalog, where both stars can be found with measurements corresponding to the same date (1999-10-05). The first row of Table 2 show the data obtained from the coordinates in this catalog.

This measurement was complemented by images taken by the author on July, 3, 6, and 7, 2008. The reduction phase relied on the program Astrometrica (Raab, 2008) using the catalog UCAC-2, following the

HJ 1853: Old Companion Lost, New Companion Found

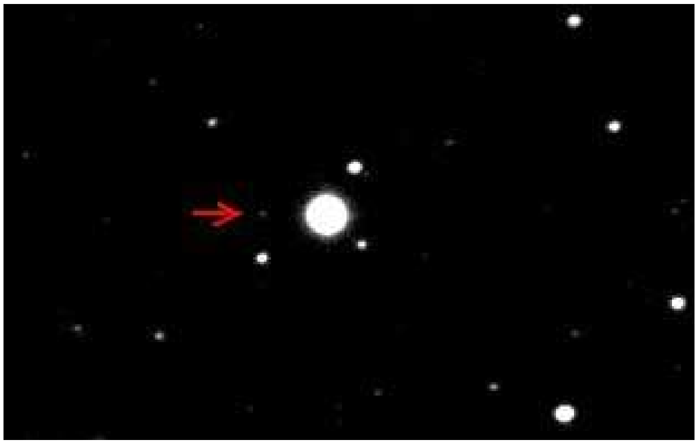


Figure 3: Image of the AC system with a DSIPro camera in a 4" refractor. The C component is pointed by an arrow.

next procedure:

- First every individual image was reduced using Astrometrica.
- All the images with residuals greater than 0.11" (either in Dec or in RA) were discarded.
- The rest of the images were stacked and reduced by Astrometrica to obtain the data.

The values of the second row of Table 2 show the result. However it must be mentioned that these results are unusually imprecise, with a standard deviation of 0.22 in the separation and of 0.37 in the PA w.r.t. the set of individual images. These deviations are the result of the large difference in stellar magnitude of the two components which can be observed in the image of Figure 3. In particular, the component C is too faint and this makes the reduction less reliable, while the relatively bright primary appears overexposed, which makes calculating the centroid an imprecise task.

Therefore, more reliable measurements of this pair would be useful, perhaps following specific techniques for high delta m doubles such as those described in (Daley, 2007). Also the photometry of C in Table 2 must be considered preliminary since C's visual magnitude cannot be found in the catalogs, and no V filter was used in the author's images. In order to improve the photometry, the images were calibrated with respect to other stars with known visual magnitude. After the calibration a test over another ten stars in the image with similar characteristics (visual mag. between 13 and 16, blue mag.- red mag. > 0) presented a maximum absolute error of 0.4 mags.

Physical Characteristics of the AC System

The A component has a mass of 0.9 solar masses (Allende Prieto, 1999) and with a MK spectral type of G8 V (Gray *et al.*, 2003). Located at only 23.45 parsecs (76.5 light years) from the Sun, it is in the *25pc sample of sun-like stars* catalog (Grether, 2006), but without indicating any known companion, confirming that C had not been noticed up to now. If we assume that C is also at 23.45 parsecs we have that both stars are separated by at least about 1172 AU, and hence probably the pair has a very long period. Finally, combining the distance d=23.45 with the estimated apparent magnitude m=15.25 by means of the formula $M = m + 5 - 5\ Log\ d$, an absolute magnitude M for C of approximately 13.40 is obtained. This visual magnitude corresponds in the HR-diagram either to a white or to a red dwarf, but the B, R magnitudes in the NOMAD catalog are 17.52 and 13.86 respectively and the strong predominance of the red magnitude indicates that C is likely a red dwarf.

Conclusions

The main contribution of this paper is the (serendipitous) discovery of a new possibly physical

Name	RA+DEC	Mags	PA	Sep	Date	N	Notes
HJ1853AC	23108+4531	7.00	87.03	50.31	1999.760	-	1
HJ1853AC	23108+4531	7.00, 15.25	86.82	49.79	2008.506	3	2

Table 2: Measures of the HJ 1853 A-C pair

Table Notes

1. Note 1: Obtained from the coordinates in the 2MASS catalog.
2. Note 2: Images taken with a DSI Pro camera and a refractor ED 100mm/900mm.

HJ 1853: Old Companion Lost, New Companion Found

binary star formed by HJ 1853 A and a new component C. Some initial measurements of the pair are given, although the high magnitude difference influences the reliability of the author's measurements. From an amateur point of view this paper shows that even novice observers with modest equipment can obtain some results in this field, in particular thanks to the impressive set of resources (catalogs, plates) available on the internet.

Acknowledgements

My thanks to Dr. William I. Hartkopf, U. S. Naval Observatory, who taught me the basics of chasing missing doubles in the catalogs, and to Francisco Rica for his invaluable help. In this research I made use of the ALADIN Interactive Sky Atlas and of the VizieR database of astronomical catalogs, all maintained at the Centre de Données Astronomiques, Strasbourg, France. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

References

Allende Prieto, C; Dambert D.L. 1999, "Fundamental parameters of stars". VizieR on-line data catalog

Bonnarel, F et al., 2000, "The ALADIN interactive sky atlas. A reference tool for identification of astronomical sources", Astron. Astrophys., Suppl. Ser., 143, 33-40.

Daley, J. A., 2007. "A Method of Measuring High Delta m Doubles". Journal of Double Star Observations 3(4), 159-164.

Gray R.O. et al. 2003, "Contributions to the Nearby Stars (NSTARS) Project: Spectroscopy of Stars Earlier than M0 within 40 parsecs". The Astronomical Journal 126, 2048-2059.

Grether D; Lineweaver C.H. 2006. "25pc sample of Sun-like stars". VizieR on-line data catalog.

Halbwachs J.L., 1986, "Common proper motion stars in the AGK3". Bull. Inf. Centre Donnees Stellaires, Vol. 30, p.129.

Hartkopf, W.I., 2008, personal communication on Binary Stars Uncensored Yahoo group.

Mason B. D.; Wycoff, G., Hartkopf, W. I. 2003, "The Washington Double Star Catalog", http://ad.usno.navy.mil/proj/WDS/wds.html

Monet D. et al. 2003, "The USNO B Catalog". The Astronomical Journal 125, 984-993

Raab H, Astrometrica, 2008, software available at http://www.astrometrica.at/

Zacharias N. et al.. 2004, The Second US Naval Observatory CCD Astrograph Catalog (UCAC2). The Astronomical Journal 127, 3043-3059.

When he was a child, Mr. Caballero wanted to be an astronomer. However, his parents thought that computers were more useful for his future so, instead of a telescope, he got a computer for Christmas. Now he works in the field of computer science during the day, but still dreams of being an astronomer while watching the stars at night.

Measurements of 16th Hour Northern Neglected Double Stars

Gary A. Vander Haagen

Stonegate Observatory
Ann Arbor, Michigan 48103

Email: garyvh2@att.net

Abstract: CCD images were taken of 16 neglected double stars from the United States Naval Observatory (USNO) northern list of neglected double stars. The star group's positional data were all measured using the software measurement utility, MPO Canopus. All CCD images were made at Stonegate Observatory Ann Arbor, Michigan, June 20, 2008 at 42:17:48N and 83:50:14W.

Introduction

The double stars were selected from the Washington Double Star (WDS) catalog listing of neglected double stars [1]. Stars were all chosen for low air mass positions during the early morning measurement period. All data were collected using a 14 inch, f/6.6 Schmidt-Cassegrain telescope mounted on a Software Bisque Paramount and imaged using a ST-10XME SBIG CCD camera. A minimum of four 30 second exposures were made of each star group.

Method

The resulting CCD images were processed and star positions measured using MPO Canopus Double Star Utility [2]. The software utility plate solved each image and determined the scale and coordinates of key stars. The primary and secondary stars were identified on each image and the position angle and separation determined. Canopus is capable of photometric reductions but all images were made with a clear filter only and are recorded as instrumental magnitudes. The position angle (PA) and separation measurements (SEP) were averaged and are shown in Table 1.

Conclusions

All data trends closely correlate with previous data collected with exception of KZA 116 taken in 1984. These data show significant change with PA increasing from 212 to 292.6 or 80.6 degrees. Considering a possible charting error, the primary and secondary positions were exchanged yielding a PA = 111.5 degrees which is 100.5 degrees decrease from 1984, an even greater movement. No explanation is apparent other than the system is fast moving or measurement errors. This system represents a good short term target to verify potential PA rotation at 17 seconds per month.

References

1. Mason, Brian D. et al, US Naval Observatory, Neglected Northern Doubles List, Set III. http://ad.usno.navy.mil/wds/NEGLECTED/neglectednorth3.html
2. Warner, B.D. (2007). MPO Software, Canopus version 9.4.0.3, Bdw Publishing, http://minorplanetobserver.com/

Table on next page.

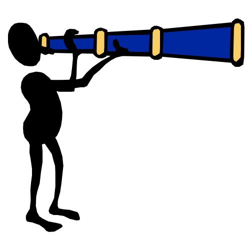
Measurements of 16th Hour Northern Neglected Double Stars

WDS Name	RA+DEC	MAGS	PA	SEP	DATE	N	NOTES
ES 1089AB	1646.6+4759	10.2, 10.3	150.4	11.00	2008.467	4	1
ES 1089AC	1646.6+4759	10.2, 11.7	29.5	32.48	2008.467	4	2
KZA 111	1644.3+4550	11.7, 12.8	92.5	12.51	2008.467	4	3
KZA 112	1646.8+4527	10.5, 12.9	350.6	38.16	2008.467	5	4
KZA 113	1647.4+4637	12.8, 13.2	157.0	21.36	2008.467	5	5
KZA 114AB	1647.7+4615	12.4, 13.4	247.2	37.62	2008.467	8	6
KZA 114AC	1647.7+4615	12.4, 13.9	239.5	60.58	2008.467	4	6
KZA 114AD	1647.6+4615	12.4, 12.3	212.4	68.57	2008.467	4	7
KZA 114AE	1647.6+4615	12.4, 12.9	228.7	80.75	2008.467	5	6
KZA 115	1649.2+4544	11.6, 12.5	287.7	30.85	2008.467	5	4
KZA 116	1649.5+4620	13.0, 13.0	292.6	13.13	2008.467	3	8
KZA 117	1650.9+4601	12.8, 13.0	325.4	7.93	2008.467	5	9
KZA 120	1653.4+4602	12.6, 12.5	79.1	10.73	2008.467	5	4
KZA 121AB	1654.7+4518	10.9, 11.3	181.7	43.03	2008.467	4	10
KZA 121AC	1654.7+4518	10.9, 12.2	251.1	50.25	2008.467	5	4
KZA 121AD	1654.7+4518	10.9, 12.2	220.8	109.42	2008.467	4	11

Table 1: Measurement data of the 16th hour neglected double stars. All magnitudes are instrumental.

Table Notes:

1. Consistent change with 1911/1983 data of PA = 141, 148 and SEP = 2, 8. PA increased 2.4 degrees, SEP increased 3 seconds.
2. No change from 1911/1911 data of PA = 30, 30 and SEP = 32.6, 32.6.
3. Previous data 1983/84; PA increased 2 degrees from average.
4. Data consistent with 1983/84.
5. Previous data 1983/84; PA decreased 1 degree.
6. Correlates with 1983/84 data.
7. Previous data 1983/84; PA decreased 0.6 degrees.
8. Significant change from 1984; PA increased 80.6 degrees, SEP increased 2.6 seconds.
9. Previous data 1984; PA increased 5.4 degrees.
10. Data consistent with 1892/1998.
11. Data consistent with 1984.



Observation Report 2006 Humacao University Observatory

R. J. Muller, J.C. Cersosimo, V. Miranda, C. Martinez, D. Centeno, L. Rivera, E. Franco, K. Ramos, K. Morales

Humacao University Observatory
Department of Physics and Electronics
The University of Puerto Rico at Humacao
College Station, Humacao, Puerto Rico 00791

E-mail: rjmullerporrata@gmail.com

Abstract: Measurement of position angle and separation of 98 binary pairs are reported. The data was obtained using the NURO Telescope at the Anderson Mesa location of Lowell Observatory near Flagstaff, Arizona on May and August 2006. We gathered the data using the new 2K x 2K CCD camera,-NASACAM,- at the prime focus of the 31 inch telescope. The data was transferred and analyzed at the Humacao University Observatory by undergraduate students undertaking research projects.

Introduction

We report measurement of separation and position angle of binary stars gathered from CCD images obtained with the new NASA CAM CCD at the prime focus of the National Undergraduate Research Observatory (NURO) telescope. The Humacao Campus of the University of Puerto Rico is a member of NURO, a consortium of primarily undergraduate institutions (www.nuro.nau.edu) with access to a 31 inch telescope, property of Lowell Observatory. It is located roughly 20 miles east of Flagstaff, Arizona at Anderson Mesa, at an altitude of 7200 feet. We use the NURO telescope twice a year, usually during late spring and early fall.

The data presented in this report was acquired on two trips on 2006, May 27 to 29 and August 14 to 16. We were rained out August 14 and 15; all the data was acquired the 16.

The NASA cam is a 2K x 2K CCD camera with 15 micron pixels. The new camera does not need liquid nitrogen to cool down to -100, saving us a lot of time in the camera-telescope setup. The field of view of the old camera was 4 arc minutes by 4 arc minutes. The field of view of the new camera is 16 arc minutes by 16 arc minutes.

However, an optical reducer with ratio 2:1 lies in the optical path, so the separation of binaries in the images looks almost the same as before, in a much wider field.

Procedure

As in past reports, the CCD images where analyzed by students with undergraduate research projects at our department. The students used the pixelization of the CCD images to obtain the separation and position angle (Muller et al, 2003). Then the CCD images where analyzed a second time using the software Astronomical Image Processing for Windows (Berry et al, 2002). Since the software does not provide for introducing your telescope's plate scale in the computations you have to make your final number crunching with a hand calculator. The software in the program is also mirror reversed as far as position angle is concerned, so you must be very careful when you figure the correct angle from the one given by the software.

The design value for the plate scale with the new NASA CAM is .515 arc seconds/pixel. We used 22 binaries with very long periods to obtain an experimental value for the plate scale. With this small sample it came to be .524 ± .009, in close agreement

Observation Report 2006 Humacao University Observatory

with the design value. We will use our value when calculating the separation of binaries.

There is a systematic error in position angle that occurs when the CCD camera is inserted into the telescope. This error can be corrected by using well known binary systems and binary systems that "don't move". Binary systems that "don't move" can be found in the neglected section of the Washington Double Star catalog, as binary stars that have been measured for the last 100 years and show no change in position angle. By imaging a mix of well known binaries and fixed binaries (we use around 20 of them total) and comparing the value of position angle given in the WDS with the value obtained from our images, the systematic error in the position angle can be corrected. We call such error the offset error and is incorporated in the position angle values given in the accompanying table.

Data

The tables, with 98 entries, display first the WDS name of the pair, then the coordinates from the WDS in the second column (both RA and Dec). After that, the tables present the visual magnitudes for the primary and the secondary. These magnitude values are obtained from the WDS. Next we display our measurement of position angle (PA) and also display the measured separation. Finally, in the NOTE column the number of images of each binary obtained in that particular night. We must stress that although sometimes more than one image was obtained of a binary in a particular night, in the analysis and calculations of PA and separation only one image was used in all cases. Table I displays the data acquired in May. Table II presents the data obtained in August.

We have gathered data for many of these binaries in 2003, 2004 and 2005 (Muller et al, 2007) and we plan to analyze and compare the data obtained to eliminate spurious results.

Acknowledgements:

This research has made extensive use of the Washington Double Star Catalog maintained at the U. S. Naval Observatory and of the NURO telescope property of the Lowell Observatory.

We would like to acknowledge support from the Puerto Rico Space Grant Consortium. We would also like to acknowledge support from the M.A.R.C. Program at the Humacao Campus of the University of Puerto Rico. We also thank Ed Anderson of NURO for his efforts on behalf of our students.

References

Muller, Rafael, *et al.*, 2003, The Double Star Observer, **9**, 4-16.

Muller, Rafael, *et al.,* 2007, Journal of Double Stars Observations, **3**, 11-16.

The Handbook of Astronomical Image Processing, R. Berry, J. Burnell, Willmann-Bell Inc., Virginia 2002.

NAME	RA	DEC	MAGS	PA	SEP	DATE	NOTE
HJ 816	09 34 25.6	+10 09 05	10.3 12.5	19	17.0	2006.405	1
AG 342	10 59 38.31	+2526 15.4	8.57 9.22	110	5.2	2006.408	1
HJ 2553	11 02 11.1	+07 24 59	10.6 12.78	267.8	16.5	2006.408	1
BAL1443	11 08 30.9	+01 17 44	10.8 11	175.8	6.5	2006.408	1
STT 231AB	11 11 01.87	+3026 44.4	10.9 9.12	262.8	35.3	2006.405	1
STI 738	12 03 17.7	+59 24 05	10.1 11	38	7.1	2006.405	1
HJ 2605	12 15 04.4	+55 00 55	10.8 11.8	320	18.0	2006.405	1
STF1622	12 16 07.5	+40 39 36	5.8 8.71	260	11.7	2006.408	1
STF1636 17 Vir	12 22 32.1	+05 18 20	6.5 10.48	337	21.2	2006.408	1
KZA 36AC	12 28 57.5	+37 35 41	8.9 10.5	327	87.9	2006.405	1

Table 1: Double star measurements acquired in May 2006.

Table 1 continued on next page.

Observation Report 2006 Humacao University Observatory

NAME	RA	DEC	MAGS	PA	SEP	DATE	NOTE
SHJ 145 δ Crv	12 29 54	+16 30 54	2.95 8.47	216	24.7	2006.408	1
STF1657	12 35 07.7	+18 22 37	5.11 6.33	270	20.5	2006.405	1
STF1673AB	12 42 56.1	-02 15 04	9.09 10.6	92	51.9	2006.408	1
STF1744AB ζ UMa	13 23 55.4	+54 55 31	2.23 3.88	153	14.5	2006.408	1
BAL 552	13 52 36	-02 12	11.2 11.2	94	17.0	2006.408	1
SKI 15AC	13 52 37.3	-16 10 13	8.8 -	266	16.1	2006.408	1
KU 47AE	13 54 00.4	+32 09 04	10.7 -	321	29.0	2006.408	1
HJ 4637	13 57 10.7	-12 32 47	9.8 10.5	137	13.2	2006.408	1
LDS4421	13 57 32	-09 17 18	13.1 13.69	15	46.8	2006.408	1
LDS 951	13 57 37	+17 41 18	13.5 14.7	269	20.3	2006.408	1
COU 59AB	14 00 42.18	+1753 55.2	9.9 12.2	172	8.5	2006.402	2
				167	8.0	2006.408	
ARA 74	14 01 26.4	-16 36 00	13.3 13.3	15	13.6	2006.402	1
LDS1402	14 02 27.1	+15 20 33	15.1 15.5	314	7.1	2006.402	1
ARA 695	14 03 29.2	-19 32 20	12.6 12.9	60	8.1	2006.402	2
				59	7.4	2006.408	
BAL1169	14 08 19.3	-00 11 19	10.9 11.3	297	14.8	2006.402	1
ARA 231	14 10 28.7	-18 10 11	12.9 13.6	243	6.6	2006.402	1
HJ 542	14 12 21.2	+36 46 12	12 12	68	12.7	2006.402	2
				68	12.3	2006.408	
POU3162	14 13 23.9	+24 24 12	11 12.8	347	7.0	2006.402	1
STF1821 κ Boo	14 13 27.7	+51 47 16	4.53 6.62	237	13.7	2006.402	1
LDS 953	14 13 29.8	+21 37 39	13.7 15.2	173	11.0	2006.402	2
				172.5	10.8	2006.408	
LDS 954	14 15 11	+22 15 54	11.4 12.49	191	26.6	2006.402	2
				198	21.8	2006.408	
STFA 26AB ι Boo	14 16 10	+51 22 01	4.76 7.39	34	40.4	2006.402	2
				35	38.8	2006.408	
ES 1085	14 16 30.2	+46 33 09	8.8 11.8	177	6.1	2006.402	1

Table 1 continued on next page.

Observation Report 2006 Humacao University Observatory

NAME	RA	DEC	MAGS	PA	SEP	DATE	NOTE
BU 1442AC	14 25 43.48	+23 37 01.5	9.87 9.66	75	81.8	2006.402	1
POU3176	14 52 43.4	+23 53 47	11.4 13.0	1	7.5	2006.402	1
BAL1175	15 00 23.7	+00 06 44	10.8 11.2	198	14.9	2006.402	1
STFA 27 δ Boo	15 15 30.1	+33 18 54	3.56 7.89	78	108.4	2006.402	1
KZA 80	15 20 42	+31 33 15	9.5 10.0	54	26.1	2006.402	1
HJ 2777	15 22 25.3	+25 37 27	7.5 10.4	343	42.6	2006.402	1
STFA 28a-BC μ Boo	15 24 48.6	+29 34 28	4.33 7.09	170	109.0	2006.402	1

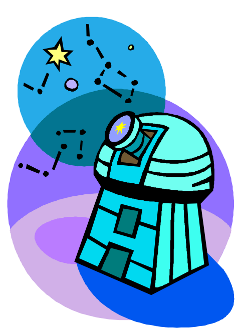
NAME	RA	DEC	MAGS	PA	SEP	DATE	NOTE
AG 348	16 00 11.9	+14 11 12	9.5 10.0	170	41.7	2006.624	1
HJ 1284	16 00 36	-00 30	10 14	184	22.7	2006.624	1
ARA 243	16 01 04.1	-17 40 59	13.1 13.3	297	13.4	2006.624	1
HJ 580	16 02 50.6	+37 05 27	9.2 12.2	7	41.3	2006.624	1
STF1999AB Struve (1999)	16 04 25.9	-11 26 57	7.52 8.05	97	12.1	2006.624	1
ARA 433	16 06 35.8	-18 19 11	11.6 14.1	54	10.9	2006.624	1
HJ 582	16 07 06	+35 07	9.7 12.0	232	22.7	2006.624	1
ALI 370	16 07 26.8	+35 48 29	13.7 14.1	147	13.0	2006.624	1
POU3214	16 07 48.8	+23 05 29	11.1 13.3	82	12.3	2006.624	1
STF2010AB κ Her	16 08 04.5	+17 02 49	5.10 6.21	14	27.7	2006.624	1
H 5 6Aa-C ν Sco	16 11 59.7	-19 27 38	4.21 6.60	335	41.7	2006.624	1
HJ 1288	16 12 40.8	-16 45 18	11.0 12.3	120	19.0	2006.624	1
ES 627	16 18 35.7	+51 19 51	9.6 10.8	288	12.2	2006.624	1
GRV 940	16 51 36.98	+00 28 41.9	9.29 10.69	341	46.1	2006.624	1
BAL2429	16 54 51.2	+03 18 41	10.5 11.5	52	11.8	2006.624	1
SLE 76	17 00 15.7	+33 12 20	14.3 15.0	14	8.6	2006.624	1
ES 1255	17 01 00.5	+46 16 27	8.0 11.7	48	7.8	2006.624	1
BU 1088AC	17 05 20.3	+54 28 15	5.8 13.7	175	12.6	2006.624	1

Table 2: Double star measurements acquired in August 2006.

Table 2 continued on next page.

Observation Report 2006 Humacao University Observatory

NAME	RA	DEC	MAGS	PA	SEP	DATE	NOTE
WFC 186	17 06 05.5	+43 28 56	11.4 13.0	15	18.0	2006.624	1
PTT 16	17 06 42	+38 39	8.8 13.0	52	22.6	2006.624	1
STFA 35 ν Dra	17 32 15.8	+55 10 22	4.87 4.90	311	63.5	2006.624	1
STF2214AB	17 43 20.8	+43 44 52	9.61 10.15	211	18.8	2006.624	1
STF2293	18 09 53.8	+48 24 05	8.08 10.34	83	13.2	2006.624	1
SLE 343AB	18 27 33.4	+08 03 42	8.8 12.8	345	12.9	2006.624	1
STF2330	18 31 12.9	+13 10 55	8.27 9.69	167	16.5	2006.624	1
STF2337AB	18 34 55.1	-14 42 10	8.14 9.05	297	17.0	2006.624	1
STF2346	18 37 15.2	+03 14 3	7.93 10.0	298	30.0	2006.624	1
HJ 1349	18 48 48.8	+33 19 12	8.3 10.7	92	29.8	2006.624	1
STFA 39AB β Lyr	18 50 04.7	+33 21 45	3.63 6.69	148	46.7	2006.624	1
STF2417AB θ Ser	18 56 13.18	+04 12 12.9	4.59 4.93	104	22.8	2006.624	1
POU3652	19 01 22.4	+25 09 51	9.9 14.0	186	13.9	2006.624	1
BEM 37	19 01 25.48	+53 27 47.3	11.87 11.90	309	11.5	2006.624	1
AG 375	19 14 13.4	+26 26 28	9.6 10.5	296	18.9	2006.624	1
STFA 43Aa-B (Albireo)	19 30 43.2	+27 57 34	3.37 4.68	54	35.2	2006.624	1
HJ 603AB	19 50 33.9	+38 43 20	5.38 10.54	114	57.3	2006.624	1
ES 204	20 14 13.9	+35 21 42	7.6 10.5	281	14.3	2006.624	1
HJ 1619AB	21 12 26.5	+14 31 56	10.0 11.0	173	7.4	2006.624	1
MLB 424	21 15 30.2	+37 19 19	9.3 10.7	58	4.9	2006.624	1
STI2722	22 21 59.1	+56 19 52	10.6 13.0	71	14.7	2006.624	1
STF2922Aa-B 8 Lac	22 35 52.2	+39 38 03	5.66 6.29	185	22.4	2006.624	1
AG 423	22 36 15.6	+29 44 43	8.3 9.7	154	23.7	2006.624	1
STI2872	22 50 16.7	+57 36 20	12.6 12.6	52	11.2	2006.624	1
STI2876	22 51 26.3	+56 19 32	12.6 12.6	60	12.8	2006.624	1



Ludwig Schupmann Observatory Measures of Large Δm Pairs - Part Two

James A. Daley

Ludwig Schupmann Observatory
New Ipswich, NH

Email: rigel@net1plus.com

Abstract: This report, the second in this 3 part series, presents recent measurements in theta and rho space of 50 components in 25 mostly large Δ m systems. A comparatively small number of these pairs are physical.

Introduction

Difficulties attending CCD measurements of large Δm pairs are described in an article by the author in a previous article (Daley, 2007). The specialized tail-piece optics used to make the measures reported here is also covered in that article and in a later article (Daley, 2008). Keen-eyed observers such as S. W. Burnham, Alvan Graham Clark and the Herschel's, William and John, were dominant in the discovery of these contrasting component pairs. They usually employed the biggest reflectors and refractors of the time. It is only recently, with the introduction of the CCD, that amateurs with small telescopes have an opportunity to measure these systems.

The Measures

The following data is listed in the conventional way. From left to right: the discoverer's designation , WDS identifier (Epoch 2000 RA & Dec), WDS mags rounded off to the first place (LSO unfiltered CCD "red" magnitudes in bold italics are Δm inferred from known stars in the system), LSO position angle in degrees, LSO separation in seconds of arc, decimal date of observation, number of nights observed and a notes column. In the notes column entries such as 5m83 signifies 5 previous measures, the last being 83 years ago. Other self explanatory items, perhaps of interest, appear in this column.

There is no note section as all-in-all the work, although tedious, was without surprise; the optical components, for the most part, showing giant motions and the binaries displaying small but detectable position changes in most cases, the motions being reasonably consistent with previous measures- old and recent. Most measures are the mean of at least 12 CCD frames.

Among the few discoveries is an interesting red cpm pair in UMa (DAL 43, 12hr 05m 47.4988s +53° 54' 55.491"). Photometric measures (currently incomplete) of this wide pair will be presented in a future article.

Some CCD Images

Figure 1 shows STF 1110 (Castor), a popular fast moving pair. Both the A and B components are clearly resolved behind the foil. The slightly overexposed image of the eclipsing red pair YY Gem, which is physical with Castor, and the faint optical component "D" are well shown in this 10 second unfiltered exposure.

Figure 2 shows an image of BU 103 (upsilon Gem) with the primary highly attenuated behind the occulting foil strip. Relying on the one discovery measure 97-years ago, careful graphing demonstrates that the apparent motion of the secondary is precisely what is predicted by the proper motion of the primary, thus the companion is almost certainly optical.

Finally, Figure 3 is an image of Sirius utilizing a square aperture mask and no occultor. Although interesting, it would be a challenge to measure. However, the intersection of the diffraction spikes may give a reasonably good location of the primary as the mask is positioned very close to the objective's first

Ludwig Schupmann Observatory Measures of Large Δm Pairs - Part Two

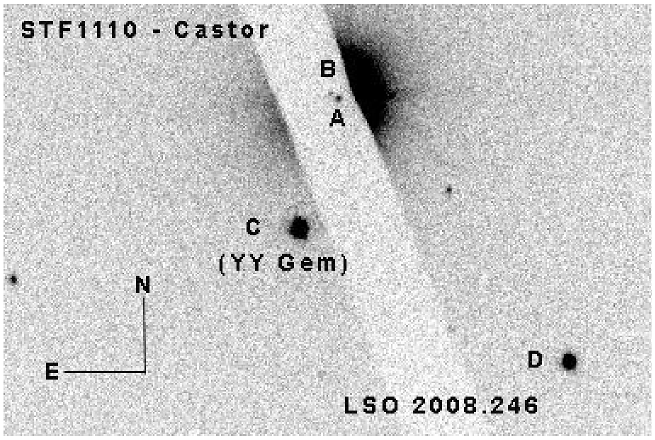


Figure 1: Castor (STF1110) with A B components visible through filter.

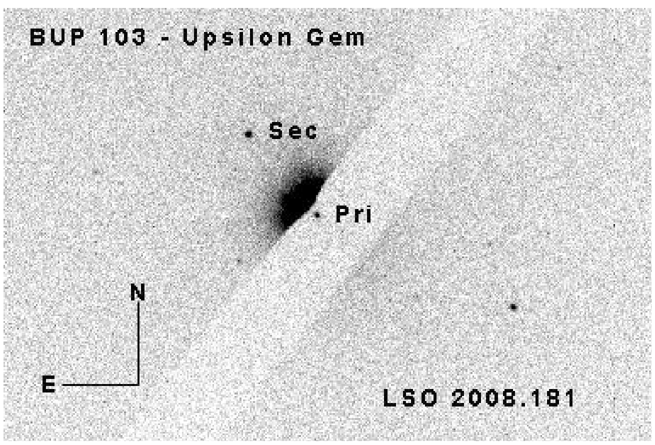


Figure 2: Image of υ Gem, almost certainly an optical double (see text).

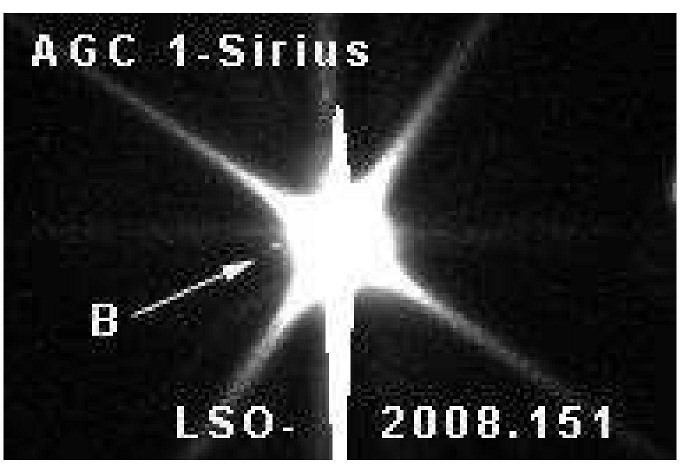


Figure 3: Image of Sirius and B component taken with no occultor

surface. A set of occulted images of Sirius were used for the included LSO measure and may be presented in a future article As with the other images, North is up and East is left.

All images shown here are single frames (no stacking).

This ongoing measurement program is guided by an observation list generated by Brian Mason based on LSO's instrumentation capability and, in general, covers a Δm range of 8 to 12 with the primary component no fainter than 4.5. Measurements are performed with a 9-inch aperture Schupmann medial telescope, a tailpiece stellar coronagraph and an unfiltered ST-7XE CCD.

References

Daley, J.A. (2007), "A Method of Measuring High Delta m Doubles", JDSO, vol 3, pg 159 - 164.

Daley, J.A. (2008), "Ludwig Schupmann Observatory Measures of Large Δm Pairs - Part One", JDSO, vol 4, 34 - 39.

Table begins on next page.

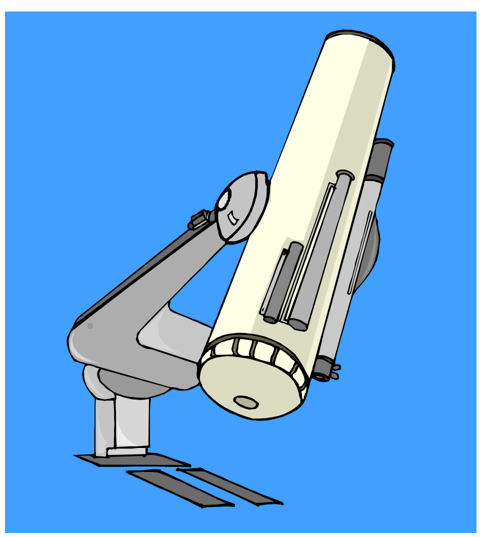
Ludwig Schupmann Observatory Measures of Large Δm Pairs - Part Two

Discoverer	RA & Dec	Mags	PA	Sep	Date	n	Notes
BU 554AB	05020+4349	3.0 14.0	225.2	29.72	2008.129	1	5m83, Epsilon Aur, binary
BU 554AC	05020+4349	3.0 11.3	275.5	43.44	2008.129	1	
BU 554AD	05020+4349	3.0 12.0	316.4	45.14	2008.129	1	5m83
STF 668A-BC	05145-0812	0.3 6.8	203.5	9.20	2008.120	2	Rigel
BU 555AD	05145-0812	0.3 ***10.5***	1.1	44.60	2008.121	3	5m87, red mag of D
BU 558Aa-B	05320-0018	2.2 14.0	228.3	33.41	2008.129	1	Delta Ori
STF 14Aa-C	05320-0018	2.2 6.8	0.2	52.49	2008.129	1	binary
BU 1056AB-C	06024+0939	4.1 14.0	284.7	18.91	2008.151	1	7m53 Mu Ori
BU 1405AC	06041+2316	4.3 13.0	24.9	105.61	2008.153	1	1 Gem
J 2016AB	06119+1413	4.5 13.0	186.6	37.81	2008.153	1	Xi Ori
J 2016BC	06119+1413	12.3 2.3	150.5	4.68	2008.153	1	2m24
DAL 40AD	06119+1413	4.5 ***11.4***	164.0	36.01	2008.153	1	new component, red mag
DAL 40AE	06119+1413	4.5 ***11.8***	22.2	43.52	2008.153	1	new component, red mag
HJ 348AB	06149-0617	4.0 13.1	26.1	53.74	2008.162	1	1m 103, Gamma Mon
DAL 41AC	06149-0617	4.0 ***13.6***	308.1	47.89	2008.162	1	new component, red mag
STF 900AB	06238+0436	4.4 6.6	28.9	12.50	2008.173	1	Epsilon Mon
STF 900AC	06238+0436	4.4 12.7	254.1	91.80	2008.173	1	
AGC 1AB	06451-1643	-1.5 8.5	97.2	8.07	2008.151	1	Sirius
BU 1411AF	06451-1643	-1.5 ***9.5***	62.1	122.75	2008.271	1	4m33, estimated red mag
SHJ 77AC	07041+2034	4.0 7.7	347.0	101.27	2008.181	1	Zeta Gem
SHJ 77AD	07041+2034	3.8 12.0	353.5	67.75	2008.181	1	2m24,
SHJ 77CD	07041+2034	7.8 12.9	154.1	34.71	2008.181	1	
J 58	07119-0030	4.1 13.0	171.7	33.21	2008.181	1	Delta Mon
BUP 101AB	07272+0817	2.9 13.0	77.1	48.97	2008.192	1	Beta CMi
BUP 101AC	07272+0817	2.9 11.2	25.3	104.15	2008.192	1	
BUP 101AD	07272+0817	2.9 11.1	75.71	131.82	2008.192	1	
BUP 101AE	07272+0817	2.9	313.6	138.33	2008.192	1	
SLE 571AF	07272+0817	2.9 12.5	166.6	79.66	2008.192	1	
SLE 571AG	07272+0817	2.9 13.0	176.7	83.83	2008.192	1	
SLE 571FG	07272+0817	12.5 13.0	245.3	15.13	2008.192	1	

Table continued on next page.

Ludwig Schupmann Observatory Measures of Large Δm Pairs - Part Two

Discoverer	RA & Dec	Mags	PA	Sep	Date	n	Notes
DAL 41FH	07272+0817	12.5 ***13.4***	53.7	3.96	2008.192	1	new component, red dm= 0.9
LAM 4AB	07282+0856	4.3 13.3	233.7	26.62	2008.181	1	5m24, Gamma CMi
LAM 4AC	07282+0856	4.3 12.3	261.4	114.50	2008.181	1	1m97
STF1110AC	07346+3153	1.9 10.1	163.5	70.54	2008.246	1	Castor, C is YY Gem
STF1110AD	07346+3153	1.9 10.1	221.4	182.97	2008.246	1	
BUP 103	07359+2654	4.1 13.2	40.4	55.17	2008.181	1	1m97, Upsilon Gem
LAM 6AC	07393+0514	0.4 11.7	20.5	177.17	2008.246	1	51m24, Procyon
BU 1065AB	08165+0911	3.5 14.3	293.6	30.14	2008.194	1	Beta Cnc, binary
DAL 42AC	08165+0911	3.5 ***12.2***	37.7	69.77	2008.194	1	new component
RST5507	08464-1333	4.3 13.7	266.4	27.12	2008.227	1	12 Hya
STF1273AB-D	08468+0625	3.5 12.5	199.7	18.03	2008.225	1	Eps Hya, Hyperbolic orbit
HJ 2489AB	09144+0219	3.9 9.8	241.0	20.30	2008.230	1	Theta Hya
HJ 2489AC	09144+0219	3.8 11.9	298.4	100.96	2008.230	1	2m46
B 2674AD	09144+0219	4.6 12.4	145.4	82.35	2008.230	1	
GAN 5	10079+1000	4.4 13.6	40.8	7.98	2008.230	1	7m74, 31 Leo, cpm
STF 6AB	10084+1158	1.4 8.24	307.3	176.98	2008.271	1	Regulus
BU 593AB	10106-1221	3.6 13.3	103.0	71.34	2008.271	1	5m86, Lambda Hydra
DAL 43	12058+5355	9.2 11.9	349.9	55.24	2008.408	1	discovery, red cpm pair
BLL 29	12154+5702	3.3 10.2	73.50	182.03	2008.399	2	Megrez
BUP 140AC	12154+5702	3.3 12.0	128.0	175.33	2008.399	2	



Journal of Double Star Observations

Fall 2008
Volume 4, Number 4

The *Journal of Double Star Observations* is an electronic journal published quarterly by the University of South Alabama. Copies can be freely downloaded from http://www.jdso.org.

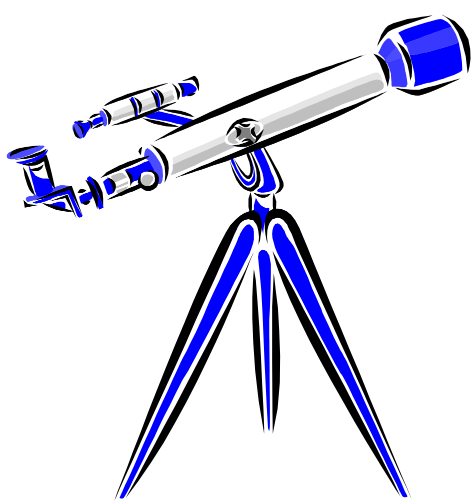
Questions, comments, or submissions may be directed to rkentclark@jaguar1.usouthal.edu or to rmollise@bellsouth.net

The *Journal of Double Star Observations* (*JDSO*) publishes articles on any and all aspects of astronomy involving double and binary stars. The *JDSO* is especially interested in observations made by amateur astronomers. Submitted articles announcing measurements, discoveries, or conclusions about double or binary stars may undergo a peer review. This means that a paper submitted by an amateur astronomer will be reviewed by other amateur astronomers doing similar work.

Not all articles will undergo a peer-review. Articles that are of more general interest but that have little new scientific content such as articles generally describing double stars, observing sessions, star parties, etc. will not be refereed.

Submitted manuscripts must be original, unpublished material and written in English. They should contain an abstract and a short description or biography (2 or 3 sentences) of the author(s). For more information about format of submitted articles, please see our web site at www.jdso.org

Submissions should be made electronically via e-mail to rclark@jaguar1.usouthal.edu or to rmollise@bellsouth.net. Articles should be attached to the email in Microsoft Word, Word Perfect, Open Office, or text format. All images should be in jpg or fits format.



We're on the web!

http://www.jdso.org