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Inside this issue:

Using VizieR/Aladin to Measure Neglected Double Stars

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Abstract: The VizierR service of the Centres de Donnes Astronomiques de Strasbourg (France) offers amateur astronomers a treasure trove of resources, including access to the most current version of the Washington Double Star Catalog (WDS) and links to tens of thousands of digitized sky survey plates via the Aladin Java applet. These plates allow the amateur to make accurate measurements of position angle and separation for many neglected pairs that fall within reasonable tolerances for the use of Aladin. This paper presents 428 measurements of 251 neglected pairs from the WDS.

In the January 2013 issue of *The Journal of Double Star Observations*, I outlined how to use the Aladin digitized sky survey plate applet embedded in the VizieR service supported by the *Centre de Donnes astronomiques de Strasbourg* (CDS) of the University of Strasbourg, France. I will not repeat what I wrote in that article about the use of this amazing service and leave it to the reader to secure that resource on his or her own if you want to see how this service was used to compile these measurements. For those interested in the site, here is its URL:

http://cdsarc.u-strasbg.fr/viz-bin/VizieR

Format of the Data Table

The data table that follows reports 428 measurements of 251 neglected pairs from th Washington Double Star Catalog (WDS, URL: http://ad.usno.navy.mil/proj/WDS/wds.html). The table headers describe the following data:

POS (2010): The WDS catalog number and position in hhmmt±ddmm format (where the 5th character, “t”, is tenths of a minute)

ID: The traditional discoverer code and catalog number in that discoverer’s list

Epoch Orig: The epoch of the last measurement contained in the WDS

ρ : The separation at the epoch of the last measurement on record

θ : The position angle at the epoch of the last measurement on record

Epoch: The epoch of the digitized sky survey plate used for the measurement

Apert: The diameter of the telescope’s objective used for that plate

Avg ρ : The average of six measurements of r on that

plate

Avg θ : The average of six measurements of q on that plate

Δρ : The difference between the latest and prior measurements of ρ expressed in milli-arcseconds (mas) per year. If more than one measure was made for a pair, the values of Δρ should in the same general range. Wide differences could indicate (a) an unreliable measurement from the original WDS epoch; (b) a very short time gap between the original

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WDS measurement and the digitized sky survey plate epoch; (c) sudden changes in orbital motion of a true binary.

Δθ : The difference between the latest and prior measurements of θ expressed in degrees per year. Comments about the changes in values stated for Δρ apply here as well.

Plate Series: The source of the plate for the measurement (POSS I, POSS II, 2 MASS, SERC, AAO, ESO).

Plate Quality: An assessment of the quality of the image used. Generally, the poorer the quality, the less reliable the measurement.

Notes: A number that refers to a footnote after the table containing comments or remarks about that pair.

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POS (2010)	ID	Epoch Orig	r	q	Epoch	Apert	Avg r	Avg q	D r	D q	Plate Series	Plate Quality	Notes
06001+2421	POU 841	1954	12.5	288	1992.062	48-in	11.55	286.9	-24.96	0.0	POSS II	Good	
06016+1248	J 254 AC	1910	12.7	195	1955.939	48-in	17.81	197.9	111.27	0.1	POSS I	Good	
					1990.864	48-in	18.23	197.5	11.93	0.0	POSS II	Good	
06030+2348	POU 854	1954	11.3	118	1992.062	48-in	9.22	120.0	-54.74	0.1	POSS II	Good	
06032+2447	POU 856 AB	1954	18	349	1992.062	48-in	14.29	346.6	-97.43	-0.1	POSS II	Medium	
06033+2340	POU 858	1954	11.4	73	1992.062	48-in	11.30	70.1	-2.76	-0.1	POSS II	Medium	
06036+2446	POU 861	1954	12.6	37	1992.062	48-in	11.40	37.9	-31.44	0.0	POSS II	Good	
06037+2357	POU 866	1954	11.2	87	1992.062	48-in	10.09	85.2	-29.25	0.0	POSS II	Good	
06040+2457	POU 870	1954	16.1	138	1992.062	48-in	15.74	141.9	-9.50	0.1	POSS II	Good	
06042-4109	HJ 3831 AC	1938	15.1	186	1976.961	24-in	16.34	190.6	31.78	0.1	SERC	Very poor	
					1990.128	1 m	17.37	187.5	77.97	-0.2	SERC	Medium	
06044+3906	ALI1065	1928	10.9	178	1953.122	48-in	10.46	177.7	-17.71	0.0	POSS I	Poor	
					1989.769	48-in	10.60	177.7	4.05	0.0	POSS II	Poor	
06051+2412	POU 908	1954	10.5	68	1992.062	48-in	7.81	70.4	-70.59	0.1	POSS II	Poor	
06052+2443	POU 910	1954	14.6	29	1992.062	48-in	14.39	26.2	-5.47	-0.1	POSS II	Good	
06056+2329	POU 918	1954	10	312	1992.062	48-in	11.60	353.8	42.04	1.1	POSS II	Good	
06061+2313	POU 931	1954	13.9	156	1997.026	48-in	13.05	155.9	-19.87	0.0	POSS II	Good	
06067+3611	ALI 317	1930	14.7	146	1989.823	48-in	16.04	62.0	22.37	-1.4	POSS II	Good	1
06079+3853	ALI 816	1929	13.1	164	1953.122	48-in	12.91	161.9	-8.08	-0.1	POSS I	Poor	2
					1989.769	48-in	12.62	164.0	-7.73	0.1	POSS II	Medium	
06097+2342	POU1069	1926	10.6	295	1954.891	48-in	10.04	296.1	-19.50	0.0	POSS I	Medium	
					1997.026	48-in	10.09	296.4	1.15	0.0	POSS II	Medium	
06110+3302	FOX 144 AB	1932	18.8	286	1954.006	48-in	18.43	275.1	-16.97	-0.5	POSS I	Medium	
					1989.823	48-in	23.40	265.4	138.95	-0.3	POSS II	Good	

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POS (2010)	ID	Epoch Orig	ρ	θ	Epoch	Apert	Avg ρ	Avg θ	Δ ρ	Δ θ	Plate Series	Plate Quality	Notes
06152+0631	A 2717 AB -C	1960	14.1	319	1990.817	48-in	13.66	350.1	-14.39	1.0	POSS II	Medium	
06171-2243	HJ 3845	1959	47.6	6	1981.036	1 m	52.76	2.4	234.33	-0.2	SERC	Good	
06173+0506	BUP 87 AC	1911	58.5	265	1950.940	48-in	51.57	258.5	-173.55	-0.2	POSS I	Poor	
					1990.817	48-in	45.31	247.8	-156.94	-0.3	POSS II	Good	
06173+0506	BUP 87 AD	1911	69.3	231	1950.940	48-in	67.98	223.8	-33.05	-0.2	POSS I	Poor	
					1990.817	48-in	67.55	214.5	-10.78	-0.2	POSS II	Good	
06203-1434	DAW 191	1920	12.4	33	1955.942	48-in	12.21	35.6	-5.38	0.1	POSS I	Poor	
					1993.147	24-in	11.45	33.7	-20.43	-0.1	SERC	Medium	
06212+6120	STI 597	1905	12.7	124	1954.012	48-in	12.64	124.6	-1.16	0.0	POSS I	Medium	
					1990.001	48-in	12.69	123.2	1.30	0.0	POSS II	Medium	
06220+3513	ALI 86	1928	14.6	105	1954.006	48-in	13.42	105.1	-45.25	0.0	POSS I	Poor	
					1996.775	48-in	10.05	102.1	-78.95	-0.1	POSS II	Medium	
06237+0155	BAL1312	1910	15.4	64	1955.879	48-in	15.37	65.7	-0.58	0.0	POSS I	Good	
					1986.029	48-in	15.19	64.8	-6.08	0.0	POSS II	Good	
06250-4630	RSS 108	1976	16.6	266	1994.215	48-in	15.61	266.1	-54.63	0.0	POSS II	Medium	
06259+0944	OPI 11 AC	1926	40	120	1951.912	48-in	39.82	126.3	-6.82	0.2	POSS I	Medium	
					1989.845	48-in	38.39	126.8	-37.79	0.0	POSS II	Good	
06290+0335	BAL2172	1910	15.3	263	1953.941	48-in	15.18	261.0	-2.73	0.0	POSS I	Poor	
					1990.817	48-in	14.76	262.3	-11.30	0.0	POSS II	Good	
06309+2342	POU1378	1925	15.6	332	1949.900	48-in	16.08	335.2	19.34	0.1	POSS I	Medium	
					1990.825	48-in	16.93	336.5	20.61	0.0	POSS II	Good	
06310+2353	POU1383	1925	11.6	66	1949.900	48-in	10.55	73.9	-42.24	0.3	POSS I	Poor	
					1990.825	48-in	9.57	88.9	-24.03	0.4	POSS II	Medium	
06311-2037	ARA 863	1920	11.7	188	1979.895	24-in	11.32	189.2	-6.37	0.0	SERC	Good	
					1985.938	1 m	11.82	188.0	83.57	-0.2	SERC	Poor	
06312+2253	POU1390	1925	14.1	324	1949.900	48-in	13.95	322.8	-5.89	0.0	POSS I	Medium	
					1990.825	48-in	13.33	325.6	-15.19	0.1	POSS II	Good	
06314-5737	HJ 3873	1912	18.8	295	1979.984	1 m	14.48	294.2	-63.62	0.0	SERC	Poor	
					1984.904	1 m	14.43	312.3	-9.82	3.7	SERC	Very poor	
06321+0300	BAL2176	1953	12.9	294	1986.029	1 m	12.24	292.0	-20.13	-0.1	SERC	Medium	
06323+5521	STI2146	1918	11.4	235	1954.148	48-in	9.08	236.4	-64.18	0.0	POSS I	Poor	
					1991.104	48-in	7.38	238.8	-46.05	0.1	POSS II	Poor	
06327+2356	POU1421	1925	15.1	350	1949.900	48-in	15.31	353.2	8.37	0.1	POSS I	Poor	
					1990.825	48-in	14.64	351.0	-16.29	-0.1	POSS II	Medium	
06328+3904	ALI1073	1929	10.3	8	1953.187	48-in	8.40	4.8	-78.42	-0.1	POSS I	Poor	
					1986.902	48-in	8.09	7.7	-9.44	0.1	POSS II	Good	
06328-2724	I 755	1921	30	150	1979.986	1 m	34.66	174.6	79.00	0.4	SERC	Good	
					1996.131	48-in	36.29	176.3	100.96	0.1	AAO	Medium	
06353+2351	POU1531	1906	12.9	322	1949.900	48-in	12.58	322.7	-7.40	0.0	POSS I	Poor	
					1990.825	48-in	13.57	323.9	24.27	0.0	POSS II	Good	

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POS (2010)	ID	Epoch Orig	ρ	θ	Epoch	Apert	Avg ρ	Avg θ	Δ ρ	Δ θ	Plate Series	Plate Quality	Notes
06374+0056	BAL1320	1910	16.7	286	1955.879	48-in	16.86	287.4	3.49	0.0	POSS I	Medium	
					1991.178	1 m	16.81	285.6	-1.42	-0.1	SERC	Medium	
06382+2305	POU1714	1906	15.1	139	1949.900	48-in	15.17	138.5	1.56	0.0	POSS I	Good	
					1990.825	48-in	15.22	138.8	1.30	0.0	POSS II	Good	
06383+5611	STI2153	1918	12.7	356	1954.148	48-in	13.15	358.4	12.31	0.1	POSS I	Good	
					1991.104	48-in	12.67	356.9	-12.99	0.0	POSS II	Good	
06389-2846	HJ 2334	1918	10.8	299	1978.998	1 m	11.72	299.9	15.11	0.0	SERC	Poor	
					1993.163	1 m	10.79	301.1	-65.89	0.1	SERC	Medium	
06403+2320	POU1825	1906	15.3	33	1949.900	48-in	16.77	33.3	33.41	0.0	POSS I	Medium	
					1990.825	48-in	18.54	30.3	43.29	-0.1	POSS II	Good	
06404+0344	BAL2184	1910	17.1	205	1953.941	48-in	16.66	205.2	-10.09	0.0	POSS I	Poor	
					1998.872	48-in	16.18	205.8	-10.57	0.0	POSS II	Medium	
06407+6424	STI 617	1908	12.2	148	1953.124	48-in	12.37	151.0	3.77	0.1	POSS I	Very poor	
					1989.971	48-in	11.65	149.1	-19.50	-0.1	POSS II	Poor	
06421+2420	POU1913	1906	15.7	208	1949.900	48-in	15.16	207.9	-12.26	0.0	POSS I	Medium	
					1990.825	48-in	16.73	206.2	38.32	0.0	POSS II	Medium	
06424+2423	POU1921	1925	10.5	106	1949.900	48-in	9.81	106.2	-27.71	0.0	POSS I	Poor	
					1990.825	48-in	10.38	109.0	13.85	0.1	POSS II	Medium	
06426+0000	BAL1013	1893	15.6	282	1955.879	48-in	14.48	286.3	-17.76	0.1	POSS I	Poor	
					1991.178	48-in	14.13	285.8	-10.15	0.0	POSS II	Medium	
06431-0140	BAL 332	1893	12.3	29	1955.879	48-in	12.81	34.2	8.16	0.1	POSS I	Poor	
					1991.178	1 m	13.17	33.4	10.15	0.0	SERC	Medium	
06431-0239	BAL 70	1893	12.3	347	1955.879	48-in	12.00	348.6	-4.82	0.0	POSS I	Poor	
					1985.057	1 m	12.11	347.9	3.71	0.0	SERC	Medium	
					1997.105	48-in	12.31	348.2	16.60	0.0	POSS II	Good	
06432+0022	BAL1019	1893	17.4	174	1955.879	48-in	17.50	174.5	1.62	0.0	POSS I	Medium	
					1991.178	48-in	17.40	174.2	-2.88	0.0	POSS II	Good	
06435+2421	POU1956	1925	16.4	289	1949.900	48-in	16.54	288.3	5.42	0.0	POSS I	Poor	
					1990.825	48-in	16.25	288.4	-7.05	0.0	POSS II	Good	
06437+0024	BAL1020	1893	12.1	228	1955.208	48-in	11.86	227.0	-3.88	0.0	POSS I	Poor	
					1990.959	48-in	11.66	227.0	-5.45	0.0	POSS II	Good	
06442-0117	BAL 333	1897	13.7	8	1955.208	48-in	13.04	6.2	-11.28	0.0	POSS I	Very poor	
					1997.105	48-in	12.52	6.0	-12.53	0.0	POSS II	Medium	
06447-0002	BAL1027 AB	1897	17.7	307	1955.208	48-in	18.23	307.0	9.16	0.0	POSS I	Medium	
					1997.105	48-in	18.27	306.9	0.95	0.0	POSS II	Good	
06449-0119	BAL 336	1893	12.3	293	1955.208	48-in	12.37	301.1	1.13	0.1	POSS I	Poor	
					1997.105	48-in	12.23	300.4	-3.26	0.0	POSS II	Good	
06449-2352	B 117 AC	1928	20.7	264	1979.973	1 m	20.69	269.3	-0.22	0.1	SERC	Medium	
					1996.131	48-in	20.21	267.5	-29.91	-0.1	AAO	Poor	
06451+0251	BAL1715	1910	17.8	314	1953.993	48-in	18.02	313.2	4.93	0.0	POSS I	Poor	
					1997.182	48-in	17.84	2.0	-4.01	-7.2	2 MASS	Poor	

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POS (2010)	ID	Epoch Orig	ρ	θ	Epoch	Apert	Avg ρ	Avg θ	Δ ρ	Δ θ	Plate Series	Plate Quality	Notes
06459+0158	BAL1718	1910	16.6	224	1955.208	48-in	16.29	226.0	-6.93	0.0	POSS I	Medium	
					1997.105	48-in	16.09	226.3	-4.69	0.0	POSS II	Good	
06460-6624	RSS 115	1976	12	326	1982.886	1 m	12.37	324.6	53.49	-0.2	SERC	Poor	
					1996.134	48-in	14.95	321.3	195.12	-0.2	AAO	Medium	
06462+2440	POU2000	1925	10.1	24	1949.900	48-in	10.38	25.7	11.31	0.1	POSS I	Medium	
					1990.825	48-in	10.18	24.4	-4.97	0.0	POSS II	Good	
06477+0005	BAL1039	1893	13.5	275	1955.208	48-in	12.87	272.9	-10.07	0.0	POSS I	Medium	
					1997.105	48-in	12.60	270.2	-6.64	-0.1	POSS II	Good	
06478-0136	BAL 344	1893	11.9	188	1955.208	48-in	10.85	183.7	-16.96	-0.1	POSS I	Medium	
					1997.105	48-in	10.82	182.7	-0.72	0.0	POSS II	Good	
06487-0208	BAL 85	1893	17	132	1955.208	48-in	16.75	131.8	-4.05	0.0	POSS I	Medium	
					1997.105	48-in	16.28	130.8	-11.10	0.0	POSS II	Good	
06490+2345	POU2035	1925	12.7	108	1949.900	48-in	12.17	110.3	-21.29	0.1	POSS I	Poor	
					1990.825	48-in	12.06	108.3	-2.69	0.0	POSS II	Good	
06491+0148	BAL1341	1910	19.7	177	1955.208	48-in	18.36	181.5	-29.60	0.1	POSS I	Poor	
					1997.105	48-in	19.46	179.1	26.10	-0.1	POSS II	Good	
06540-0207	BAL 91	1892	12.3	359	1955.208	48-in	11.49	359.2	-12.81	0.0	POSS I	Poor	
					1992.914	48-in	11.53	1.2	1.02	-9.5	POSS II	Medium	
06543+2328	POU2122	1907	13.4	256	1956.265	48-in	12.89	256.3	-10.39	0.0	POSS I	Good	
					1994.028	48-in	12.40	257.6	-12.93	0.0	POSS II	Medium	
06549-0224	BAL 95	1896	18.4	27	1955.208	48-in	17.82	28.7	-9.82	0.0	POSS I	Poor	
					1992.914	48-in	18.16	28.2	9.11	0.0	POSS II	Good	
06550+2355	POU2134	1907	13.3	35	1956.265	48-in	13.65	34.2	7.17	0.0	POSS I	Good	
					1994.028	48-in	13.62	35.3	-1.02	0.0	POSS II	Medium	
06554-0149	BAL 361	1897	12.7	291	1955.208	48-in	12.62	291.4	-1.43	0.0	POSS I	Medium	
					1992.914	48-in	12.23	288.9	-10.25	-0.1	POSS II	Good	
06555-0150	BAL 362	1897	17.6	338	1955.208	48-in	18.10	340.1	8.62	0.0	POSS I	Medium	
					1992.914	48-in	17.64	339.6	-12.20	0.0	POSS II	Good	
06570-0155	BAL 366	1897	15.7	92	1955.208	48-in	15.48	89.5	-3.84	0.0	POSS I	Medium	
					1992.914	48-in	15.77	86.4	7.74	-0.1	POSS II	Good	
06574-0157	BAL 367	1897	17.8	314	1955.208	48-in	17.81	315.3	0.11	0.0	POSS I	Good	
					1992.914	48-in	17.97	315.3	4.24	0.0	POSS II	Good	
06587-0026	BAL 745	1897	12.4	92	1955.208	48-in	12.08	92.2	-5.55	0.0	POSS I	Poor	
					1992.914	48-in	11.99	92.7	-2.30	0.0	POSS II	Medium	
06588+0235	BAL1748	1910	11.3	255	1955.208	48-in	11.14	254.5	-3.54	0.0	POSS I	Poor	
					1997.237	48-in	11.30	255.2	3.73	0.0	POSS II	Medium	
06588+2605	BUP 95 AB	1925	28.8	34	1956.265	48-in	27.99	46.3	-25.94	0.4	POSS I	Poor	
					1994.028	48-in	31.56	57.8	94.49	0.3	POSS II	Poor	
06589-0106	BAL 746	1897	13.8	109	1955.208	48-in	13.70	109.3	-1.72	0.0	POSS I	Medium	
					1992.914	48-in	13.68	111.7	-0.57	0.1	POSS II	Good	

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POS (2010)	ID	Epoch Orig	ρ	θ	Epoch	Apert	Avg ρ	Avg θ	Δ ρ	Δ θ	Plate Series	Plate Quality	Notes
06594+2356	POU2211	1908	13.2	188	1956.265	48-in	13.13	188.2	-1.38	0.0	POSS I	Good	
					1994.028	48-in	13.31	188.6	4.77	0.0	POSS II	Good	
06598+2438	POU2229	1908	11.1	329	1956.265	48-in	11.87	329.8	15.85	0.0	POSS I	Medium	
					1994.028	48-in	11.28	327.8	-15.62	-0.1	POSS II	Medium	
07012+2304	POU2270	1908	14.9	227	1956.265	48-in	14.65	229.3	-5.18	0.0	POSS I	Good	
					1994.028	48-in	14.86	228.0	5.61	0.0	POSS II	Good	
07014+7049	BLL 18	1910	117	357	1953.114	48-in	117.77	358.2	17.86	0.0	POSS I	Good	
					1989.971	48-in	118.41	358.3	17.36	0.0	POSS II	Good	
07025+2252	POU2319	1908	11.4	292	1956.265	48-in	11.41	293.2	0.14	0.0	POSS I	Good	
					1994.028	48-in	11.38	293.2	-0.75	0.0	POSS II	Medium	
07027+2249	POU2324	1908	14.2	46	1956.265	48-in	14.59	46.6	8.08	0.0	POSS I	Good	
					1994.028	48-in	14.20	48.4	-10.42	0.0	POSS II	Medium	
07052-0237	BAL 114	1896	11.6	75	1955.208	48-in	11.37	77.4	-3.88	0.0	POSS I	Poor	
					1992.914	48-in	11.15	74.8	-5.97	-0.1	POSS II	Medium	
07064-2318	ARA2034	1922	13	99	1979.968	1 m	13.66	99.4	11.33	0.0	SERC	Good	
					1994.201	48-in	13.25	97.9	-28.69	-0.1	AAO	Medium	
07077-0233	BAL 127	1893	12.9	267	1955.890	48-in	12.59	265.2	-4.98	0.0	POSS I	Medium	
					1989.030	48-in	12.10	264.8	-14.84	0.0	POSS II	Good	
07099+2300	POU2515	1956	10.7	7	1956.265	48-in	9.18	9.7	-5723.27	10.3	POSS I	Medium	
					1994.028	48-in	9.25	5.4	1.85	-0.1	POSS II	Good	
07100+0254	J 57 BC	1949	19.8	55	1989.030	48-in	18.30	57.4	-37.56	0.1	POSS II	Medium	
07102-0414	BUP 97 AD	1923	120.4	2	1955.882	48-in	112.48	2.2	-240.86	0.0	POSS I	Poor	
					1989.174	48-in	105.70	2.0	-203.65	0.0	POSS II	Good	
07103+2335	POU2518	1956	15.6	24	1994.028	48-in	15.06	26.5	-14.29	0.1	POSS II	Good	
07128+2328	POU2563	1956	11.6	120	1956.265	48-in	11.55	120.4	-188.68	1.6	POSS I	Excellent	
					1997.026	48-in	11.45	121.7	-2.41	0.0	POSS II	Excellent	
07128-0709	LV 18 AC	1917	20.1	20	1955.882	48-in	19.76	19.6	-8.66	0.0	POSS I	Medium	
					1986.198	48-in	19.99	19.6	7.59	0.0	POSS II	Medium	
07135+0507	HJ 48	1897	27.6	231	1954.173	48-in	26.72	245.3	-15.39	0.2	POSS I	Medium	
					1991.098	48-in	28.63	244.9	51.82	0.0	POSS II	Good	
07135-4438	HJ 3943	1913	62	214	1980.118	1 m	83.87	211.6	325.84	0.0	SERC	Medium	
					1992.194	48-in	88.00	211.1	342.00	0.0	POSS II	Medium	
07139+2501	BUP 98 AB	1910	50.3	156	1956.265	48-in	56.78	137.6	140.10	-0.4	POSS I	Good	
					1997.026	48-in	67.34	107.9	259.03	-0.7	POSS II	Good	
07155+2444	POU2608	1956	11	1	1997.026	48-in	10.60	2.1	-9.83	0.0	POSS II	Good	
07175-2239	ARA1683	1922	14.6	333	1980.208	1 m	14.33	332.4	-4.70	0.0	SERC	Good	
					1995.094	48-in	15.46	328.8	76.25	-0.2	AAO	Medium	
07200-5128	RSS 129	1976	10.8	52	1978.015	1 m	10.31	56.8	-244.00	2.4	SERC	Good	
					1992.178	48-in	10.56	69.6	18.00	0.9	AAO	Good	
07209+2439	POU2705	1954	14.9	51	1954.970	48-in	13.77	52.6	-1164.95	1.6	POSS I	Good	
					1997.026	48-in	13.59	51.2	-4.24	0.0	POSS II	Good	

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POS (2010)	ID	Epoch Orig	ρ	θ	Epoch	Apert	Avg ρ	Avg θ	Δ ρ	Δ θ	Plate Series	Plate Quality	Notes
07225-0215	ROE 29	1910	10.3	212	1990.206	48-in	10.32	210.9	0.27	0.0	POSS II	Medium	
07250-2315	ARA2046	1922	13	151	1980.208	1 m	13.72	157.9	12.40	0.1	SERC	Good	
					1995.094	48-in	13.67	155.5	-3.58	-0.2	AAO	Good	
07251-2230	ARA1686	1922	14.1	40	1980.211	1 m	14.43	39.6	5.58	0.0	SERC	Poor	
					1995.077	48-in	14.12	40.3	-20.40	0.0	AAO	Medium	
07270+2335	POU2783 AC	1954	14.9	77	1954.970	48-in	13.95	248.9	-984.54	177.2	POSS I	Medium	3
					1997.026	48-in	14.20	248.1	5.98	0.0	POSS II	Good	
07290-1908	ARA 376	1918	13.7	138	1980.211	1 m	13.54	142.7	-2.52	0.1	SERC	Poor	
					1995.077	48-in	13.29	141.8	-17.27	-0.1	AAO	Good	
07309-1933	ARA 601	1918	12	3	1980.211	1 m	11.12	0.2	-14.15	0.0	SERC	Poor	
					1995.077	48-in	11.51	2.5	26.35	0.2	AAO	Poor	
07317-2356	ARA2056	1922	14.1	333	1980.208	1 m	12.85	334.0	-21.53	0.0	SERC	Poor	
					1995.094	48-in	13.87	333.6	68.52	0.0	AAO	Poor	
07325-2738	HJ 2398	1919	11.7	43	1978.998	1 m	27.45	52.6	262.43	0.2	SERC	Very poor	
					1992.181	48-in	10.57	51.1	-1279.80	-0.1	AAO	Medium	
07328-2332	ARA2058	1922	15.1	212	1980.222	1 m	17.73	198.8	45.20	-0.2	SERC	Good	
					1995.094	48-in	18.81	195.5	72.17	-0.2	AAO	Good	
07331-2112	ARA 944	1920	13.3	191	1983.957	1 m	13.09	191.6	-3.34	0.0	SERC	Medium	
					1995.077	48-in	12.16	194.6	-83.63	0.3	AAO	Medium	
07365-2024	ARA 964	1920	12.8	90	1983.957	1 m	12.77	91.1	-0.52	0.0	SERC	Good	
					1996.118	48-in	12.74	92.9	-2.47	0.1	AAO	Good	
07365-2106	ARA 965	1920	10.7	340	1983.957	1 m	10.94	336.5	3.67	-0.1	SERC	Poor	
					1996.118	48-in	11.05	336.6	9.18	0.0	AAO	Very poor	
07372-2123	ARA1363	1920	11.4	50	1988.957	1 m	13.42	54.1	29.25	0.1	SERC	Good	
					1996.118	48-in	12.97	55.5	-63.07	0.2	AAO	Poor	
07433+2853	BLL 23	1909	182.2	316	1958.124	48-in	188.28	318.3	123.77	0.0	POSS I	Good	
					1989.083	48-in	194.45	319.3	199.30	0.0	POSS II	Good	
07448-0123	BAL 487	1896	10.4	90	1953.002	48-in	12.51	79.1	37.02	-0.2	POSS I	Good	
					1992.966	48-in	12.85	76.7	8.59	-0.1	POSS II	Good	
07493-0034	HJ 64	1896	15.3	326	1953.002	48-in	15.22	324.0	-1.40	0.0	POSS I	Poor	
					1987.083	48-in	14.14	325.8	-31.64	0.1	POSS II	Good	
07500+0127	BAL1413	1909	10.4	286	1953.002	48-in	10.44	284.3	0.98	0.0	POSS I	Poor	
					1987.083	48-in	9.78	286.0	-19.56	0.0	POSS II	Medium	
07504-3210	HJ 4009 AC	1928	30	180	1983.144	ESO	36.45	179.3	117.00	0.0	ESO	Medium	
					1992.181	48-in	36.76	181.1	33.57	0.2	AAO	Poor	
07517+2104	HO 248	1905	20.4	94	1950.935	48-in	20.39	87.8	-0.33	-0.1	POSS I	Medium	
					1998.001	48-in	20.76	79.2	7.93	-0.2	POSS II	Good	
07550+0036	BAL1123	1893	15.5	41	1953.002	48-in	15.19	45.6	-5.11	0.1	POSS I	Poor	
					1997.182	48-in	14.68	46.7	-11.54	0.0	POSS II	Poor	
07573-2154	ARA1412	1920	11.9	305	1983.957	1 m	11.57	304.8	-5.13	0.0	SERC	Medium	
					1995.091	48-in	11.15	306.8	-38.32	0.2	AAO	Medium	

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POS (2010)	ID	Epoch Orig	ρ	θ	Epoch	Apert	Avg ρ	Avg θ	Δ ρ	Δ θ	Plate Series	Plate Quality	Notes
07577-2317	ARA2090	1922	11.1	112	1978.038	1 m	12.85	121.1	31.26	0.2	SERC	Good	
					1996.123	48-in	14.04	125.6	65.89	0.2	AAO	Poor	
08000-0050	BAL 842	1893	13.3	88	1954.924	48-in	13.17	90.7	-2.18	0.0	POSS I	Medium	
					1988.189	48-in	13.07	92.8	-2.76	0.1	POSS I	Medium	
08029-0242	BAL 194	1931	10.7	147	1954.924	48-in	11.27	148.1	23.62	0.0	POSS I	Very poor	
					1997.182	48-in	11.08	146.5	-4.30	0.0	POSS I	Poor	
08068-2041	ARA1027	1920	11	147	1979.233	1 m	10.84	151.6	-2.70	0.1	SERC	Very poor	
					1995.091	48-in	10.51	149.8	-20.91	-0.1	AAO	Very poor	
08140-4021	HJ 4062	1920	51.1	341	1976.967	1 m	56.37	339.4	92.42	0.0	SERC	Excellent	
					1991.102	48-in	51.20	338.8	-365.64	0.0	AAO	Good	
08248-3240	PRO 56	1914	16.8	230	1980.271	1 m	16.53	230.3	-4.15	0.0	SERC	Poor	3
					1998.324	1 m	16.54	230.2	1.02	0.0	SERC	Poor	
08269-0058	BAL 851	1893	13.1	29	1954.968	48-in	8.15	42.7	-79.88	0.2	POSS I	Very poor	
					1987.020	1 m	8.19	41.9	1.25	0.0	SERC	Poor	
08468-0004	BAL1142	1892	12.9	106	1952.082	48-in	12.70	106.3	-3.27	0.0	POSS I	Poor	
					1992.033	1 m	12.50	105.1	-5.09	0.0	SERC	Poor	
09090-1411	HU 227 AC	1909	33.3	318	1954.233	48-in	30.58	321.9	-60.21	0.1	POSS I	Medium	
					1992.033	1 m	27.59	323.0	-79.06	0.0	SERC	Medium	
09142-2036	ARA1066	1920	14.6	305	1976.986	48-in	14.73	324.0	2.25	0.3	SERC	Very poor	
					1994.248	48-in	14.55	328.7	-10.62	0.3	AAO	Poor	
09347-2509	B 2220	1960	14.4	74	1980.058	48-in	15.69	79.4	64.31	0.3	SERC	Poor	
					1995.091	48-in	17.98	81.5	152.33	0.1	AAO	Medium	
09357-2230	ARA1768	1922	13.3	52	1980.058	1 m	13.46	54.6	2.70	0.0	SERC	Medium	
					1995.091	48-in	13.09	53.0	-24.61	-0.1	AAO	Medium	
10008-1809	ARA 220	1916	13.6	335	1984.122	1 m	9.82	353.4	-55.44	0.3	SERC	Poor	
					1995.302	48-in	9.44	355.6	-34.14	0.2	AAO	Very poor	
10319+3223	HJ 482	1934	46.9	245	1955.282	48-in	49.22	246.0	108.78	0.0	POSS I	Poor	
					1989.177	48-in	52.84	247.4	106.85	0.0	POSS II	Good	
10536-0742	J 90 BC	1936	14	205	1954.152	48-in	13.15	197.2	-46.83	-0.4	POSS I	Poor	
					1996.195	1 m	11.58	192.7	-37.46	-0.1	SERC	Medium	
11330-3151	HJ 4449 AB	1928	68.2	149	1980.137	1 m	71.79	141.0	68.86	-0.2	SERC	Good	
					1991.144	48-in	73.24	138.8	131.73	-0.2	AAO	Good	
11396-5244	SEE 132	1959	29.6	92	1979.411	1 m	35.63	94.1	295.43	0.1	SERC	Medium	
					1997.128	1 m	41.05	95.4	306.11	0.1	SERC	Poor	
12069-6437	HJ 4501 AB	1945	46.4	302	1987.261	1 m	47.23	300.6	19.522	0.0	SERC	Medium	
					1996.298	48-in	47.77	300.0	59.939	-0.1	POSS II	Good	
12251+6348	BU 1432	1908	51.2	245	1953.122	48-in	50.85	244.6	-7.720	0.0	POSS I	Good	
					1993.303	48-in	50.44	243.7	-10.162	0.0	POSS II	Good	
12300+5132	BUP 143 AB	1908	109.2	172	1953.289	48-in	112.35	165.1	69.553	-0.2	POSS I	Medium	
12301-1324	LV 19 AC	1918	91	294	1954.389	48-in	83.63	297.9	-202.534	0.1	POSS I	Good	
					1991.111	48-in	75.75	301.8	-214.585	0.1	POSS II	Good	

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POS (2010)	ID	Epoch Orig	ρ	θ	Epoch	Apert	Avg ρ	Avg θ	Δ ρ	Δ θ	Plate Series	Plate Quality	Notes
12301-1324	LV 19 AD	1918	79.2	183	1954.389	48-in	75.92	177.7	-90.137	-0.1	POSS I	Good	
					1991.111	48-in	76.40	170.5	38.371	0.1	POSS II	Good	
12350-4717	HJ 4530 A-BC	1966	42.1	88	1976.304	48-in	46.45	88.3	421.843	0.0	SERC	Good	
					1996.238	48-in	54.39	86.8	398.649	-0.1	SERC	Poor	
12413-1301	STF1669 BC	1988	57.8	229	1992.394	48-in	58.90	234.2	251.100	1.2	SERC	Good	
12426-2437	HJ 4542	1987	28.2	62	1991.280	48-in	37.49	62.1	2170.171	0.0	AAO	Good	
12428-6405	TOB 114	1987	13.9	148	1997.093	1 m	13.55	148.4	-34.512	0.0	SERC	Poor	
12468-3319	HDO 219	1929	65	226	1976.408	1 m	70.68	222.1	119.811	-0.1	SERC	Good	
					1999.187	1 m	74.69	220.2	176.039	-0.1	SERC	Good	
13119+2753	STT 578	1924	85.8	238	1955.285	48-in	87.41	213.6	51.462	-0.8	POSS I	Good	
					1993.289	48-in	108.69	189.8	559.941	-0.6	POSS II	Good	
13153+1612	SLE 917	1985	22.5	300	1997.346	48-in	27.67	299.7	418.489	0.0	POSS II	Good	
13167-5950	HJ 4577 AD	1874	12	180	1978.319	1 m	8.54	144.0	-33.215	-0.3	SERC	Medium	
					1999.125	1 m	7.90	143.5	-30.760	0.0	SERC	Poor	
13252-6429	HJ 4583	1935	25.7	203	1987.084	1 m	21.84	185.3	-74.047	-0.3	SERC	Medium	
					1997.099	1 m	21.82	180.4	-2.330	-0.5	SERC	Medium	
13343-0019	STF1757 AD	1921	128	72	1952.077	48-in	132.65	72.2	149.628	0.0	POSS I	Medium	
					1997.267	48-in	141.61	74.0	198.274	0.0	POSS II	Medium	
13496-2016	ARA 693	1919	10.4	0	1977.153	48-in	10.19	359.8	-3.554	6.2	SERC	Poor	
					1993.279	48-in	9.17	717.9	-63.665	22.2	SERC	Poor	
13514+6443	HJ 3342 AC	1911	90.2	63	1955.375	48-in	90.66	61.5	10.366	0.0	POSS I	Good	
					1990.075	48-in	89.51	61.3	-33.141	0.0	POSS II	Good	
14195-6838	I 325 AC	1902	44.8	44	1980.391	1 m	49.72	44.0	62.741	0.0	SERC	Medium	
					1993.538	1 m	50.50	44.4	59.456	0.0	SERC	Medium	
14313-1538	BU 117 AC	1911	107.3	335	1955.285	48-in	125.63	333.7	413.910	0.0	POSS I	Poor	
					1996.318	1 m	143.03	333.0	424.049	0.0	SERC	Poor	
14463+0939	STF1879 AB-C	1925	53	208	1954.417	48-in	47.54	214.6	-185.550	0.2	POSS I	Medium	
					1989.245	48-in	42.44	224.6	-146.434	0.3	POSS II	Good	
15010-0831	J 1586 AB	1950	67	90	1953.450	48-in	65.31	90.9	-489.855	0.3	POSS I	Medium	
					1996.231	1 m	68.23	89.7	68.255	0.0	SERC	Good	
15173-3137	PRO 121	1913	10.8	127	1975.300	48-in	10.62	108.5	-2.916	-0.3	SERC	Medium	
					1991.455	48-in	11.28	102.4	40.751	-0.4	SERC	Poor	
15241-3302	HJ 4765	1942	10.5	99	1975.193	48-in	10.31	97.4	-5.624	0.0	SERC	Medium	
					1994.259	48-in	11.18	98.6	45.194	0.1	SERC	Poor	
15255-2309	ARA1806	1922	11.6	224	1976.386	48-in	10.61	225.3	-18.234	0.0	SERC	Poor	
					1993.279	48-in	10.44	228.0	-9.866	0.2	SERC	Poor	
15292+8027	STF1972 AC	1983	153.8	102	1994.436	48-in	152.30	104.6	-131.165	0.2	POSS II	Good	
16218-4935	AOT 66	1987	11.3	178	1980.392	48-in	11.00	176.6	45.904	0.2	SERC	Poor	
					1997.320	48-in	11.51	177.8	30.423	0.1	SERC	Very Poor	
16219+1909	SHJ 227 BC	1910	84.7	298	1950.204	48-in	81.98	296.9	-67.655	0.0	POSS I	Very Poor	
					1991.430	48-in	82.90	297.8	22.316	0.0	POSS II	Medium	

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POS (2010)	ID	Epoch Orig	ρ	θ	Epoch	Apert	Avg ρ	Avg θ	Δ ρ	Δ θ	Plate Series	Plate Quality	Notes
16243-1338	BUP 169 AB	1909	103	281	1954.267	48-in	95.31	287.1	-169.881	0.1	POSS I	Poor	
16288-0808	STF2048 AC	1960	131.9	301	1992.640	48-in	130.22	301.7	-51.471	0.0	SERC	Good	
16435+4544	KZA 109 AC	1984	79.6	189	1991.296	48-in	79.93	189.5	45.230	0.1	POSS II	Poor	
17320+6808	BU 1458	1960	103.4	344	1993.625	48-in	158.34	342.9	1633.903	0.0	POSS II	Medium	
18025+2619	HO 564 AC	1924	80.3	57	1951.485	48-in	81.76	43.4	53.12	-0.5	POSS I	Medium	
					1991.365	48-in	90.08	25.2	208.63	-0.5	POSS II	Good	
18070-2005	ARA1134	1923	12.6	97	1992.581	48-in	11.67	98.0	-13.37	0.0	SERC	Medium	
18070-2121	ARA1510	1923	14.6	267	1992.581	48-in	14.13	266.6	-6.73	0.0	SERC	.	
18079+3042	SLE 138	1982	14	308	1989.349	48-in	9.79	327.0	-572.41	2.6	POSS II	Medium	
18124-2207	ARA1853	1923	10.7	114	1992.581	48-in	11.37	113.7	9.68	0.0	SERC	Poor	
18132-2230	ARA1856	1920	11.5	308	1992.581	48-in	11.02	307.8	-6.61	0.0	SERC	Medium	
18192-2146	ARA1527	1922	12.9	15	1951.646	48-in	13.10	15.2	6.80	0.0	POSS I	Very Poor	
					1992.581	48-in	12.72	13.8	-9.32	0.0	SERC	Poor	
18201+0807	SLE 154	1982	10.5	259	1993.535	48-in	10.10	261.2	-34.82	0.2	POSS II	Poor	
18218+0852	SLE 158	1982	11.1	120	1993.535	48-in	10.72	118.0	-33.23	-0.2	POSS II	Poor	
18222+0734	SLE 160	1982	12.9	305	1993.535	48-in	12.93	306.1	2.31	0.1	POSS II	Poor	
18264-2111	ARA1534	1922	13.1	78	1992.581	48-in	12.90	84.6	-2.83	0.1	SERC	Medium	
18322+1713	SLE 189	1982	16.2	288	1995.638	48-in	12.57	292.3	-266.05	0.3	POSS II	Medium	
18337-1426	SLE 190	1982	14.4	32	1996.701	48-in	14.13	33.9	-18.25	0.1	SERC	Medium	
18384+6708	STF2384 AB-C	1910	113.5	167	1954.428	48-in	123.34	164.3	221.48	-0.1	POSS I	Good	
					1991.378	48-in	130.49	163.0	193.50	0.0	POSS II	Good	
18455-5356	HJ 5057	1913	10.9	81	1991.669	48-in	11.35	91.9	5.66	0.1	AAO	Medium	
18510-1958	ARA1162	1922	10.3	293	1985.529	1 m	9.97	292.5	-5.14	0.0	ESO	Medium	
					1998.538	48-in	10.74	292.5	59.19	0.0	SERC	Poor	
18556-2241	ARA1904	1923	13.1	260	1984.668	1 m	12.35	258.5	-12.11	0.0	ESO	Medium	
					1998.538	48-in	12.00	257.7	-25.84	-0.1	SERC	Poor	
18570+3254	BU 648 AB-C	1960	64.7	289	1992.634	48-in	70.34	292.3	172.83	0.1	POSS II	Good	
18570+3254	BU 648 AE	1934	105.3	320	1992.634	48-in	118.77	318.4	229.73	0.0	POSS II	Good	
18598+2336	POU3636	1950	17.1	42	1992.419	48-in	16.38	40.3	-17.01	0.0	POSS II	Good	
19021+2403	POU3655	1950	14.1	143	1992.419	48-in	13.74	143.9	-8.53	0.0	POSS II	Good	4
19053-0026	BAL 904	1908	14.5	38	1988.469	48-in	13.84	39.8	-8.22	0.0	POSS II	Medium	
19079+4050	HJ 1370 AC	1905	21.2	301	1995.466	48-in	24.76	322.7	39.39	0.2	POSS II	Good	
19082+0859	HJ 876	1914	30.2	5	1950.608	48-in	26.66	1.4	-96.79	-0.1	POSS I	Poor	
					1987.408	48-in	24.59	357.5	-56.07	9.7	POSS II	Good	
19096+2506	POU3732	1905	16.4	315	1950.453	48-in	16.60	315.4	4.47	0.0	POSS I	Poor	
					1992.419	48-in	16.55	317.1	-1.19	0.0	POSS II	Medium	
19134-0545	J 2583 AC	1943	25	315	1986.445	48-in	34.31	314.1	214.37	0.0	POSS II	Medium	
19140+3252	SEI 580	1893	15.5	343	1992.435	48-in	9.65	351.1	-58.88	0.1	POSS II	Poor	
19143-0843	A 98 AB	1937	26	128	1988.449	48-in	23.60	128.4	-46.62	0.0	POSS II	Poor	
19158-0020	BAL 905	1895	11.8	10	1951.641	48-in	12.58	1.1	13.77	-0.2	POSS I	Medium	
					1987.395	48-in	14.71	358.6	59.57	10.0	POSS II	Medium	

Table continues on next page.

Using VizieR/Aladin to Measure Neglected Double Stars

POS (2010)	ID	Epoch Orig	ρ	θ	Epoch	Apert	Avg ρ	Avg θ	Δ ρ	Δ θ	Plate Series	Plate Quality	Notes
19160-2530	J 1841 AC	1941	25	280	1985.532	48-in	19.17	279.8	-130.92	0.0	SERC	Poor	
19260+3555	BU 1286 AD	1908	37.6	39	1955.378	48-in	45.52	36.2	167.10	-0.1	POSS I	Very Poor	
					1992.662	48-in	52.16	34.9	178.05	0.0	POSS II	Medium	
19278-0012	BAL 910	1892	14.9	188	1987.395	48-in	12.13	187.6	-29.05	0.0	POSS II	Poor	
19322+3522	SEI 620	1983	22.4	28	1992.662	48-in	22.53	26.7	13.11	-0.1	POSS II	Medium	5
19324+5702	STI2437	1905	12.2	38	1953.607	48-in	12.31	31.7	2.26	-0.1	POSS I	Medium	6
					1989.642	48-in	11.80	30.7	-14.06	0.0	POSS II	Medium	
19357-0014	BUP 193	1909	113	258	1950.521	48-in	108.32	264.3	-112.71	0.2	POSS I	Medium	
					1985.686	48-in	104.63	270.7	-104.93	0.2	SERC	Medium	
19373+1628	H 6 26 AD	1899	160.8	343	1950.540	48-in	163.83	347.9	58.79	0.1	POSS I	Good	
					1992.432	48-in	162.75	347.6	-25.78	0.0	POSS II	Medium	
19399+3924	ALI1115	1928	10.5	194	1951.518	48-in	11.40	194.9	38.27	0.0	POSS I	Very Poor	
					1988.520	48-in	11.99	192.4	16.04	-0.1	POSS II	Poor	
19436-1528	BUP 197	1960	70.4	127	1985.624	48-in	64.49	125.3	-230.64	-0.1	SERC	Good	
19521+1138	BUP 200	1924	90.5	156	1953.615	48-in	86.70	147.1	-128.31	-0.3	POSS I	Good	
					1991.540	48-in	86.79	135.7	2.37	-0.3	POSS II	Good	
19522-5115	HJ 5150 AC	1925	23.3	258	1985.488	48-in	26.10	255.0	46.24	0.0	SERC	Medium	
19539+2348	POU4134	1906	13	194	1951.520	48-in	12.58	192.2	-9.26	0.0	POSS I	Medium	
					1996.525	48-in	12.71	189.6	3.00	-0.1	POSS II	Medium	
19541-0834	HJ 900	1906	46.4	78	1953.751	48-in	46.32	75.4	-1.71	-0.1	POSS I	Medium	
					1984.643	48-in	45.99	76.2	-10.67	0.0	SERC	Medium	
19547+2402	POU4136	1906	15.9	163	1951.529	48-in	16.35	162.0	9.96	0.0	POSS I	Medium	
					1996.525	48-in	16.90	161.2	12.19	0.0	POSS II	Poor	
19548+3724	SMA 110 AC	1929	13.7	12	1952.539	48-in	12.06	7.7	-69.53	-0.2	POSS I	Very Poor	
					1991.594	48-in	11.05	5.7	-25.86	-0.1	POSS II	Very Poor	
19550+0441	BAL2954 AC	1910	17	212	1950.524	48-in	14.95	213.0	-50.55	0.0	POSS I	Poor	
					1990.699	48-in	13.76	210.2	-29.58	-0.1	POSS II	Poor	
19572+3712	ALI 401	1929	11.1	104	1950.603	48-in	16.25	119.8	238.39	0.7	POSS I	Medium	
					1991.594	48-in	16.09	121.0	-3.98	0.0	POSS II	Medium	
20116+0145	BAL1548	1909	12.3	155	1987.712	48-in	12.70	157.0	5.02	0.0	POSS II	Poor	
20116+5539	STI2511	1917	10.9	155	1989.581	48-in	13.05	156.4	29.58	0.0	SERC	Poor	
20124-1237	BUP 206 AB	1979	83.5	269	1987.710	48-in	84.70	269.1	137.77	0.0	SERC	Medium	
20153+2536	BU 983 AC	1912	115.8	83	1992.716	48-in	115.07	82.7	-9.04	0.0	POSS II	Good	
20247-3445	HJ 5195 AB	1919	19.3	317	1985.687	1 m	20.13	317.2	12.45	0.0	ESO	Medium	
20324-0951	BU 668 AC	1921	103.2	200	1986.650	48-in	117.96	207.8	224.83	0.1	SERC	Good	
20408+1956	BUP 215 AB	1924	93.7	25	1951.513	48-in	84.16	23.9	-346.75	0.0	POSS I	Good	
					1992.665	48-in	71.19	25.1	-315.17	0.0	POSS II	Good	
20481+0224	BAL2035	1910	14.1	305	1987.573	48-in	13.23	303.6	-11.22	0.0	POSS II	Medium	7
21023+3931	WRD 1 EH	1875	35	140	1951.515	48-in	37.25	159.7	29.45	0.3	POSS I	Medium	
					1992.719	48-in	37.37	159.3	2.75	0.0	POSS II	Medium	

Table concludes on next page.

Using VizieR/Aladin to Measure Neglected Double Stars

POS (2010)	ID	Epoch Orig	ρ	θ	Epoch	Apert	Avg ρ	Avg θ	$\Delta\rho$	$\Delta\theta$	Plate Series	Plate Quality	Notes
21077-0534	BUP 225	1908	42	296	1953.680	48-in	46.82	279.0	105.41	-0.4	POSS I	Medium	
					1987.704	48-in	52.57	270.1	169.15	-0.3	SERC	Good	
21101+5715	STI2561	1917	14.5	5	1952.708	48-in	15.24	3.1	20.82	-0.1	POSS I	Medium	
					1989.666	1 m	14.38	2.8	-23.36	0.0	ESO	Medium	
21111-2219	ARA1939	1922	11.4	280	1989.759	1 m	13.94	275.7	37.41	-0.1	ESO	Poor	
21115+4115	STT 431 BC	1932	50.6	353	1991.518	48-in	55.23	354.7	77.76	0.0	POSS II	Medium	
21190+0559	HJ 3022 AB	1920	18.1	77	1995.578	48-in	17.13	76.9	-12.83	0.0	POSS II	Medium	
21221+1948	STFB 11 AC	1921	74.3	19	1991.526	48-in	66.72	14.8	-107.48	-0.1	POSS II	Medium	
21243+0327	BAL2561	1909	19.7	286	1952.643	48-in	19.59	287.1	-2.52	0.0	POSS I	Medium	
					1987.641	48-in	19.89	287.4	8.67	0.0	POSS II	Medium	
21290+2211	HJ 1647 AC	1966	40.3	129	1991.526	48-in	39.42	130.1	-34.67	0.0	POSS II	Good	
21323+3839	ALI 974	1929	10.7	206	1987.564	48-in	9.56	210.2	-19.52	0.1	POSS II	Very Poor	
21466+4713	HJ 1692	1907	11.8	250	1952.703	48-in	10.90	243.1	-19.73	-0.2	POSS I	Very Poor	
					1989.677	48-in	9.36	236.3	-41.52	-0.2	POSS II	Very Poor	
21501+3151	BU 692 BC	1913	37.8	297	1954.721	48-in	38.94	294.9	27.20	-0.1	POSS I	Good	
					1987.649	48-in	39.84	293.5	27.59	0.0	POSS II	Good	
21509-4052	CRU 2 AC	1901	47.9	45	1974.634	48-in	54.72	46.7	92.57	0.0	SERC	Good	
					1988.794	48-in	55.46	47.6	52.61	0.1	SERC	Medium	
21529+2525	POU5544	1898	18.8	19	1951.523	48-in	20.20	16.9	26.09	0.0	POSS I	Medium	
					1990.775	48-in	22.29	13.2	53.42	-0.1	POSS II	Medium	
21556-2108	HJ 3065 AB	1921	39.9	131	1984.806	1 m	40.96	128.0	16.59	0.0	ESO	Medium	
21565+6334	STI1074	1903	13.8	63	1991.695	48-in	8.29	63.4	-62.18	0.0	POSS II	Very Poor	
21592+7311	BU 1509	1930	131.4	173	1992.719	48-in	121.47	170.2	-158.33	0.0	POSS II	Good	
22273-0715	HJ 1764	1904	32.6	173	1954.519	48-in	38.14	162.7	109.66	-0.2	POSS I	Poor	
					1987.704	48-in	43.32	157.0	156.04	-0.2	SERC	Good	
22409+1433	HO 296 AB-C	1924	72.2	235	1991.698	48-in	91.01	235.0	277.85	0.0	POSS II	Excellent	
22467+1210	HJ 301 AC	1924	145	15	1953.632	48-in	155.25	11.0	345.91	-0.1	POSS I	Good	
					1990.633	48-in	173.43	6.7	491.34	-0.1	POSS II	Good	
22498-1104	BU 1219 AC	1909	116.6	147	1991.541	48-in	130.18	143.9	164.52	0.0	SERC	Good	8
22587+5731	STI2918	1920	12.9	114	1989.676	48-in	14.33	110.5	20.52	-0.1	POSS II	Medium	
23118+2651	BUP 234 AB	1924	82.9	240	1954.601	48-in	77.07	238.7	-190.52	0.0	POSS I	Good	
					1991.753	48-in	68.89	238.9	-220.18	0.0	POSS II	Excellent	
23134-7821	HJ 5385 AB	1918	40.1	325	1976.655	48-in	49.36	319.5	157.90	-0.1	SERC	Good	
					1984.748	1 m	50.64	319.1	157.34	-0.1	ESO	Good	
					1994.651	48-in	52.52	318.1	189.84	-0.1	SERC	Good	
23198+5543	HJ 1868	1908	14.4	208	1952.706	48-in	17.94	227.1	79.07	0.4	POSS I	Medium	
					1990.786	48-in	22.41	239.7	117.52	0.3	POSS II	Medium	
23354+5534	STI3004	1917	11.9	249	1995.638	48-in	14.61	252.7	34.42	0.0	POSS II	Medium	9

Table Notes on next page.

Table Notes:

1. The closest thing to this description is a pair with primary at 060650.70+361011.6. But θ is off by about 90°. I wonder if Ali misread his micrometer dial.
2. CPM pair.
3. Quadrant reversal is likely.
4. Actual position of primary is 190205.25+240237.3.
5. Actual position of primary is 193209.86+352107.7.
6. Actual position of primary is 193224.10+570143.4.
7. Actual position of primary is 204807.45+022207.0.
8. Actual position of primary is 224941.04-110659.3.
9. Actual position of primary is 233523.48+553351.1.

(Continued from page 76)

Acknowledgements

The author wishes to recognize the following as sources for material for this paper:

The Washington Double Star Catalog (WDS), hosted at http://ad.usno.navy.mil/proj/WDS/wds.html; this exhaustive database is the authoritative source for all modern double star research and is maintained at the U.S. Naval Observatory. This research has also made use of the VizieR catalogue access tool, CDS, Strasbourg, France. The original description of the VizieR service was published in A&AS 143, 23.

Richard Harshaw has been viewing the heavens for 50 years, the last 6 from his home in Cave Creek, Arizona. He served on the board of the Astronomical Society of Kansas City while a resident of that city, and has served two terms as President of Phoenix's Saguaro Astronomy Club and is currently its Secretary and newsletter editor. Richard has logged over 26,000 double star observations, including over 1,400 measurements registered with the WDS. He is the author of several papers for astronomical journals and also one book, The Complete CD Atlas of the Universe (published by Springer Verlag).

BN Orionis (TYC 126-0781-1) Duplicity Discovery from an Asteroidal Occultation by (57) Mnemosyne

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Abstract: An occultation of BN Orionis (SAO 112952, HD 245465, TYC 126-0781-1) by the asteroid (57) Mnemosyne on March 11, 2012 showed this star to be a double star. The separation of the two components (Sep) is 0.0038 ± 0.0008 arcseconds at a position angle (PA) of 63.6 ± 15.2 degrees. The magnitude of the primary component is estimated to be 9.9 ± 0.1. The magnitude of the secondary component is estimated to be 10.8 ± 0.2.

Target Star

TYC 126-0781-1 is the star that was targeted for this observation. Unknown to the observers at the time of the occultation, TYC 126-0781-1 is also listed in the General Catalogue of Variable Stars as BN Ori, an INSB eruptive variable. The target star is not listed in either the Fourth Interferometric Catalog or the Washington Double Star catalog. See text box labeled Figure 8 for documentation of the known stellar properties and a condensed description of the FU Ori (FUOR) characteristics of BN Ori.

Observation and Analysis

On 2012 March 11, Brooks, Conard, D. Dunham, J. Dunham, Jones, Lipka, Thomas, Warren, Wasson, and Wisniewski observed the asteroid (57) Mnemosyne occult the star TYC 126-0781-1 at thirteen locations across the United States, from the mid-Atlantic

(Continued on page 92)

Table 1: Observers, Site Locations, Telescopes and Observing Methods
Video+GPS time ins = NTSC CCD video with GPS time inserted on each frame
Video+GPS linked = NTSC CCD video with GPS time linked to each frame by calibrating GPS UT to digital video recorder clock time.

Observer	Location	Telescope Type	Telescope Diam (cm)	Observing Method
T. Lipka	Uniontown, MD	Newtonian	20	Video+GPS time ins
S. Conard	Gamber, MD	Schmidt-Cassegrain	36	Video+GPS time ins
R Wasson	Murrieta, CA	Newtonian (Dobson)	30	Video+GPS time ins
J. Brooks	Winchester, VA	Schmidt-Cassegrain	30	Video+GPS time ins
S. Conard	Dayton, MD	Schmidt-Cassegrain	13	Video+GPS time ins
W. Warren J. Dunham	Greenbelt, MD	Refractor	8	Video+GPS time ins
J. Wisniewski	The Plains, VA	Dobson Newtonian	30	Visual
R Jones	Salton City, CA	Schmidt Camera	20	Video+GPS time ins
D. Dunham	Hawthorne, MD	Refractor	8	Video+GPS linked
W. Thomas	Anza Borrego State Park, CA	Schmidt-Cassegrain	28	Video+GPS time ins
D. Dunham	Port Conway, VA	Refractor	8	Video+GPS linked
D. Dunham	Bowling Green, VA	Refractor	8	Video+GPS linked
D. Dunham	Doswell, VA	Refractor	8	Video+GPS time ins
D. Dunham	Doswell, VA	Refractor	12	Video+GPS time ins

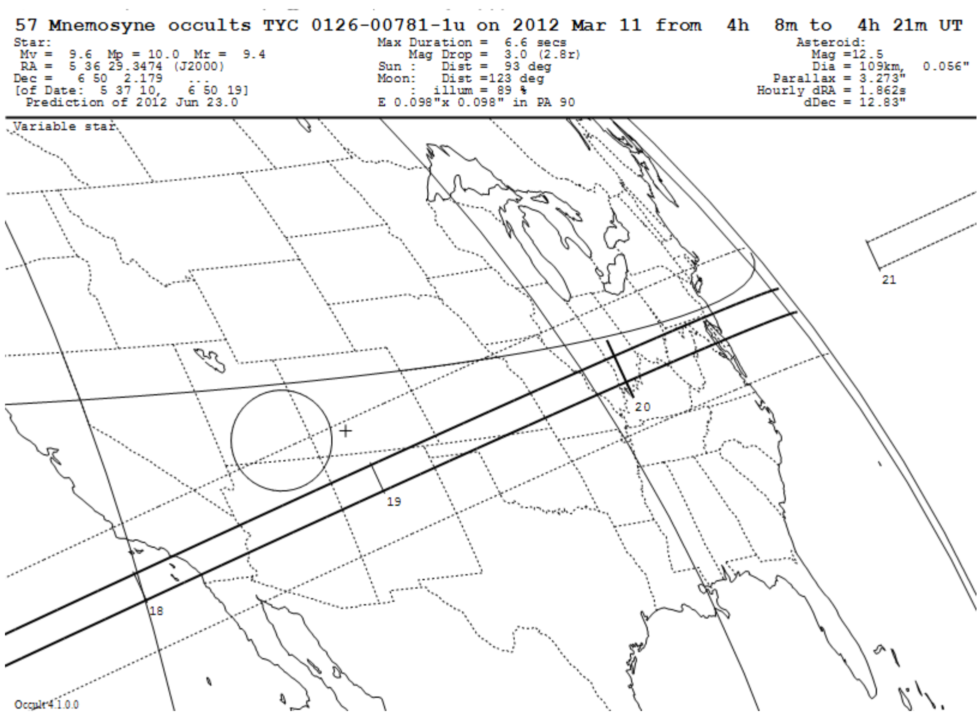

Figure 1: Occultation Path (Occult4)

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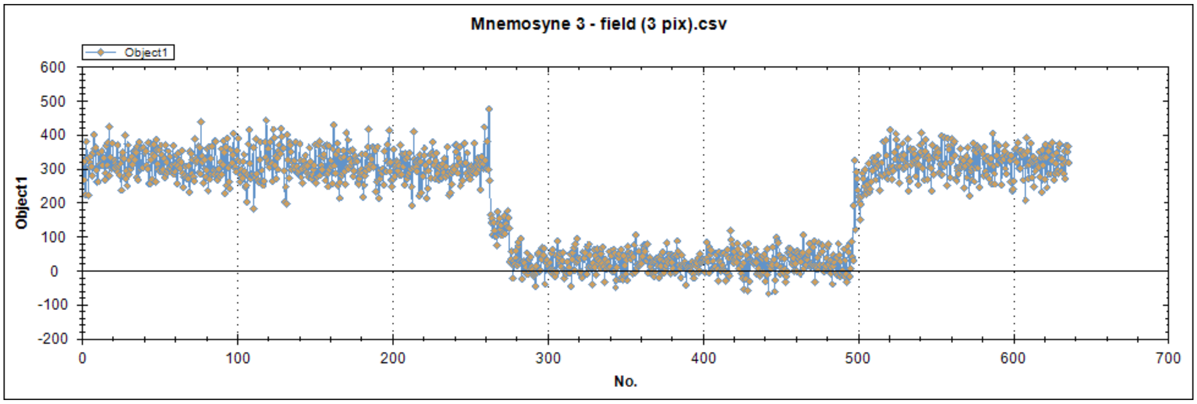


Figure 2 : Jones occultation light curve

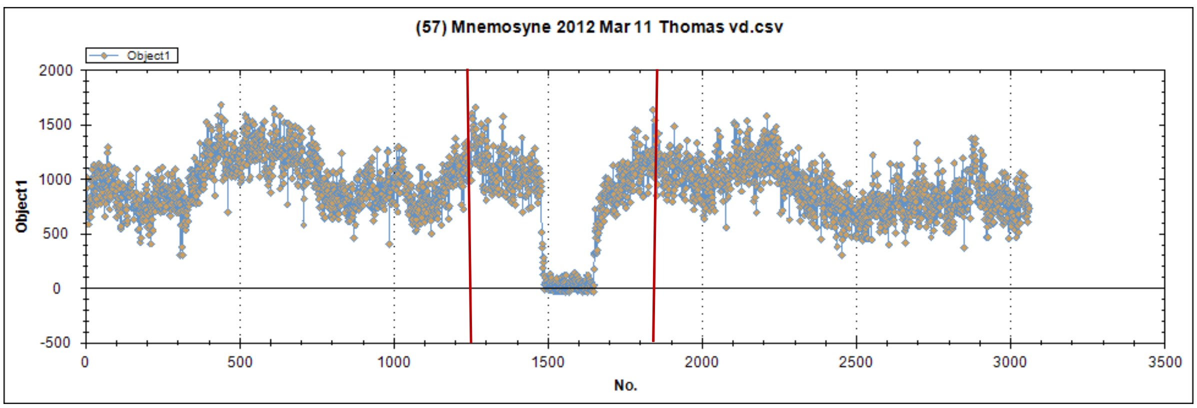


Figure 3: Thomas total raw-data light curve showing variable baseline due to clouds - data in the area between red lines were normalized and used in the final analysis of the double star solution.

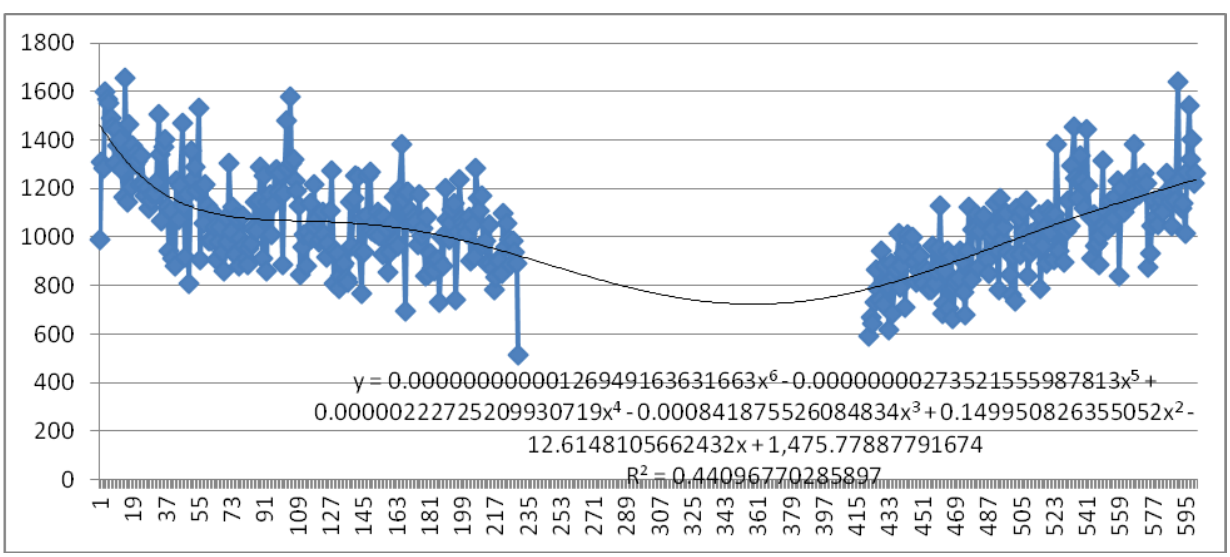


Figure 4: Thomas sixth order polynomial correction light curve between frames 1250 and 1850

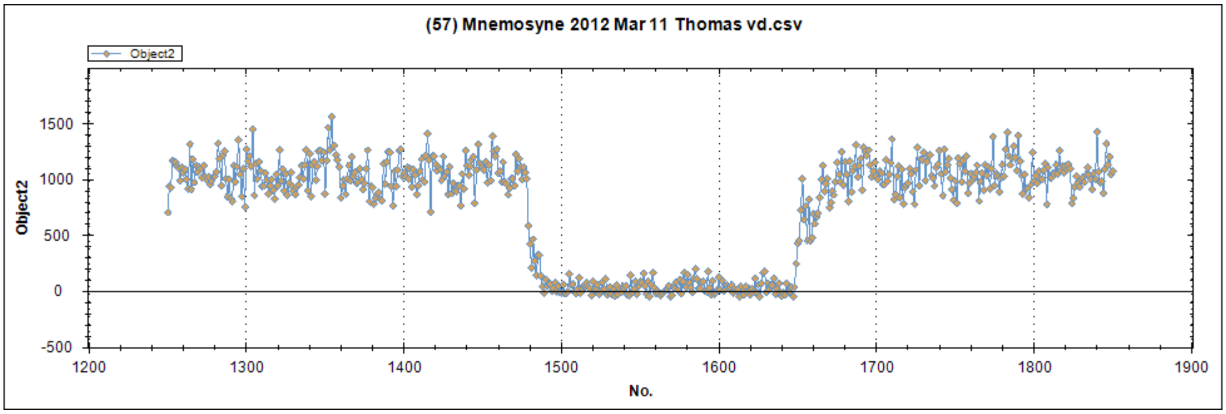


Figure 5: Thomas normalized occultation light curve

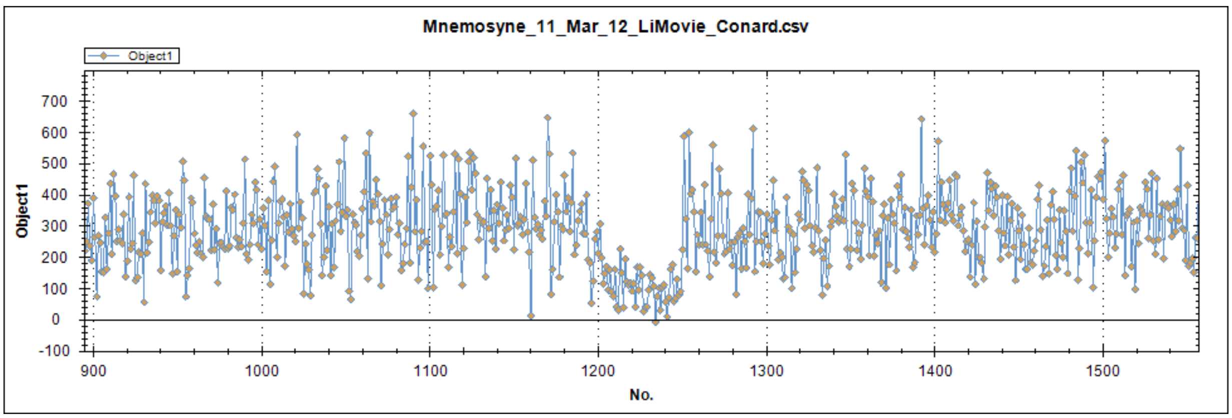


Figure 6: Conard single-step single star event

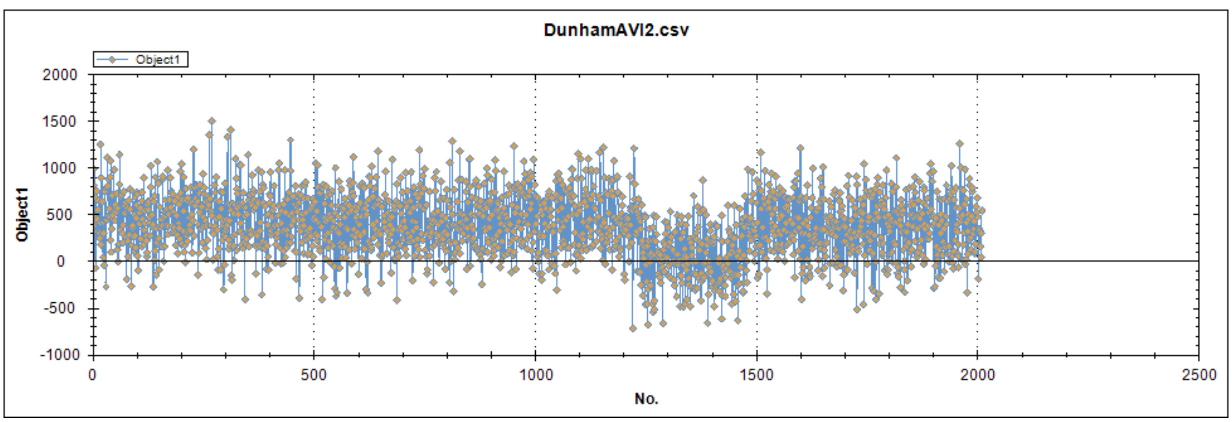


Figure 7: D. Dunham event

BN Orionis (TYC 126-0781-1) Duplicity Discovery from an Asteroidal Occultation by ...

(Continued from page 88)
states to California (see Figure 1). The observations were made at the locations and with the equipment listed in Table 1. This is the second recorded occultation of a star by (57) Mnemosyne.

Jones and Thomas both observed two step-event observations. The Jones event is shown in Figure 2. The Jones event disappeared in two steps of 0.95 magnitude drop and 1.78 magnitude drop, and reappeared in two steps of 2.44 magnitude increase and 0.31 magnitude increase.

The Thomas event raw-data light curve is shown in Figure 3. It appears to have been affected by clouds. In order to correct the Thomas light curve, we analyzed the portion of the curve nearest the event (red bars shown in Figure 3) and developed a normalization curve to correct the baseline values. The sixth-order polynomial trend-line solution is shown in Figure 4. Once the trend-line solution was used to normalize the data, the Thomas light curve had step events very similar to Jones as seen in Figure 5. The normalized disappearance (D) and reappearance (R) times were used in the calculation of the asteroid profile and double star PA and Sep.

At his Dayton, MD station, Conard had a chord near the edge of the asteroid. Careful analysis of the Conard light curve (Figure 6) did not show two steps in either the light curve D or R. Instead, there was a single (slightly grazing on disappearance) step with a magnitude drop of 1.07, which is consistent with the 0.97 magnitude drop recorded by Jones. Conard had a miss of the secondary star.

Other observations made by D. and J. Dunham, and Warren with smaller aperture telescopes were either unable to show the two-step light levels event due to high noise levels, or did not show the two-step light levels event. A representative light curve of the latter non-two-step observations is shown in Figure 7.

The altitude of the target star at the time of occultation may have also been a factor in being able to clearly see the steps in the light curve. Observers in California saw the star at an altitude above 45 degrees, while those in Maryland observed at an altitude of 17 degrees.

The original target star is listed as magnitude 9.60 (magnitude in Johnson V (T5)). However, since TYC 126-781-1 is listed as the variable star BN Ori in the GCVS, the actual brightness at the time of occultation may be different from predicted. The asteroid predicted magnitude was 12.5. The predicted combined magnitude of target star and asteroid was 9.53 magnitude. The expected magnitude drop at occultation was 2.97 magnitudes. (Occult4 predictions show slightly different magnitude estimates). Jones observed a total magnitude drop of 2.72, reasonably close to the predicted drop. The first disappearance drop of the two-step event was 0.95 magnitude, and the second drop was 1.78 magnitude. On reappearance, the magnitude increase was 2.44 and 0.31 magnitudes, respectively. These results are consistent with an ABAB occultation sequence, with A the brighter star at magnitude 9.92 and B the fainter star at magnitude 10.83.

See analysis done using the Magnitude calculator routine in Occult4 (Method 3 – Magnitudes from light curve values see Figure 9) and the MV from the TYC catalog.

In order to determine the position angle (PA) and separation (Sep) of the suspected double star, the observations were analyzed in the standard manner described by IOTA. See Figure 8 for a plot of the asteroid shape, size, PA and Sep derived from the data.

Based on the data presented in this report, the characteristics of the suspected double star are shown in Text Box 2.

Based on the calculated 0.0038 arcsecond angular separation for this double star system, assuming that the second star is actually a binary and not a background star, and assuming a 450 pc distance to BN Ori, the secondary star is calculated to be 1.7 AU from the primary star.[6]

Acknowledgements

The authors would like to acknowledge the contribution of Dave Herald, Hristo Pavlov, and Steve Preston to the observation and analysis of the BN Orionis occultation. Steve Preston provided the updated path predictions needed for the observers to get in the correct positions to observe the event. Hristo Pavlov provided the program OccultWatcher that observers used to coordinate site locations. Dave Herald provided the program Occult4 used for data reduction and analysis and comments on the solution of the asteroid profile, PA and Sep.

References

1. "Dunham, D.W., Herald, D., Frappa, E., Hayamizu, T., Talbot, J., and Timerson, B., Asteroid Occultations V10.0. EAR-A-3-RDR-OCCULTATIONS-V10.0. NASA Planetary Data System, 2012." The data is found at the URL:

(Continued on page 95)

BN Orionis (TYC 126-0781-1) Duplicity Discovery from an Asteroidal Occultation by ...

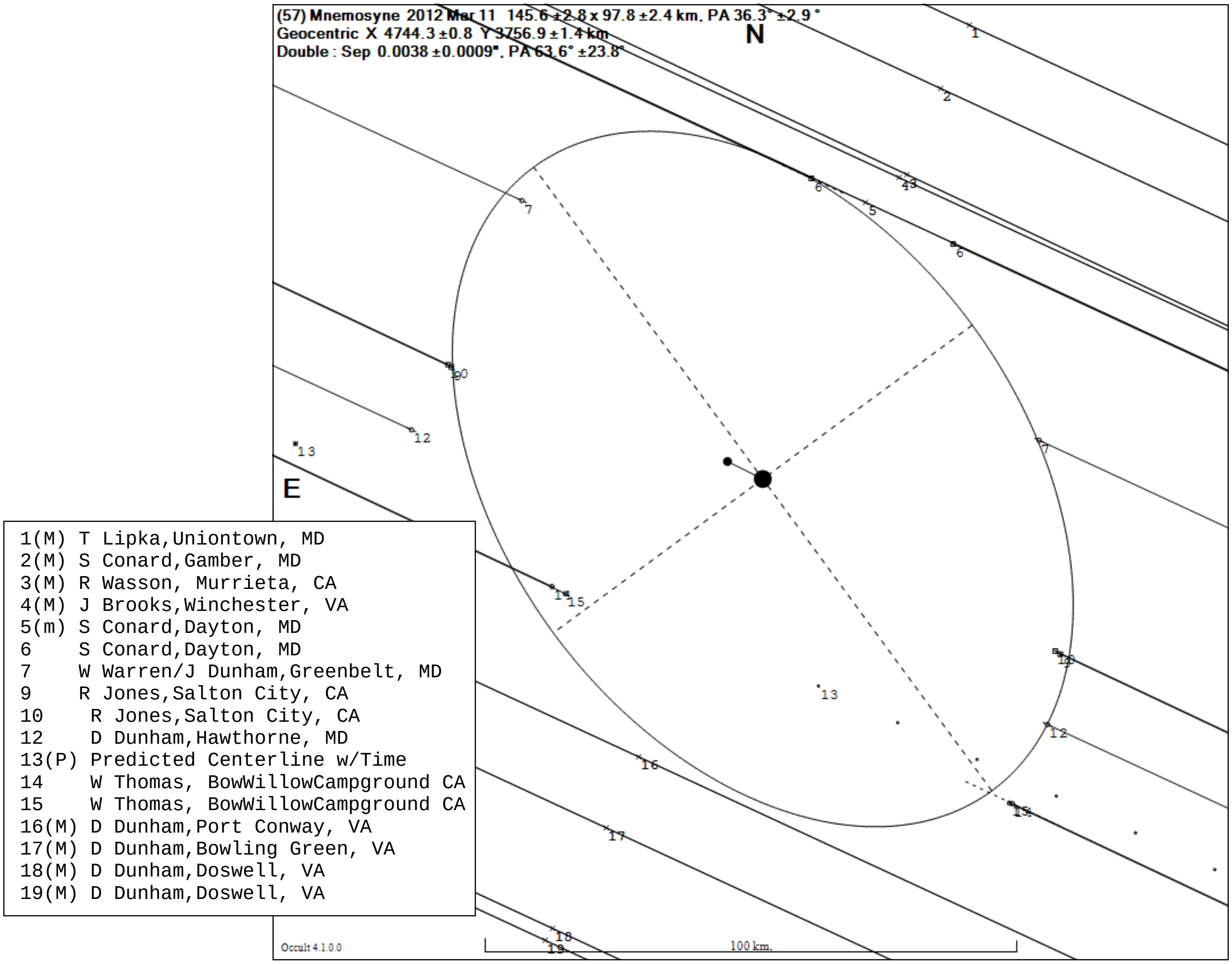


Figure 8: (57) Mnemosyne occultation of TYC 126-0781-1 – video CCD observations – ellipsoid of best fit and double star solution plot. Chord 8 was a visual observation and not used in the double star solution.

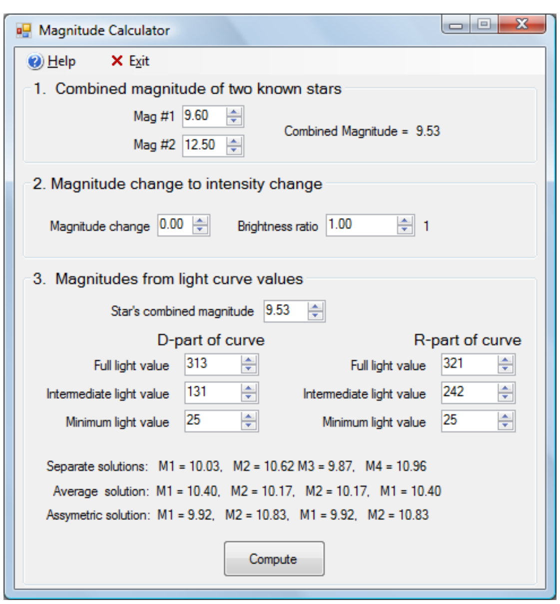


Figure 9 Calculation of component star magnitudes

BN Orionis (TYC 126-0781-1) Duplicity Discovery from an Asteroidal Occultation by ...

Star Diameter
diameter = .0001" [Estimated]
= 0% of the asteroid's diameter
=> Fades caused by the star diameter are not expected.
Fresnel diffraction
diffraction for light drop of 2 mag (to 16%) = 0.0002"
fades of 0.02 secs might be expected
diffraction for light drop of 4 mag (to 2.5%) = 0.0005"
fades of 0.05 secs might be expected
AAVSO Variable star entry

Variable identifier	Type	Max	Min
BN Ori	INSB	8.8	13.9

From its discovery as a variable until 1947 the star behaved more like a Herbig Ae-type star with strong and irregular brightness variations. Then in 1947 the behaviour changed to FU-Ori object, or FUOR with a sharper large scale rise in brightness followed by a more gradual fading over 15 years and remained constant for 30 years thereafter. The current stellar classification is A7 (Pre Main Sequence) , 2-5 solar masses, with some surrounding gas and dust (faint emission nebula) and possessing an accretion disk, at a distance of some 400 pc but is rotating at speeds upward of 220 km/sec making it a faster than usual FUOR like object. The change in brightness since 1947 and steady output seems to indicate that a FUOR event blew away or at least for now cleared the dust shell and was triggered by thermal runaway in the inner accretion disk by a moderate increase in accretion rate. In 1991 there was a slight 0.5m drop in brightness that lasted for approximately 51 nights and this was attributed to infilling circumstellar dust.

Source: “The FUOR characteristics of the PMS star BN Orionis inferred from new spectroscopic and photometric observations”; Shevchenko, V. S.; Ezhkova, O.; Tjin A Djie, H. R. E.; van den Ancker, M. E.; Blondel, P. F. C.; de Winter, D. **Astronomy & Astrophysics Supplement** series, Vol. 124, July 1997, 33-54.

Text Box 1 – Documentation of miscellaneous star properties

Star Catalogue No.[3]	SAO 112952 BD +06° 971 HD 245465 AGK3 +06° 0599 TYC 126-0781-1 UCAC2 34055899 3UC 194-028123 NOMAD 0968-0002500 PPMXL n06d-0135833
Spectral Type	A7[4]
Coordinates (J2000)[5]	RA 05 36 29.365 Dec +06 50 02.11
Mag A	9.92 ±0.15
Mag B	10.83±0.15
Separation	0.0038 +/- 0.0008 arcseconds
Position Angle	63.6 +/- 15.2degrees

Text Box 2: Characteristics of the suspected double star

BN Orionis (TYC 126-0781-1) Duplicity Discovery from an Asteroidal Occultation by ...

(Continued from page 92)

http://sbn.psi.edu/pds/resource/occ.html. The most recent version of the database is always listed at the top. You may 'Browse' or 'Download' the database. If you 'Browse', there are six links. The first, "aareadme.txt", is a high -level summary. The asteroid occultation data is found by clicking on the "data" link. Under the "data" link. The file "occsummary.tab" contains information about all of the occultation solutions, ordered by asteroid number. The file "occlist.tab" lists all of the observed asteroidal occultations, in chronological order by "SEQ_NUM". The file "occlist.lbl" describes the format and information in the columns. The file "occtimings.tab" give the individual timings, in event chronological order, then in order of observers. The first column is the "SEQ_NUM" for the occultation, which is the same "SEQ_NUM" used in the "occlist.tab" file. All of these terms are defined in a format specific to the NASA PDS system. The details of reading the files are explained at: http://pdssbn.astro.umd.edu/howto/understand.shtml.

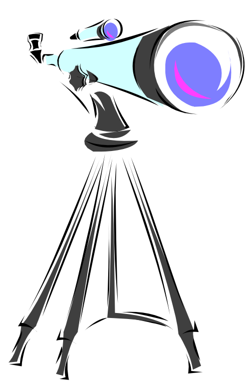
2. New Double Stars from Asteroidal Occultations, 1971 – 2008, Dave Herald, Canberra, Australia, Journal of Double Star Observations, Volume 6 Number 1 January 1, 2010

3. C2A (Computer Aided Astronomy), Philippe Deverchère, a Planetarium software that displays the following catalogues: SAO, GCVS, WDS and Hipparcos, Guide Star, Tycho-2, USNO-SA1.0, USNO-A2.0, USNO-B1.0, UCAC1, UCAC2, UCAC3, NOMAD and PPMXL.

4. Positions and Proper Motions - North (Roeser+, 1988)

5. The Hipparcos and Tycho Catalogues (ESA 1997), VizieR, Centre de Données astronomiques de Strasbourg

6. Personal communication: Dr. Mario van den Ancker, European Southern Observatory



Study of a New CPM Pair 2Mass 14515781-1619034

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Abstract: In this paper I present the results of a study of 2Mass 14515781-1619034 as components of a common proper motion pair. Because PPMXL catalog's proper motion data not provide any information about secondary star, I deduced it independently, obtaining similar proper motions for both components. Halbwalchs' criteria indicates that this is a CPM system. The criterion of Francisco Rica, which is based on the compatibility of the kinematic function of the equatorial coordinates, indicates that this pair has a 99% probability of being a physical one (Rica, 2007). Also other important criteria (Dommanget, 1956, Peter Van De Kamp, 1961, Sinachopoulus, 1992, Close, 2003), indicate a physical system.

With the absolute visual magnitude of both components, I obtained distance modulus 7.29 and 7.59, which put the components of the system at a distance of 287.1 and 329.6 parsecs. Taking into account errors in determining the magnitudes, this means that the probability that both components are situated at the same distance is 96%.

I suggest that this pair be included in the WDS catalog .

Introduction

The main purpose is to study the pair, 2Mass 14515781-1619034, shown in Figure 1, to determine some important astrophysical features such as distance, spectral type of the components, etc. This was done by an astrophysical evaluation using kinematics, photometric spectral and astrometric data, obtaining enough information to determine if there is a gravitational tie between both components.

In this study, I used Francisco Rica Romero's spreadsheet (Astrophysics, SDSS-2MASS-Johnson conversions) that makes many astrophysics calculations

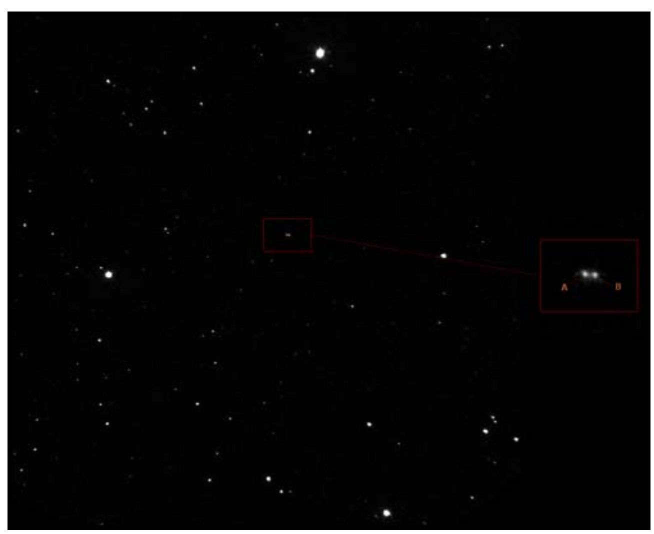

Figure 1: Picture based on DENIS plate that shows the system under study with components clearly identified.

Proper motion

I started by obtaining the proper motions for the pair given in the PPMXL catalog (a catalog that provides positions and proper motions) and shown in Table 1.

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Table 1: Proper motion of the pair described in this study from the PPMXL catalog.

Component	Proper Motion RA (mas/yr)	Proper Motion DEC (mas/yr)
A	-21.0 ± 4.0	-15.9 ± 4.0
B	?	?

Unfortunately, I couldn't find any information about the secondary star, so I made an independent study about the proper motions of this system, where I calculated components' positions from different dates plates that I obtained using Aladin Sky Atlas with a short timeline difference of 9.1595 years and showed large and similar proper motions. I made the measurements using Astrometrica software, the stars were not saturated in any plate, so that the measurements were easily made. The results are shown in Tables 2 and 3.

The proper motions being quite similar suggest that this system could be a CPM pair and that was the reason I decided to study this system.

With those results, I obtained the tangential velocities given in Table 4.

Relative Astrometry

Relative astrometry measurements were based on plates from different dates with resolution of 1.1 a.s., all plates were obtained from Aladdin software. I used Astrometrica software for obtaining angle deviation and applying that value on Reduc software calibration parameters for each plate. Reduc also let me obtain Theta and Rho values for each plate (see Table 5).

Photometry / Spectral type of the components

I retrieved all plates with plate resolution around 1 arcsecond/pixel and catalog data of the image field from 2MASS (Table 6).

Using Francisco Rica Romero's astrophysics spreadsheet **"**SDSS-2MASS-Johnson conversions**",** I obtained the results shown in Table 7.

With this set of photometry in bands J,H,K, the deduced B,V,I and using the Francisco Rica Romero's "Astrophysics" spreadsheet, I can evaluate and calculate the spectral type of each component from photometric data. I obtained M0V and M0.5V for the primary and secondary respectively.

Using the same spreadsheet I obtained the reduced proper motions for the companions presented in Table 8. Reduced Proper Motions Diagram (Figure 2)

Table 2: Coordinates vs Besselian date information used to calculate proper motion for each component

Besselian date	Primary RA (°)	Primary DEC (°)	Secondary RA (°)	Secondary DEC (°)
1992.2425	222.990750	-16.317722	222.989875	-16.317722
1993.2529	222.990792	-16.317611	222.989917	-16.317611
1999.2995	222.990708	-16.317750	222.989833	-16.317750
2001.4020	222.990917	-16.317722	222.990042	-16.317722

Table 3: Proper motions deduced using coordinates from Besselian date plates (Besselian date vs coordinates)

	Primary RA	Primary DEC	Secondary RA	Secondary DEC
Proper motion (mas/year) (± error)	+61.92 ± 3.97	-26.28 ± 2.8	+61.92 ± 3.97	-26.28 ± 2.8

Table 4: Tangential velocity calculation based on deduced proper motions given in Table 3.

Tangential Velocity Calculation	A	B
Mu (alpha) =	0.062	0.062
Mu (delta) =	-0.026	-0.026
Pi (") =	0.0035	0.0035
Ta (km/s)	84	97
Td (km/s)	-36	-41
Vt (Km/s)	92	105

Table 5: Theta / Rho measurements obtained with Reduc software

Besselian Date	Theta (deg)	Rho (as)
1992.2425	266.38	3.832
1993.2529	266.85	3.886
1999.2995	262.18	4.119
2001.4020	266.55	4.161

Table 6: Photometric magnitudes pulled from 2MASS (infrared) catalog.

	J	H	K
A	13.583	12.986	12.614
B	14.043	13.362	13.046

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shows that both components are situated in the swarf/subdwarf region.

With this set of photometry in bands J,H,K, the deduced B,V,I and using the Francisco Rica Romero's "Astrophysics" spreadsheet, I calculated the spectral type of each component from photometric data. I obtained M0V and M0.5V for the primary and secondary respectively.

Using the same spreadsheet, I obtained the reduced proper motions for the companions presented in Table 8. In that table, H is the apparent magnitude the star would have at a distance for which its proper motion is 0.1 as/yr. The Reduced Proper Motion Diagram (Figure 2) shows that both components are situated in the dwarf/subdwarf region.

The results suggest that the primary component as well its companion are main sequence stars.

The absolute visual magnitude of both components enable the calculation of the distance modulus, I used Francisco Rica Romero's spreadsheet "Astrophysics" and the results are shown in Table 9.

Distance moduli obtained for each component were similar, which means that taking into account the errors in determining the magnitudes, the probability that components are at the same distance is 96%.

Conclusions

If we consider the spectroscopy obtained above to be reliable, we can estimate the sum of the masses to be 0.64 solar masses at a distance calculated above. Wilson and Close criteria indicate a physical system as do the Jean Dommanget, Peter Van de Kamp and Dimistris Sinachopoulos criteria.

The distance moduli put both components at the same distance 287.1 (primary) and 329.6 (secondary) parsecs, which means that the probability that both components are at the same distance is 96%, and is a good indicator of the possible physical relation between the components

Respect to the kinematics, I intended to verify the plate kinematics through digitized plates from different dates being the difference (besselian date): 9.1595 years, It's a short period of time but in that study the proper motions are high. I made this study because I couldn't find any information about secondary's proper motion, obtaining good and similar results on RA and DEC, that results suggest that system as CPM.

The latest image available from Aladin software (2001.4020) gives astrometry values $\Theta = 266.55°$ and $\rho = 4.161''$. Using these numbers in Francisco Rica

Table 7: Color indices (B-V), (V-I), and V magnitude from JHK (2MASS) photometric magnitudes and using Francisco Rica Romero's "SDSS-2MASS-Johnson conversions". Bolometric correction calculated using Rica Romero's "Astrophysics" spreadsheet.

	Color B-V	Color V-I	Magnitude V	Bolometric correction
A	1.42	1.58	16.29	- 0.939
B	1.49	1.63	16.84	- 1.024

Table 8: Reduced Proper Motion

BAND	Mag (A)	H(A)	Mag (B)	H(B)
V	16.29	15.4	16.84	16.0
K	12,614	11.8	13.046	12.2

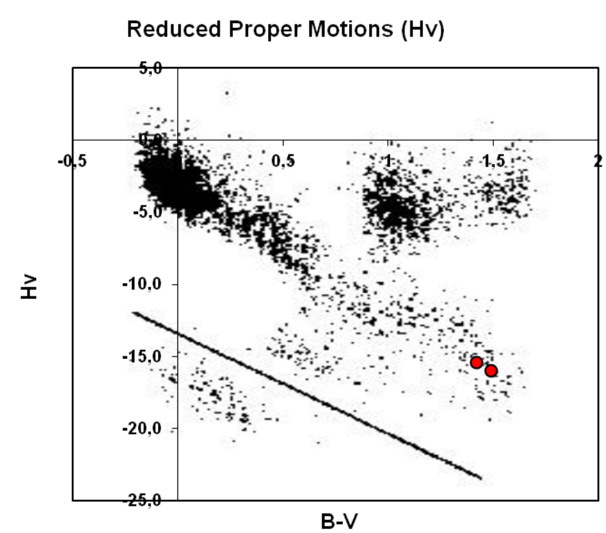

Figure 3: Reduced-Proper diagrams after II. Luyten's White Dwarf Catalog (Jones, 1972). This diagram shows that both components are situated in the swarf/subdwarf region.

Table 9: Distance modulus and distance in parsec values obtained using Francisco Rica Romero's spreadsheet "Astrophysics"

Component	Distance modulus	Distance (parsec)
A	7.29	287.1
B	7.59	329.6

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Romero's spreadsheet calculates the parameter (p/μ) representing the time it takes the star to travel a distance equal to their angular separation and gives T = 59 years. This result is consistent with the system being a bound system. Halbwachs' criteria tell us that this is a CPM system and Rica criterion (Rica, 2007), indicates that this pair has a probability of 96% to be a physical one.

In summary, with the present information we can consider this pair as a binary and I suggest that this pair be included in the WDS catalog.

Acknowledgements

I used Florent Losse's "Reduc" software for relative astrometry and Herbert Raab's "Astrometrica" software to calculate plate's angle deviation.

I used Francisco Rica Romero's "Astrophysics" and "SDSS-2MASS-Johnson conversions" spreadsheets with many useful formulas and astrophysical concepts.

The data analysis for this paper has been made possible with the use of Vizier astronomical catalogs service maintained and operated by the Center de Donnès Astronomiques de Strasbourg (http://cdsweb.ustrasbg.fr)

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Divinus Lux Observatory Bulletin: Report #28

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Abstract: This report contains theta/rho measurements from 133 different double star systems. The time period spans from 2012.552 to 2012.669. 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.

This article contains a listing of double star measurements that are part of a series, which have been continuously reported at Divinus Lux Observatory, since the spring of 2001. The selected double star systems, which appear in the table below, have been taken exclusively from the 2006.5 version of the Washington Double Star (WDS) Catalog, with published measurements that are no more recent than ten years ago. There are also some noteworthy items that are discussed, which pertain to a few of the measured systems.

To begin with, there are some possible common proper motion pairs, which don't appear to have been previously cataloged, that have been labeled with the ARN prefix in the table below. The first one is identified as ARN 116 (19355+1148) in the constellation of Aquila. The second such double star, listed as ARN 117 (19457+3930), is located in Cygnus. The third one appearing in the table, bearing the label of ARN 118 (19482+3256), is also located in Cygnus. Not far from ARN 118 is a fourth new find labeled as ARN 119 (19486+3258), also located in Cygnus. The final new pair appearing in the table, listed as ARN 120 (19574+2709), is located in Vulpecula.

Two possible corrections are also being suggested for the WDS Catalog. The first one pertains to the STT 592 star system (20041+1704). As listed in the WDS, there are 3 different components that are identified with the "a" suffix. This report identifies "a" as the brightest component of the three, with measurements for "Ba" appearing in the table below. Secondly, TOB 166 (20060+3545) appears to be a duplicate entry for SHJ 325 AD (20060+3546).

Finally, regarding one of the double stars that has been measured for this report, a proper motion shift by one of the components appears to be responsible for some noteworthy changes with the theta/rho parameters. In this regard, ARY 28 AB has displayed a 3% rho increase and a 2 degrees theta decrease, since 2002, because of proper motion by the "A" component.

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Name	RA DEC	Mags	PA	Sep	Date	Notes
STF2426 AB	19000+1253	7.2 8.9	261.1	16.79	2012.552	1
STF2425	19006-0807	7.7 8.5	177.7	29.63	2012.552	2
STF2445 AB	19046+2320	7.2 8.5	262.1	12.34	2012.552	3
STF2445 AC	19046+2320	7.2 8.3	108.8	144.18	2012.552	3
STF2461 AD	19074+3230	5.2 9.0	291.4	137.26	2012.552	4
STF2467	19081+3048	10.1 0.3	262.6	10.37	2012.552	5
STT 177 AC	19126+1651	6.8 7.9	276.5	98.75	2012.552	6
STT 366 AB	19142+3413	7.7 10.5	229.9	21.73	2012.552	7
SHJ 292 AB	19164+3808	4.3 10.1	70.2	99.74	2012.552	8
STF2497	19200+0535	7.6 8.4	356.6	30.12	2012.552	9
STF2511 AC	19205+5020	7.3 10.0	118.1	77.52	2012.552	10
STF 41 AB	19244+1656	6.2 6.8	78.3	342.66	2012.552	11
ARY 17	19254+2542	8.2 8.7	267.7	116.53	2012.552	12
STF2521 AC	19265+1953	5.8 10.5	325.7	75.05	2012.552	13
STF2521 AD	19265+1953	5.8 10.5	62.2	152.08	2012.552	13
BU 1469	19265+0020	4.7 9.4	287.4	200.46	2012.555	14
STF 42	19287+2440	4.4 5.8	28.4	426.60	2012.555	15
ARY 18	19300+2600	8.9 10.4	12.7	109.61	2012.555	16
ARG 104	19302+5525	6.9 9.2	94.1	75.54	2012.555	17
BKO 63 AC	19330+3317	9.3 10.7	99.4	34.56	2012.555	18
ARY 19 AB	19333+2629	8.8 9.3	12.7	48.39	2012.555	19
ARY 19 AC	19333+2629	8.8 9.9	146.3	145.16	2012.555	19
BU 653 AE	19341+0723	4.4 9.4	61.9	165.90	2012.555	20
ARY 20	19352+2601	7.9 8.3	338.3	109.61	2012.555	21
ARN 116*	19355+1148	10.4 10.6	95.3	24.19	2012.555	22
ARY 21	19363+2640	8.2 9.6	274.0	63.20	2012.555	23
H 26 AB	19373+1628	5.7 8.3	82.0	87.69	2012.555	24
S 722	19392-1654	7.1 7.4	235.7	9.88	2012.555	25
SEI 654	19393+3152	9.2 10.6	115.0	14.81	2012.555	26
STF2557 AB	19396+2945	7.5 10.2	102.9	10.86	2012.555	27
ABH 124 AD	19396+2945	7.5 10.6	146.7	47.89	2012.555	27
ABH 124 AF	19396+2945	7.5 10.3	179.5	88.88	2012.555	27
ABH 124 AH	19396+2945	7.5 10.5	92.4	103.69	2012.555	27
STF2561	19409+2708	7.7 10.6	300.0	17.78	2012.557	28
BUP 196	19426+4002	7.9 8.3	165.7	106.65	2012.557	29
STF2562 AB	19428+0823	6.9 8.6	251.2	27.16	2012.557	30
STF2562 AD	19428+0823	6.9 9.7	221.7	117.51	2012.557	30
ARY 22	19441+5054	8.2 9.9	221.8	59.25	2012.557	31
ARN 117*	19457+3930	8.6 9.9	161.5	28.64	2012.557	32
ARN 118*	19482+3256	10.1 10.4	22.4	11.85	2012.557	33
ARN 119*	19486+3258	8.9 9.9	283.2	57.77	2012.557	34
STF2588 A-BC	19490+4423	7.7 8.1	158.8	9.88	2012.557	35
H 99 AB	19500+1757	8.0 10.7	83.1	25.18	2012.557	36
H 99 AC	19500+1757	8.0 9.1	255.7	68.63	2012.557	36
HJ 604	19557+4024	7.4 9.3	92.7	70.61	2012.557	37
BU 1474	19572+4022	5.4 9.3	315.7	64.68	2012.557	38
ARN 120*	19574+2709	9.6 10.2	92.7	93.32	2012.557	39
S 730 AB	20001+1737	7.0 8.4	14.3	112.58	2012.568	40
S 730 AC	20001+1737	7.0 10.2	337.6	78.51	2012.568	40
S 730 AD	20001+1737	7.0 10.7	198.0	40.49	2012.568	40

Table continues on next page.

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Name	RA DEC	Mags	PA	Sep	Date	Notes
H 100 AB	20001+1731	9.9 10.0	255.6	24.19	2012.568	41
H 100 AC	20001+1731	9.9 5.4#	296.2	113.56	2012.568	41
STT 396	20033+1830	6.0 10.3	207.7	46.41	2012.568	42
STF2624 Aa-C	20035+3601	7.1 9.2	327.4	42.96	2012.568	43
STF 592 AB	20041+1704	5.8 9.4	290.2	163.93	2012.568	44
STF 592 AC	20041+1704	5.8 6.9	334.6	216.26	2012.568	44
STT 202 Ba	20041+1704	9.4 8.8#	230.4	181.70	2012.568	44
SHJ 316 AB	20057+3536	7.8 8.8	323.0	69.62	2012.568	45
SHJ 315 AD	20060+3546	7.9 8.7	235.6	20.24	2012.568	46
ENG 70	20062+5310	5.8 9.7	135.3	169.85	2012.568	47
STF2627 AC	20077+0446	9.6 7.5#	260.7	81.96	2012.568	48
ARN 20 AD	20077+0446	9.6 8.7#	126.7	99.74	2012.568	48
STF2693 AB	20093+3529	7.8 8.7	301.8	5.93	2012.568	49
BLL 46 AB	20119+3612	8.1 10.6	108.8	53.33	2012.568	50
AG 249	20123+3451	7.7 10.7	132.4	32.59	2012.568	51
BLL 47 AB	20134+3844	7.6 7.1#	353.9	131.34	2012.571	52
BLL 47 AC	20134+3844	7.6 9.3	105.8	154.05	2012.571	52
S 470	20142+0635	7.7 8.0	191.7	43.45	2012.571	53
ENG 72 AB	20145+3648	4.9 6.6	155.3	216.26	2012.571	54
ENG 72 AC	20145+3648	4.9 9.9	21.5	212.31	2012.571	54
ENG 72 BD	20145+3648	6.6 10.6	119.6	217.25	2012.571	54
S 743	20155+4743	4.0 8.3	174.7	208.36	2012.571	55
STT 404 AB	20158+5230	7.4 9.7	115.1	28.64	2012.571	56
ARY 24	20165+3703	6.4 9.6	306.9	96.78	2012.571	57
AGC 12 AD	20181-1233	3.6 10.4	158.7	153.06	2012.571	58
STF 51 AE	20181-1233	3.6 4.2	290.2	381.18	2012.571	58
WAL 131 AE	20183+2539	7.0 8.1	151.2	122.45	2012.571	59
H 87	20194-1907	5.3 9.2	179.7	56.29	2012.571	60
ARY 26	20209+3657	8.5 10.6	307.2	111.59	2012.571	61
STF 52 Aa-Ba	20210-1447	3.1 6.1	266.5	205.40	2012.571	62
STF 52 Aa-C	20210-1447	3.1 9.0	133.0	226.14	2012.571	62
STF2681 AC	20228+5325	8.0 8.1	199.0	38.51	2012.571	63
ENG 74 AC	20242+1113	8.7 10.7	96.7	159.98	2012.574	64
STF2679 AB	20244+1935	7.9 9.6	77.2	24.69	2012.574	65
S 749 AB	20275-0206	6.7 7.4	188.5	59.74	2012.574	66
STI2535 AB	20289+5655	9.7 10.5	227.3	13.83	2012.574	67
STF2691	20297+3808	8.1 8.5	31.3	17.28	2012.574	68
S 755 AB	20309+4913	6.6 9.7	277.8	60.24	2012.574	69
BU 1489 AB	20339+4642	5.8 9.3	16.0	116.53	2012.574	70
STF2699 AB	20369-1244	8.0 9.1	196.8	9.38	2012.574	71
A 742 A-BC	20378+2943	8.2 10.3	343.3	56.78	2012.574	72
ARY 28 AB	20413+3012	8.2 9.4	332.1	62.21	2012.574	73
ARY 28 AC	20413+3012	8.2 9.7	35.0	102.70	2012.574	73
BUP 217 AD	20433+2549	7.0 9.2	102.2	388.09	2012.574	74
BUP 217 AE	20433+2549	7.0 10.2	286.1	442.40	2012.574	74
SKI 11	20465-1642	9.0 9.6	291.0	3.95	2012.574	75
ARG 93	20469+3252	8.3 9.6	87.9	10.86	2012.577	76
STT 414 AB	20472+4225	7.4 8.9	94.1	9.88	2012.577	77
BOT 4 AC	20472+4225	7.4 9.9	15.5	105.66	2012.577	77

Table continues on next page.

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Name	RA DEC	Mags	PA	Sep	Date	Notes
S 763 AB	20484-1812	7.1 7.7	293.4	15.80	2012.577	78
ES 94 AB	20496+5008	6.6 10.4	14.8	102.70	2012.577	79
GUI 34 AD	20496+5008	6.6 10.6	58.3	86.90	2012.577	79
STF2729 AD	20514-0538	6.3 9.5	323.7	137.26	2012.577	80
BLL 52	20539+3326	5.5 10.2	59.3	186.64	2012.577	81
BU 1034 AC	20569-0942	5.5 9.8	66.0	177.75	2012.577	82
A 756 AC	20577+5849	7.9 9.3	196.5	53.82	2012.577	83
ARN 34 AD	20577+5849	7.9 7.9	265.0	215.28	2012.577	83
STF2738 AB	20585+1626	7.5 8.6	254.3	14.81	2012.577	84
STF2738 AC	20585+1626	7.5 8.1	103.7	209.35	2012.577	84
BU 1138 AC	21028+4551	6.5 7.7	329.5	152.08	2012.593	85
ARN 21 AF	21035+2906	6.9 10.0	232.8	220.21	2012.593	86
HDS3001	21044+4631	9.3 10.7	93.5	18.27	2012.593	87
ROE 45 AB	21061+4448	8.1 10.3	285.8	134.30	2012.593	88
ROE 45 AD	21061+4448	8.1 10.5	240.8	131.34	2012.593	88
ROE 45 BC	21061+4448	10.3 10.5	238.1	123.44	2012.593	88
STF2754 AB	21062+1311	9.0 10.5	298.0	29.63	2012.593	89
SEI1407 AB	21072+3657	8.2 10.7	274.4	13.33	2012.593	90
S 779	21091+3844	7.5 9.6	8.9	110.60	2012.593	91
S 781 AB-D	21135+0713	7.3 7.1#	172.2	183.68	2012.593	92
BU 682 AC	21145+0441	7.5 10.3	179.4	92.83	2012.593	93
STF2787 AB	21218+0202	7.4 8.6	19.2	22.71	2012.593	94
POP1233 AC	21223+5734	8.2 8.6	191.6	83.44	2012.593	95
STF2799 AC	21289+1105	7.3 10.1	331.3	136.28	2012.596	96
STF2803 AB	21299+5256	7.2 9.5	285.0	25.68	2012.596	97
GUI 35 AC	21299+5256	7.2 9.9	1.5	87.39	2012.596	97
HO 603 AB	21321+3412	7.5 9.7	250.9	80.48	2012.596	98
STF2810	21346+5906	8.4 9.0	290.3	16.79	2012.596	99
ES 34 AC	21370+5032	8.4 9.5	70.1	39.01	2012.596	100
H 6	21371-1928	4.5 10.1	46.0	66.66	2012.596	101
HJ 1677	21373+5900	9.8 10.5	127.9	16.29	2012.596	102
STT 447 AE	21395+4144	7.5 8.4	44.6	28.64	2012.596	103
S 796 AB	21416+4048	6.1 9.5	233.4	58.26	2012.596	104
ES 382 AC	21509+3240	8.3 8.3	322.3	58.26	2012.596	105
SHJ 336 AB	21586+0601	8.0 8.8	222.3	93.81	2012.596	106
ARN 23 AD	22150+5703	4.2 10.2	180.8	200.46	2012.631	107
STT 469 AB	22205+3507	7.5 9.7	292.7	27.16	2012.631	108
ARY 30	22221+0045	8.5 9.2	339.8	119.49	2012.631	109
ARY 31	22272-0019	8.8 9.3	257.2	96.28	2012.631	110
ARY 32 AB	22306+0151	9.3 9.9	289.2	97.27	2012.631	111
STF2916 AB	22313+4113	8.0 10.0	336.6	43.94	2012.631	112
S 813	22393+3903	4.8 10.3	49.0	62.71	2012.631	113
S 815	22415+4014	5.2 10.7	14.7	68.64	2012.631	114
H 140 AC	22421-0506	6.5 9.7	185.7	159.98	2012.631	115
ARN 22 AB-D	22514+2623	7.0 9.2	114.1	204.41	2012.631	116
HDS3262	22558+4334	8.0 9.5	166.8	28.14	2012.631	117
STT 536 AB-C	22586+0921	6.4 10.7	78.8	202.44	2012.631	118
HJ 1842 AC	23038+2805	2.3 10.5	101.4	238.98	2012.667	119
STF2985	23100+4758	7.1 7.9	256.3	15.80	2012.667	120
STT 598 AC	23118+2651	6.2 9.6	299.1	218.24	2012.667	121

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Name	RA DEC	Mags	PA	Sep	Date	Notes
STF2992 AB	23131+4000	7.6 9.5	284.4	14.32	2012.667	122
STF3022 AB	23309+5825	8.3 9.9	226.4	20.74	2012.667	123
STF3021 AB	23314+1613	8.0 9.2	308.4	8.89	2012.667	124
STF3021 AC	23314+1613	8.0 10.7	23.4	118.50	2012.667	124
STT 499 A-BC	23332+5724	7.4 9.5	75.3	9.88	2012.667	125
WAL 194 AD	23332+5724	7.4 10.4	38.9	95.29	2012.667	125
ES 2729	23380+5249	7.9 9.5	143.1	19.75	2012.667	126
BU 1532 Aa-D	23460+4625	5.0 9.3	151.6	186.64	2012.667	127
ARN 27 Aa-E	23460+4625	5.0 10.4	317.6	240.95	2012.667	127
STT 248 AB	23461+5040	7.3 9.7	144.3	50.86	2012.669	128
S 835 AB	23479-0246	5.5 9.8	282.8	177.75	2012.669	129
ES 2734	23481+4106	8.3 10.0	221.1	28.64	2012.669	130
ARG 108	23530+4121	7.0 9.4	147.0	52.34	2012.669	131
SHJ 358	23543+3154	8.1 10.3	335.6	36.04	2012.669	132
ARY 33	23592+5032	7.2 8.0	139.2	99.74	2012.669	133

* Not listed in the WDS CATALOG.

\# Companion star is the brighter component.

Notes

1. In Aquila. Relatively fixed. Spect. K5, F.
2. In Aquila. Sep. & p.a. decreasing. Spect. G5, G5.
3. In Vulpecula. AB=sep. dec.; cpm. AC=sep. & p.a. inc. Spect. B2V, B3, K5.
4. 17 Lyrae. Sep. increasing; p.a. decreasing. Spect. F0V, A2.
5. In Lyra. Relatively fixed. Common proper motion. Spect. F5, F8.
6. In Sagitta. Sep. & p.a. decreasing. Spect. B9IV, G5.
7. In Lyra. Relatively fixed. Common proper motion. Spect. B8V.
8. Theta or 21 Lyrae. Separation increasing. Spect. K0II, K2.
9. In Aquila. Relatively fixed. Common proper motion. Spect. G5, G5.
10. In Cygnus. Position angle increasing. Spect. K5.
11. In Sagitta. Separation increasing. Spect. A2III, A0.
12. In Vulpecula. Position angle increasing. Spect. K0, B9.
13. In Vulpecula. AC=sep. & p.a. inc. AD=sep. inc.; p.a. dec. Spect. K5III, F8, A5.
14. Nu or 32 Aquilae. Relatively fixed. Spect. F2I, A2.
15. Alpha or 6 Vulpeculae. Separation increasing. Spect. M0III, K0.
16. In Vulpecula. Relatively fixed. Spect. A2, A0.
17. In Cygnus. Position angle increasing. Spect. K0, G0.
18. In Cygnus. Separation decreasing.
19. In Vulpecula. AB = sep. inc.; p.a. dec. AC = sep. dec. Spect. F2, F8, K0.
20. Mu or 38Aquilae. Sep. & p.a. decreasing. Spect. K3III, K0.
21. In Vulpecula. Position angle decreasing. Spect. K5, K7.
22. In Aquila. Possible common proper motion.
23. In Vulpecula. Relatively fixed. Common proper motion. Spect. K0, A2.
24. Epsilon or 4 Sagittae. Separation decreasing. Spect. G9III, B8.
25. In Sagittarius. Relatively fixed. Common proper motion. Spect. A8III, F2III.
26. In Cygnus. Sep. & p.a. decreasing. Spect. G8III.
27. In Cygnus. AB = cpm; p.a. dec. AD, AF, AH = relatively fixed. Spect. B8V, A0.
28. In Vulpecula. Common proper motion; p.a. decreasing. Spect. A0.
29. In Cygnus. Separation increasing. Spect. A0, F5.
30. In Aquila. AB=relfix,cpm. AD=sep. inc.; p.a. dec. Spect. F8V, G0V, K2.
31. In Cygnus. Separation decreasing. Spect. A0, F2.
32. In Cygnus. Common proper motion. Spect. G5.
33. In Cygnus. Common proper motion. Near ARN 119.
34. In Cygnus. Common proper motion. Near ARN 118. Spect. M1.
35. In Cygnus. Relatively fixed. Common proper motion. Spect. B8III, B8.

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36. In Sagittae. AB=p.a. dec. AC=relfix, cpm. Spect. AC = B7V, A0.
37. In Cygnus. Slight decrease in p.a. Spect. B1V, B8.
38. In Cygnus. Position angle decreasing. Spect. B5V, B8.
39. In Vulpecula. Common proper motion. Spect. K7, K5.
40. In Sagitta. AB & AC = sep. & p.a. dec. AD = sep. inc. Spect. K0, K5, A2.
41. 13 Sagittae = C component. AB = relfix. AC=sep. & p.a. dec. Spect. AC=K0, M2.
42. In Sagitta. Position angle increasing. Spect. K3II.
43. In Cygnus. Relatively fixed. Spect. B1III, B2.
44. 15 Sagittae. AB=sep. dec.; p.a. inc. AC=sep. & p.a. inc. Spect. G1V, K0, A2, K2.
45. In Cygnus. Relatively fixed. Spect. O7III, B2.
46. In Cygnus. Relatively fixed. Common proper motion. Spect. B5, B5.
47. In Cygnus. Position angle increasing. Spect. F5V, K5.
48. In Aquila. AC = sep. increasing. AD = sep. decreasing. Spect. A5, K2, K5.
49. In Cygnus. Relatively fixed. Common proper motion. Spect. B.5IV, B.5IV.
50. In Cygnus. Relatively fixed. Spect. O1, A7.
51. In Cygnus. Separation decreasing. Spect. K2V.
52. In Cygnus. AB & AC = sep. decreasing. Spect. C5II, B2, M2.
53. In Aquila. Relatively fixed. Common proper motion. Spect. G4IV, G.
54. 29 Cygni. AB=sep. & p.a. inc. AC=sep. & p.a. dec. BD=relfix. Spect. A2V, K5.
55. 32 Cygni. Relatively fixed. Spect. K3I, A.
56. In Cygnus. Sep. decreasing; p.a. increasing. Spect. K5III.
57. In Cygnus. Relatively fixed. Spect. B5, A0.
58. Alpha Capricorni. AD=sep dec; pa inc. AE=sep inc; pa dec. Spect AE=G9III, G0.
59. In Vulpecula. Relatively fixed. Spect. B2V, A0.
60. Sigma or 7 Capricorni. Sep. & p.a. increasing. Spect. K3III.
61. In Cygnus. Separation slightly increasing. Spect. F0.
62. Beta or 9 Capricorni. Aa-Ba=relfix, cpm. Aa-C=sep slightly dec. Spect. F8V, B9.
63. In Cygnus. Sep. & p.a. decreasing. Spect. A0V, A3.
64. In Delphinus. Sep. increasing; p.a. decreasing. Spect. G0.
65. In Delphinus. Sep. increasing; p.a. decreasing. Spect. A2V, F.
66. In Aquila. Common proper motion. Sep. & p.a. decreasing. Spect. F7V, F8.
67. In Cygnus. Common proper motion; p.a. decreasing. Spect. K0.
68. In Cygnus. Relatively fixed. Common proper motion. Spect. B6V, B8.
69. In Cygnus. Sep. & p.a. increasing. Spect. A2, A5.
70. In Cygnus. Sep. slightly decreasing. Spect. B9.
71. In Capricornus. Common proper motion; p.a. increasing. Spect. F2IV, F2IV.
72. In Cygnus. Sep. slightly decreasing. Spect. A2.
73. In Cygnus. AB=sep. inc; p.a. dec. AC=sep. & p.a. dec. Spect. G0, F, K5.
74. In Vulpecula. AD = p.a. slightly dec. AE = sep. slightly dec. Spect. A7II, A0, K2.
75. In Capricornus. Common proper motion; p.a. decreasing. Spect. K0III, K0III.
76. In Cygnus. Relatively fixed. Common proper motion. Spect. A0, A5.
77. In Cygnus. AB & AC = Relfixed; Common proper motion. Spect. B7V, B9III.
78. In Capricornus. Relatively fixed. Common proper motion. Spect. G8III, G5.
79. In Cygnus. AB = p.a. inc. AD = sep. inc. Spect. M3II.
80. In Aquarius. Sep. inc.; p.a. decreasing. Spect. F5IV, K0.
81. In Cygnus. Position angle increasing. Spect. K5III.
82. 7 Aquarii. Separation slightly increasing. Spect. K5, M.
83. In Cepheus. AC = p.a. decreasing. AD = relatively fixed. Spect. A0, A0, A0.
84. In Delphinus. AB = p.a. decreasing. AC = sep. decreasing. Spect. F5V, A0, F5.
85. In Cygnus. Position angle increasing. Spect. B8, K2.
86. In Cygnus. Relatively fixed. Spect. G8III, A5.
87. In Cygnus. Relatively fixed. Spect. B8.
88. In Cygnus. AB=sep. inc, p.a. dec. AD=sep. inc. BC=sep. dec. Spect. K0.
89. In Delphinus. Sep. & p.a. decreasing. Spect. K5, F0.

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90. In Cygnus. Sep. increasing; p.a. decreasing. Spect. A0, A0.
91. In Cygnus. Sep. & p.a. decreasing. Spect. K2, A0.
92. In Equuleus. Relatively fixed. Common proper motion. Spect. A7V, A2.
93. In Equuleus. Position angle increasing. Spect. K4III.
94. In Aquarius. Relatively fixed. Spect. A2, A0.
95. In Cepheus. Relatively fixed. Common proper motion. Spect. G5, K0.
96. In Pegasus. Sep. & p.a. decreasing. Spect. F4V, F5.
97. In Cygnus. AB = sep. inc.; p.a. dec. AC = relatively fixed. Spect. B9.5IV, F8.
98. In Cygnus. Relatively fixed. Common proper motion. Spect. F0, G0.
99. In Cepheus. Relatively fixed. Common proper motion. Spect. F8, F8.
100. In Cepheus. Relatively fixed. Spect. A0, K5.
101. Epsilon or 39 Capricorni. Separation decreasing. Spect. B2.5V.
102. In Cepheus. Relatively fixed. Common proper motion. Spect. F8, G5.
103. In Cygnus. Common proper motion; p.a. decreasing. Spect. K0III, K0.
104. In Cygnus. Sep. decreasing; p.a. increasing. Spect. A2V, A0.
105. In Pegasus. Separation decreasing. Spect. A0, K0.
106. In Pegasus. Sep. & p.a. decreasing. Spect. A2, K0.
107. Epsilon or 23 Cephei. Position angle increasing. Spect. F0IV.
108. In Pegasus. Sep. decreasing; p.a. increasing. Spect. A9III, F.
109. In Aquarius. Sep. & p.a. decreasing. Spect. K5, F0.
110. In Aquarius. Sep. decreasing; p.a. increasing. Spect. F8, K2.
111. In Aquarius. Sep. increasing; p.a. decreasing. Spect. K0, G5.
112. In Lacerta. Sep. decreasing; p.a. increasing. Spect. K2.
113. 10 Lacertae. Sep. increasing; p.a. decreasing. Spect. 09V, 05.
114. 12 Lacertae. Sep. & p.a. decreasing. Spect. B2III.
115. In Aquarius. Position angle increasing. Spect. M0.
116. In Pegasus. Separation increasing. Spect. A9V, K2.
117. In Lacerta. Relatively fixed. Common proper motion. Spect. B3V.
118. In Pegasus. Sep. & p.a. decreasing. Spect. G2V, G0.
119. Beta or 53 Pegasi. Sep. decreasing; p.a. increasing. Spect. M0.
120. In Andromeda. Common proper motion; sep. & p.a. increasing. Spect. G2IV, G5.
121. In Pegasus. Sep. decreasing; p.a. increasing. Spect. G8III, K0.
122. In Andromeda. Relatively fixed. Common proper motion. Spect. A7III, F0.
123. In Cassiopeia. Relatively fixed. Spect. A2.
124. In Pegasus. AB & AC = relatively fixed; common proper motion. Spect. F8, F8.
125. In Cassiopeia. A-BC = p.a. dec.; cpm. AD = sep. & p.a. inc. Spect. G5, G5.
126. In Cassiopeia. Relatively fixed. Spect. K5, B8.
127. Psi or 20 Andromedae. Aa-D = sep. inc. Aa-E = relatively fixed. Spect. K0, K0.
128. In Cassiopeia. Sep. decreasing; p.a. increasing. Spect. K0.
129. 20 Piscium. Sep. increasing; p.a. decreasing. Spect. G8III, G2.
130. In Andromeda. Position angle increasing. Spect. G5.
131. In Andromeda. Position angle increasing. Spect. M2III, A2.
132. In Pegasus. Position angle increasing. Spect. K0.
133. In Cassiopeia. Separation decreasing. Spect. G5, K2.

HJ 4217 - Now a Known Unknown

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Abstract: John Herschel's double, HJ 4217, is a 'neglected double' in the WDS where Herschel's observation of 1837.25 is the only record. The SIMBAD data base suggests UCAC2 497073 as the companion but this is not correct, the true companion is UCAC4 061-008434. This misidentification has come about because of the high proper motion of the primary star.

Introduction

During the evening of March 31, 1837 John Herschel (HJ), son of the equally famous William Herschel who discovered the planet Uranus, recorded the discovery of a double star in the constellation Chameleon. Working from his observing site in Feldhausen at Wynberg, Cape Town, between the years 1834 and 1838, HJ made detailed and extensive observations of the southern sky. However, it was not until nearly 10 years later, in 1847, that he had completed the hand reduction of the many thousands of observations and publishing them in his *Results of Astronomical Observations Made During the Years 1834, 1835, 1836, 1837, 1838, at the Cape of Good Hope; Being the Completion of a Telescopic Survey of the Whole Surface of the Visible Heavens, Commenced in 1825*; hereafter referred to as *Observations*.

Better known for its record of southern nebulae, *Observations* also contains a catalogue of around 5500 double stars, most of which were newly discovered by HJ.

The Double Star HJ 4217

As an introduction to a new study of southern doubles, we have undertaken a review of neglected doubles in the Washington Double Star Catalog (WDS, Mason, *et al.*, 2012) south of declination -30°. The Herschel pair HJ 4217 is represented in the WDS by only HJ's observations of 1837. It is evident that the reason for the neglect of this double is that its modern appearance does not look anything like the HJ description. Indeed, an observation reported in 1922 'Agrees with Herschel's place but not his description' (Dawson, 1922).

Figure 1 is a reproduction of part of HJ's reduced observations of HJ 4217, taken from Chapter II of *Observations*. HJ reduced his observations to equinox and equator B1830.0. The catalogued North Polar Distance (N.P.D.) corresponds to declination -77° 10' 04". The Position Angle (PA) and distance (ρ) were measured using the Twenty-Foot Reflector in survey mode, in this case on sweep 782 made 1837-3-31 (1837.25). The catalogued PA of 278.9° and separation of 20" is thus for equinox and equator B1830.0 reduced from epoch 1837.25. In the last column HJ identifies this pair as being star 3941 of Lacaille's

HJ 4217 - Now a Known Unknown

No.	R A. 1830.0. h. m. s. d.	N P D. 1830.0. ° ′ ″	Position.	Dist.	Magnitude.		Remarks.	Synon.	Sweep.
4216	9 23 24.6	159 13 35	335.5	10	10	10′	R A ::	......	429
——	9 23 28.4	121 10 13	209.9	8	7′	8	ζ Antliæ; pos 209.7, 210.1, marked as double in B. ? if Δ 78, as his position is 88° 53′.	B. 2515 Δ. 78 ?	678
4217	9 25 38.2	167 10 4	278.9	20	7	13	....	L. 3941	782
4218	9 26 5.4	125 37 54	28.9	3	8′	12	Neat double star	......	787
	8.3	39 25	25.9	4	8	12	....	......	541
——	9 26 34.7	74 52 11	82.8	45	7	9	7 *Leonis*	σ. 350	688

Figure 1: John Herschel's Observations for HJ 4217.

1763 *Coelum Australe Stelliferum* (de La Caille, 1763; Henderson, 1847).

As for the accuracy of his observations, in the descriptive prelude to the table of Chapter II, HJ expressed confidence with the precision of the PA but considered the ρ values to be "generally somewhat too small in the closer stars ... and are of course in a very high degree vague and precarious serving little more than general classification". We return to this description below.

It is obvious that the WDS data is taken directly from *Observations*, with the addition of a WDS number (09234-7753), a spectral type for the primary (F9V), a revised magnitude of the primary (7.06), a 'precise' J2000.0 position, and a cross reference to CPD -77 507. The WDS invokes similar proper motions for the two stars.

The SIMBAD data base identifies a magnitude 12.6 star, UCAC2 497073, as the companion. At equinox and epoch J2000, this star is at PA = 317° and ρ = 47.5" relative to the primary, not in good agreement with what HJ observed. Star UCAC2 497073 is Star B in Figure 2 below and Star UCAC4 061-008429 in our Table 2.

In our search for an understanding of HJ 4217 we made reference to the HIPPARCOS Input Catalogue (HIC) (Annex 1 Double and Multiple Stars, Turon, *et al.* 1993). Our understanding is that this catalogue resulted from a revision of bright double stars, demanded by the potential of multiple and moving stellar images to degrade the astrometric precision of the final astrometric catalogue. Their entry for HJ 4217 identifies the pair as HIC 46046, gives accurate (but pre HIPPARCOS) J2000 positions, and records the PA and ρ as 282° and 20.1" respectfully. We assume these values to be HJ's B1830.0 (epoch 1837.25) values precessed to Equinox J2000. The HIC also identifies the primary star as HD 82114 and SAO 256614, and, again, ascribes the same proper motions to both members.

Figure 2 is a 'modern' view of the field. This is a 3.5 x 3.0 arc minute image from the 2MASS J (Skrutskie *et al.*, 2006) survey and is typical of many such images that are available on *Aladdin* (Bonnarel *et al.*, 2000) from various surveys taken over epoch 1970 to 1999. Here the primary star is of the correct brightness (details are in Table 3) but there is no obvious companion at the HJ position. The J images of

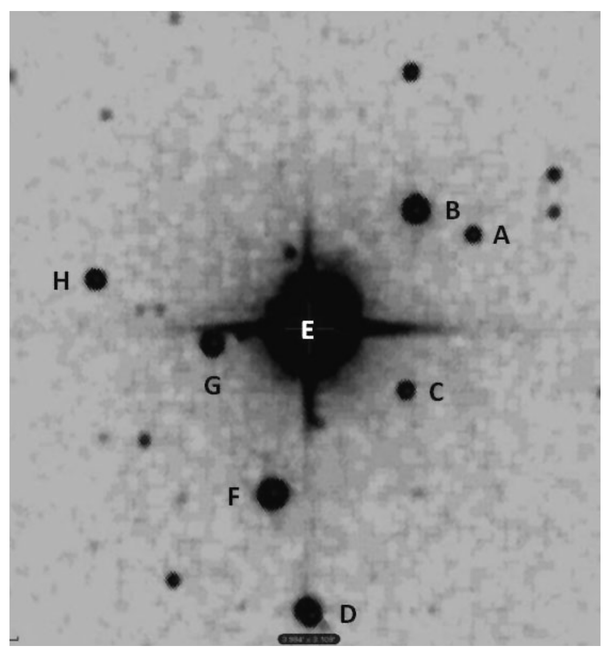

Figure 2: The 2MASS J image of HJ 4217. Stars A to H are catalogued in the UCAC4 and given in Table 2. Some faint objects close to the bright star are Filter Glints. The field is 3.5 arcmin tall and 3.0 arcmin wide. North is up and east is to the left.

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Table 1: Astrometric Data for Stars Within 90 arcsec of HJ 4217 Adopted From UCAC4.

Our Label	UCAC4	RA J2000.0	Dec J2000.0	V mag	μ_α mas/yr	μ_δ mas/yr
A	061-008427	09 23 09.046 ± 37 mas	-77 52 58.40 ± 34 mas	-	-23.9 ± 3.9	-17.5 ± 2.8
B	061-008429	09 23 14.579 ± 12 mas	-77 52 50.98 ± 12 mas	12.468 ± 0.02	-39.5 ± 1.2	51.8 ± 1.2
C	061-008431	09 23 15.484 ± 35 mas	-77 53 43.76 ± 37 mas	-	-3.8 ± 4.3	-0.3 ± 4.3
D	061-008432	09 23 24.605 ± 35 mas	-77 54 49.68 ± 45 mas	15.937 ± 0.03	1.3 ± 2.8	10.5 ± 4.9
E HJ 4217	061-008433	09 23 24.809 ± 2 mas	-77 53 25.87 ± 2 mas	8.717 ± 0.01	-251.4 ± 1.0	354.3 ± 1.0
F	061-008434	09 23 28.260 ± 14 mas	-77 54 14.11 ± 22 mas	12.499 ± 0.02	-18.1 ± 1.3	16.6 ± 1.2
G	061-008438	09 23 34.011 ± 16 mas	-77 53 30.09 ± 14 mas	-	55.0 ± 1.5	97.0 ± 1.5
H	061-008441	09 23 45.118 ± 23 mas	-77 53 11.52 ± 22 mas	14.500 ± 0.06	2.7 ± 1.9	0.4 ± 1.9

the 2MASS represent the near infrared (1.25 μm) but approximate the visual appearance. In addition to the obvious stars in this image, there are a small number of star-like artefacts called filter glints (http://irsa.ipac.caltech.edu/applications/2MASS/IM/interactive.html) but we concentrate our discussion here only on the brighter catalogued stars. North is approximately up and east is to the left.

Reduction and Further Discussion

Table 1 lists the UCAC4 stars (Zacharias, *et. al.*, 2012) within ~90 arcsec of the catalogued position of primary of HJ 4217. Here all positions and proper motions are on the FK5 system and are for equinox and equator J2000.0 and epoch 2000.0. We have labelled the stars A to H in Right Ascension order.

Figure 3 is a schematic of the field constructed from the UCAC4 data. The primary is Star E and this figure shows good agreement with the 2MASS image of Figure 2.

Resolution

A clue as to the correct nature of HJ 4217 comes from the fact that it is cross referenced in the SIMBAD data base (http://simbad.u-strasbg.fr/simbad/) as being star 3476 in the LTT catalogue (as well as being listed in 26 other catalogues). The LTT (Luyten Two Tenths (Luyten, 1957)) is a compilation of high proper-motion stars, all of which have proper motions greater than 0.2 arcsec per year.

All stars in the UCAC4 have detectable proper motions, however, the proper motion of the primary HJ 4217, (Star E) is particularly high (μ_α = -251.4 ± 1.0 mas/yr, μ_δ = 354.3 ± 1.0 mas/yr) and larger than the other stars in the field. This is a new consideration as both the WDS and the HIC assume that the proper motion of the secondary star is/will be the same as that of the primary.

To emulate what HJ saw, in Table 2 we have precessed stars A to H from the J2000.0 equinox and

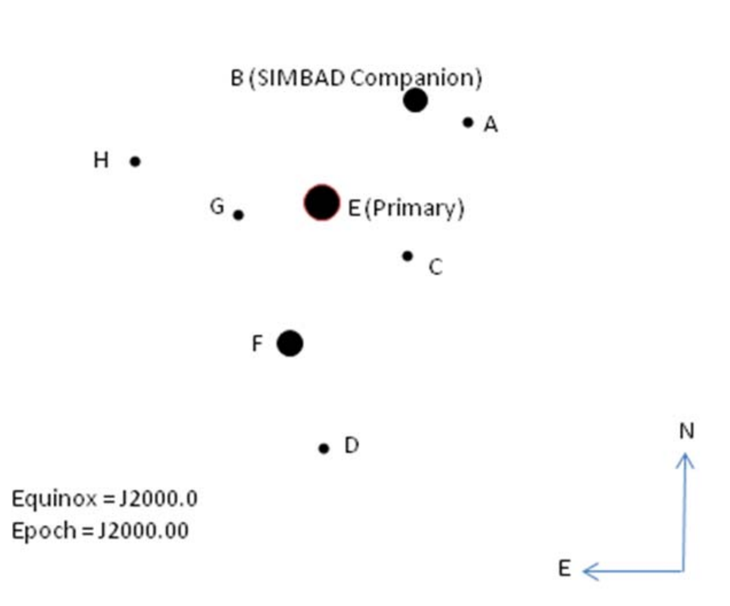

Figure 3: The year 2000 view of the HJ 4217 field based on the accurate UCAC4 data in Table 1. We have used *Polar Plot 2*, an add-in for Microsoft Excel, written by Andy Pope (http://www.andypope.info/charts/polarplot3.htm) to construct Figures 3 and 4.

HJ 4217 - Now a Known Unknown

Table 2: Positions for the Stars in Table 3 Processed to Equinox B1830.0 and Epoch 1837.25.

Label	UCAC4	PA (θ°) J2000.0 Epoch 2000.0	Sep^n (ρ") J2000.0 Epoch 2000.0	RA B1830.0 Epoch 1837.25	Dec B1830.0 Epoch 1837.25	PA (θ°) B1830.0 Epoch 1837.25	Sep^n (ρ") B1830.0, Epoch B1837.25
A	061-008427	298.98	56.70	09 25 13.03	-77 08 44.3	312.7	123.4
B	061-008429	317.30	47.47	09 25 19.06	-77 08 47.1	318.9	107.4
C	061-008431	238.63	34.37	09 25 18.81	-77 09 31.5	297.1	80.2
D	061-008432	180.44	83.81	09 25 28.13	-77 10 37.8	233.6	50.2
E HJ 4217	061-008433			09 25 40.26 ± 170 mas	-77 10 08.0 ± 170 mas	Primary	Primary
F	061-008434	167.31	49.45	09 25 32.02 ± 210 mas	-77 10 02.5 ± 200 mas	281.3 ± 0.6	28.0 ± 0.3
G	061-008438	98.29	29.26	09 25 33.43	-77 09 31.3	328.2	43.2
H	061-008441	77.34	65.50	09 25 45.96	-77 08 55.1	14.6	75.3

epoch 2000.0 to the equinox B1830.0 and epoch 1837.25 as observed by HJ. Precession was undertaken using the STARLINK web-based precession routine. The simulated 'HJ view' is shown in Figure 4.

Pleasingly, our precessed position for the primary and that of HJ are in exceptional agreement. The differences in RA and declination are an amazing 6.7 and 4.0 arcsec respectively - an indication of the care HJ took in recording his astrometric observations.

More importantly, it can be seen from Figure 4 that HJ's companion was in fact Star F (UCAC4 061-008434) and not star B (UCAC2 497073) as suggested by SIMBAD. Star F is nearest to the primary, and its visual magnitude (12.499) closely matches HJ's recorded 13. This is clearly HJ's double star 4217.

And there is good agreement in PA and ρ. HJ's PA of 278.9° and ρ of 20" are close to our precessed values of 281.3° ± 0.3° and 28.0" ± 0.3" (the formal uncertainties are computed on the uncertainties in the UCAC4 positions and proper motions).

The difference between HJ and us is 2.4° ± 0.3° and 8.0" ± 0.3" in PA and ρ respectively. We are assured of the accuracy of the UCAC4 data and therefore we look at the large-ish discrepancy in the separation. We have examined the distribution of HJ's separations for all southern pairs, and have found there an obvious rounding-off of separation values into multiples of 5 arcsec. Thus we concur that HJ's separation for HJ 4217 is, as above, "somewhat too small ... and a very high degree vague". We offer this as an explanation for the difference between our measured separations.

It is also perhaps appropriate to make a few comments on the magnitudes of the pair. We note that the UCAC4 magnitude is discordant with the other estimates for the primary. The UCAC4 is an astrometric catalogue and is based on CCD images made

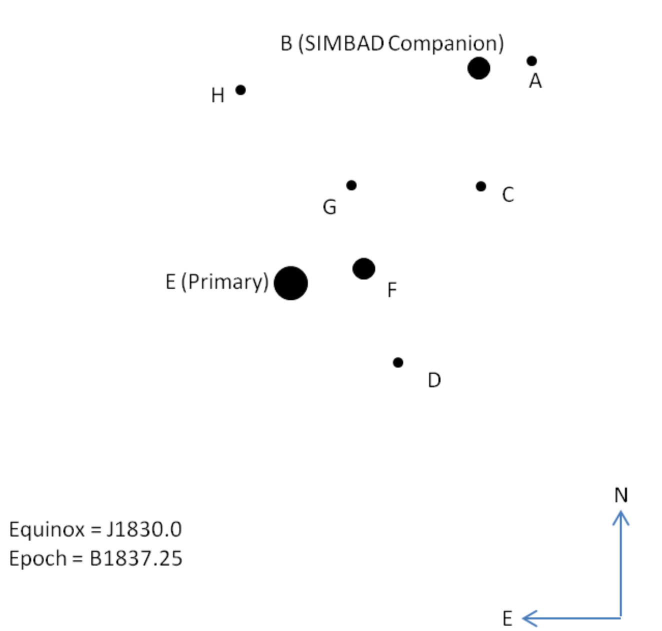

Figure 4: The field of HJ 4217 with the positions precessed to Equinox B1830 and Epoch 1837.25. This approximated what HJ would have seen. The double star is now obvious; being the 7th magnitude primary and our Star F. The PA and ρ are now in agreement with HJ's observations.

on a non-standard photometric scale that is between the V and R. It is, therefore, not consistent with the visual observation by HJ or the SIMBAD V magnitude of 7.06. We have decided to adopt the SIMBAD magnitude estimate for this star and note that this is in good agreement with HJ estimate of 7.

There is also some consideration in *Observations* as to the consistency of HJ's magnitude estimates for fainter stars, where HJ points out a potential bias that may exist between himself and another reputable observer. With no other accurate magnitudes available for the secondary, we are forced to adopt the UCAC4 estimate of 12.5 (12.499) for the companion. This is consistent with HJ's estimate of 13.

Conclusion

HJ 4217 is an unusual double star. Here the 7th magnitude primary has a high proper motion, and the clear double seen by HJ no longer exists due to the movement of the primary by some 67 arcsec relative to the secondary since 1837.25 (to 2000). This movement has lead to the wrong identification of the secondary in SIMBAD and a misrepresentation of the pair in subsequent work. Star UCAC4 061-008434 is the correct companion of HJ 4217 and star UCAC2 497073 (UCAC4 061-008429) is not the companion.

We offer the data given in Table 3 below and recommend an appropriate amendment to the WDS.

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Table 3: Proposed amendment to the WDS.

NAME	RA+DEC	MAGS	PA	SEP	DATE	N	NOTES
HJ 4217	09232-7753	7.1,12.5	167.3	49.5	2000.0	1	1

Note 1
The companion is clearly UCAC4 061-008434, and not UCAC2 497073 (UCAC4 061-008429) as suggested in SIMBAD. Data here is based on the catalogued positions, proper motions and magnitude (of secondary) from the UCAC4 (Zacharias, *et. al.*, 2012). The magnitude of the primary is from SIMBAD.

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Double Star Measures Using the Video Drift Method - III

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Abstract: This paper gives the position angle and separation for 242 multiple star systems measured using the video drift method. Standard deviations averaged 0.59" for separation, 1.8° for position angle for single drifts. The drift method generates a Cartesian (*x,y*) coordinate pair for each star for each video frame during the drift to derive position angle and separation. Many doubles had multiple drifts done over several nights resulting in 4,000 - 10,000 (*x,y*) pairs analyzed per system. Doubles with multiple drifts/nights combined gave probable errors of 0.10" in separation and 0.27° in position angle. An image intensifier was used on some doubles to reach fainter systems in which WDS catalog magnitudes were in the +13 to +15 range. The systematic accuracy of this method is discussed with multiple drifts over several nights.

Introduction

In our first and subsequent paper (Nugent and Iverson, 2011, Nugent and Iverson 2012, hereinafter called "Paper I and Paper II") we described a new method that computes both the position angle and separation for a multiple star system using 100's to 1,000's of (*x,y*) positions of the components obtained from a short video clip of the multiple star system drifting across the field of view. The freeware program *LiMovie* (Miyashita, 2006), originally intended for analysis of occultation data, is used to automatically convert the raw video into a table of Cartesian (*x,y*) positions for the two component stars being measured. *VidPro*, an Excel program written by coauthor RLN, reads the (*x,y*) coordinate data and computes a unique value for the position angle and the separation and other statistical quantities.

A detailed description of how to set up and use the *LiMovie* and *VidPro* programs plus a free *VidPro* download link can be found in Nugent (2010). The advantage of using this method is that the data collection and subsequent data analysis is automated and requires little human interaction. Unlike other methods, no calibration doubles are needed, no line is drawn to determine the east-west direction, no star catalog is needed since there is no "plate adjustment" performed and no video frames are discarded thus all (*x,y*) coordinate pairs are used with equal weight. Each double star drift is self calibrating. *VidPro* computes a unique scale factor for each drift, plus an offset correction from the east-west direction compared to the camera's pixel array. The offset of the pixel array alignment of the camera's chip from the true east-west direction (drift angle) is calculated to an accuracy of better than 0.04°.

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Table 1. Telescopes used in this research. Scale factors vary slightly due to the declination of the doubles.

TELESCOPE	APERTURE	FOCAL LENGTH	SCALE FACTOR
Meade LX-200	14" (35cm)	3550 mm f/10	0.6"/pixel
Questar	3.5" (9cm)	1299 mm f14.4	1.6"/pixel

The whole recording and analysis process can be done in just a matter of minutes per double star system at the telescope with the proper set up. Therefore, this method is ideally suited for survey projects involving hundreds of double stars.

Methodology

Preference was given to multiple star systems that the WDS reports less than 35 measurements since being discovered and those with measurements lacking in the past 10 years. This criterion applies to most, but not all of the multiple star systems measured.

Typically 3 or 4 drifts were recorded for many double stars per night. Some doubles had 10-12 drifts done. Additional drifts were made for selected double star systems when it was thought they might prove useful later in the analysis process. This included stars that had close separations or were near the magnitude limit of the telescope. When weather permitted, an effort was made to record each star system on at least two nights. Additional recordings, on other nights, were made for doubles that seemed to differ significantly from the WDS summary list in either position angle and/or separation. This was done in an effort to confirm the apparent differences.

Several drift measurements reported were made over several nights and consist of multiple drift runs per night. In several cases the same double star system was observed by both authors using different telescope/video camera systems. In any case where multiple drifts exist for a given double star system, they were combined using a weighted average function:

$$\overline{M} = \frac{\frac{1}{\sigma_1^2} M_1 + \frac{1}{\sigma_2^2} M_2 + \ldots \frac{1}{\sigma_n^2} M_n}{\frac{1}{\sigma_1^2} + \frac{1}{\sigma_2^2} + \ldots \frac{1}{\sigma_n^2}} \quad (1)$$

In equation (1) $M_1 \ldots M_n$ is the computed value from a drift run of position angle or separation and $\sigma_1 \ldots \sigma_n$ is the standard deviations of position angle or separation for that same drift run. As stated earlier, each drift run typically has 1,000's of values used for the computation of M_n.

The new standard deviation from combining measurements from different drift runs of the same double star system is computed from:

$$\sigma_{new} = \frac{1}{\sqrt{\frac{1}{\sigma_1^2} + \frac{1}{\sigma_2^2} + \frac{1}{\sigma_3^2} \ldots \frac{1}{\sigma_n^2}}} \quad (2)$$

For several doubles, Nugent used a Collins I[3] image intensifier (Collins 1998) to aid in reaching fainter doubles. This device is attached between the telescope and the video camera and adds approximately three (3) magnitudes to the faint limit of the video system. This three magnitude limit increase comes with a price – the videos are noisy. However with careful use of the *LiMovie* and *VidPro* programs for the reductions, the noise effect can be overcome in the final analysis. A sample video (made June 2012) using the Collins image intensifier and Meade 14-inch LX-200 is available on author RLN's YouTube account of the system WDS 15376-0147, (LDS 533). Its WDS component magnitudes are +12.7 and +15.2. See http://www.youtube.com/watch?v=JMJxVSirGFU .

Compare this to a typical non-image intensifier video drift made by the 9cm (3.5-inch) Questar of WDS 05005+0337 (STF 627AB). See http://www.youtube.com/watch?v=yAokhR1UR_I . Its component magnitudes are +6.59 and +6.95.

The telescope equipment used and scale factors are summarized in Table 1.

The data collection and analysis procedures used follow those described by Nugent (2010) and Paper I.

Consistency of the Method

For 104 multiple drifts the average probable error was 0.10" for separation and 0.27° for PA. The average probable error for PA's with separations less than 25" was larger at 1.4°. For all of the Table 2 doubles (this includes 138 with single drifts) with separations

(Continued on page 121)

Double Star Measures Using the Video Drift Method - III

Table 2: Results of 242 double stars using the video drift method.

WDS	Discoverer	PA°	σ-PA	Sep"	σ-Sep	Date	No. of (x,y) pairs	mag Pri	mag Sec	No. Drifts
00314+3335	HJ 5451	86	0.2	55.3	0.17	2012.786	2132	6.01	9.34	3
00352+3650	STF 40AB	310	1.0	11.6	0.15	2012.786	2620	6.72	8.48	3
00369+3343	H 5 17AB	174	0.3	37.7	0.17	2012.786	2505	4.36	7.08	3
00464+3057	STFA 1	46	0.2	47.7	0.16	2011.825	2963	7.25	7.43	4
01062+3211	S 393AB	296	0.2	58.5	0.16	2011.825	2821	6.42	10.61	4
01579+2336	H 5 12AB	47	0.3	37.7	0.19	2011.888	2131	4.80	6.65	3
02305+2514	STF 271AB	184	0.5	13.4	0.13	2011.880	5486	5.9	10.4	7
02370+2439	STFA 5	275	0.2	38.0	0.12	2011.880	4249	6.50	7.02	6
02476+2941	BU 307	317	0.9	16.0	0.18	2011.888	2384	7.2	11.6	3
02500+2716	H 5 116AC	233	0.5	28.5	0.27	2011.888	2171	3.63	10.66	3
02500+2716	STT 47AB	292	0.4	34.0	0.19	2011.888	2186	3.63	11.04	3
03040+2831	STF 339AB-C	331	1.0	13.9	0.18	2011.888	3147	8.24	11.19	4
03311+2744	STFA 7	233	0.1	44.4	0.11	2011.880	5078	7.41	7.81	7
03313+2734	STF 401	271	0.1	11.4	0.09	2011.880	5452	6.58	6.93	7
03431+2541	STF 435	3	0.5	13.5	0.10	2011.880	5505	7.20	8.87	7
06045+4416	LEP 22	290	0.0	192.4	0.07	2012.111	6071	6.74	9.11	12
06045+5134	STT 128A-BC	14	0.2	40.3	0.09	2012.140	7864	6.41	9.26	7
06055+1435	AG 321	188	0.1	36.2	0.09	2012.040	8721	7.78	8.84	12
06090+0230	STF 855AB	115	0.2	29.3	0.09	2012.040	8590	5.68	6.68	13
06090+0230	STF 855AC	107	0.1	117.8	0.12	2012.040	6642	5.68	9.68	13
06090+0230	STF 855BC	104	0.1	89.1	0.12	2012.040	6135	6.68	9.68	12
06120+1947	H 6 72AB	203	0.1	93.1	0.11	2012.111	8014	5.74	9.36	12
06141+2359	STTA 70	178	0.0	117.0	0.10	2012.111	9233	7.55	7.95	12
06145+1148	STTA 71	312	0.1	91.3	0.09	2012.040	7082	7.21	7.62	12
06194+1326	STTA 73AB	43	0.1	73.0	0.15	2012.142	2564	6.94	7.74	5
06308+5810	STT 562	107	0.1	169.2	0.17	2012.137	2954	5.96	9.50	4
06308-0939	HJ 731	33	2.3	11.4	0.54	2012.293	659	8.90	10.01	1
06310+5351	STF 908	357	1.7	8.5	0.34	2012.293	1162	10.71	10.70	1
06343+3805	STT 147A,CD	120	0.2	46.4	0.09	2012.040	6415	6.77	9.85	8
06343+3805	STT 147AB	75	0.2	43.2	0.09	2012.040	6408	6.77	8.69	8
06460+0059	BAL1333AB	321	4.1	15.5	1.17	2012.293	654	8.90	11.7	1
06461+3323	WFC 43	20	4.6	4.5	0.40	2012.293	838	9.82	10.13	1
06462+5927	STF 948AC	304	2.5	9.3	0.25	2012.293	1360	5.44	7.05	1
06530+3852	STF 974AB	223	0.3	22.6	0.10	2012.039	11542	6.14	10.20	13
06541+0641	STTA 79	90	0.0	115.7	0.13	2012.040	4370	7.20	7.52	8
06555+3755	STF 978AB	82	1.4	20.0	0.43	2012.293	850	6.85	10.00	1
06555+3755	WAL 48AC	349	0.5	81.5	0.50	2012.293	833	6.85	11.08	1
06581+1414	STTA 80AB	53	0.1	124.9	0.15	2012.041	2216	7.25	7.37	5
06581+1414	STTA 80AC	112	0.1	81.6	0.14	2012.041	2318	7.25	8.37	5
06581+1414	STTA 80BC	193	0.1	108.9	0.16	2012.041	2225	7.37	8.37	5

Table 2 continues on next page.

Double Star Measures Using the Video Drift Method - III

Table 2 (continued): Results of 242 double stars using the video drift method.

WDS	Discoverer	PA°	σ-PA	Sep"	σ-Sep	Date	No. of (x,y) pairs	mag Pri	mag Sec	No. Drifts
07376-1507	XMI 66	31	1.8	19.7	0.69	2012.293	703	10.71	11.33	1
08086-0259	STF1190AB	106	1.0	33.0	0.61	2012.293	633	4.46	10.2	1
08086-0259	STF1190AC	246	0.6	65.4	0.67	2012.293	577	4.46	9.68	1
08380-0226	HJ 98	100	4.9	9.6	1.04	2012.304	741	11.5	11.5	1
08414-0213	HJ 102AB	327	1.5	33.8	0.86	2012.293	674	12.3	13.7	1
09203-0822	AG 339	28	2.9	6.1	0.37	2012.293	713	9.21	9.78	1
09204-0821	J 1545	19	3.4	9.9	1.15	2012.293	783	11.07	11.9	1
09541+0457	S 605	287	0.2	53.5	0.16	2012.236	2500	6.89	8.40	4
09545-1255	HJ 4262AB	103	1.5	7.8	0.27	2012.236	1468	8.69	11.31	4
10141+2314	POU3075	24	1.3	16.9	0.39	2012.307	843	10.45	11.3	1
10145+2434	GRV 814	205	1.2	22.3	0.46	2012.307	846	11.31	11.97	1
10237+0237	LAM 7AB	24	0.4	131.6	1.03	2012.301	1895	7.94	8.60	2
10476-1516	STF1474AB	28	0.4	67.8	0.47	2012.354	1672	6.67	7.05	1
10476-1516	STF1474AC	28	0.6	73.3	0.69	2012.301	1105	6.67	7.59	1
10476-1516	STF1474BC	18	3.6	6.3	0.46	2012.458	674	7.8	7.5	1
10477+6528	STF1469AB	324	0.8	10.6	0.08	2012.236	6355	7.74	10.42	4
11012+2105	WEI 26	174	0.6	14.5	0.13	2012.299	4640	9.50	9.96	6
11045-1940	HDS1580	285	1.8	17.4	0.63	2012.304	718	9.76	11.07	1
11046+1240	HJ 174AB	357	1.1	59.3	0.98	2012.304	690	6.88	12.50	1
11047-0413	STF1506A-BC	224	2.2	11.9	0.40	2012.304	692	7.68	10.75	1
11061+0702	STF1507	166	2.2	8.4	0.32	2012.304	700	8.80	10.23	1
11063+1910	GRV 828	158	1.8	28.3	0.79	2012.304	716	11.4	12.1	1
11065-1325	STF1509	16	0.7	33.2	0.39	2012.304	706	7.43	9.36	1
11072+1055	STF1511	287	2.3	7.6	0.33	2012.304	716	9.27	9.50	1
11075+2203	HDS1586	203	1.7	14.0	0.43	2012.458	399	8.30	11.43	1
11093+0356	STE 9	354	0.8	39.9	0.56	2012.307	778	12.0	13.1	1
11093+1902	VVO 8	275	1.3	27.4	0.62	2012.307	772	11.0	13.3	1
11095+1138	LDS4066	101	0.4	147.1	0.93	2012.307	501	13.0	13.6	1
11107+1542	GRV 830	185	0.9	33.3	0.44	2012.307	784	10.7	12.5	1
11109-1858	ARA 415AB	152	3.9	9.3	0.68	2012.307	596	12.04	12.11	1
11109-1858	WNO 33AC	120	0.5	79.8	0.82	2012.307	653	12.04	11.00	1
11140+0804	KUI 56	256	1.8	23.6	0.73	2012.458	663	5.79	11.83	1
11157+4551	STTA109	256	0.1	83.7	0.11	2012.299	4812	7.95	8.69	6
11165+0736	HJ 2565	9	3.8	15.0	1.16	2012.301	251	10.20	11.4	1
11167-0339	SHJ 121	290	0.4	87.1	0.62	2012.301	524	4.48	9.75	1
11520+0850	STF1575	210	0.8	30.6	0.49	2012.301	683	7.43	7.89	1
11520-0824	HJ 843AB-C	263	4.0	10.2	0.73	2012.301	688	11.14	11.6	1
11524+0733	STF3075	182	1.1	18.8	0.44	2012.301	715	9.70	9.88	1
11551+4629	STF1579AB-D	114	0.2	63.1	0.22	2012.301	1679	6.68	6.97	1
11551+4629	STF1579AB-C	42	3.8	3.7	0.17	2012.458	856	6.68	8.32	1

Table 2 continues on next page.

Double Star Measures Using the Video Drift Method - III

Table 2 (continued): Results of 242 double stars using the video drift method.

WDS	Discoverer	PA°	σ-PA	Sep"	σ-Sep	Date	No. of (x,y) pairs	mag Pri	mag Sec	No. Drifts
11555+0333	ABH 75AD	131	0.4	87.9	0.75	2012.304	579	9.34	11.95	1
11555+0333	STF1580AB	262	2.3	8.8	0.40	2012.304	689	9.34	10.01	1
11558+1616	SLE 893	63	1.7	15.8	0.43	2012.304	709	10.59	10.77	1
11559-2344	ARA2174	313	3.3	14.9	0.80	2012.304	742	10.79	12.2	1
11560+2159	STF1582	75	0.6	12.1	0.11	2012.299	5257	8.09	9.53	7
11574-1939	J 1583	71	4.6	8.2	0.65	2012.304	724	10.37	12.0	1
11596+4636	ES 2639	53	3.1	9.4	0.35	2012.458	993	9.36	12.5	1
12030-2139	ARA1478	82	4.8	12.4	1.21	2012.299	816	13.3	13.3	1
12035-0227	STF1593AC	3	0.6	50.0	0.63	2012.299	729	8.70	12.2	1
12043+0724	STF1595	329	0.9	27.7	0.46	2012.299	755	9.22	10.01	1
12084+1403	KU 42	272	1.3	12.1	0.43	2012.299	778	10.93	11.36	1
12093-2403	ARA2177	157	3.4	12.9	0.78	2012.299	819	12.0	12.4	1
12094+0219	BAL1883	259	2.3	17.4	0.66	2012.299	748	11.23	12.8	1
12095-2324	WHC 10	23	3.1	12.3	0.73	2012.299	832	11.2	11.8	1
12123+4618	HJ 2602	227	2.5	20.8	0.64	2012.301	969	11.43	11.82	1
12270-0332	HJ 210AB,D	147	1.4	24.8	0.69	2012.301	669	8.51	10.20	1
12357-1650	HJ 1218AB	259	2.2	11.9	0.42	2012.304	717	6.6	11.0	1
12363-0818	HJ 848	309	2.4	11.7	0.54	2012.304	704	11.01	11.4	1
12506-2117	STN 25	177	1.8	13.2	0.47	2012.307	815	10.61	11.1	1
12506-2330	ARA1796	165	3.4	14.2	0.71	2012.307	823	12.29	12.7	1
12508-2944	HJ 4553	346	2.7	11.5	0.51	2012.307	876	10.59	11.4	1
12509-0428	LDS6270	266	3.2	6.2	0.95	2012.307	747	11.97	14.35	1
12511+0152	BAL1887	51	2.4	9.1	0.29	2012.307	742	9.5	11.5	1
12514-1020	STF1682AB	297	0.8	29.3	0.48	2012.307	723	6.59	9.69	1
12514-1020	STF1682AC	212	0.2	142.1	0.56	2012.307	624	6.59	11.0	1
12514-1020	STF1682BC	201	0.2	143.1	0.50	2012.307	611	9.69	11.0	1
12515-1920	J 1584	273	1.9	11.0	0.50	2012.307	796	11.7	11.7	1
12517-0608	STF1683	198	1.6	15.3	0.44	2012.307	732	8.45	10.69	1
12519+1910	STF1685AB	202	1.2	16.1	0.36	2012.307	824	7.31	7.78	1
12519+1910	SHJ 153AC	328	0.1	243.1	0.55	2012.307	559	7.31	8.22	1
12519+1910	SHJ 153BC	331	0.1	252.5	0.55	2012.307	571	7.78	8.22	1
12525+0712	HJ 2621AB	87	0.6	32.9	0.36	2012.307	720	9.64	9.51	1
12525+0712	HJ 2621AC	129	0.6	38.5	0.45	2012.307	724	9.64	11.42	1
12525+0712	HJ 2621BC	187	0.9	26.2	0.41	2012.307	785	9.51	11.42	1
13008+0252	HLD 14AC	100	1.0	48.5	0.90	2012.301	595	9.77	12.05	1
13021+0717	STF1708	295	1.9	11.6	0.43	2012.304	691	9.23	10.36	1
13027-0159	HJ 1225	111	2.5	14.9	0.64	2012.458	684	10.6	10.8	1
13045+0839	WS 9001AC	235	0.4	75.3	0.57	2012.307	635	8.32	12.	1
13045+0839	WS 9001AD	20	2.6	54.8	1.42	2012.307	685	8.32	12.	1
13050+1430	UC 181	206	1.0	47.7	0.69	2012.307	747	11.39	12.84	1

Table 2 continues on next page.

Double Star Measures Using the Video Drift Method - III

Table 2 (continued): Results of 242 double stars using the video drift method.

WDS	Discoverer	PA°	σ-PA	Sep"	σ-Sep	Date	No. of (x,y) pairs	mag Pri	mag Sec	No. Drifts
13054-2103	VVO 11	53	0.3	160.3	0.78	2012.307	539	10.3	10.4	1
13069-0619	AOT 51	177	2.5	9.2	0.69	2012.299	740	11.4	12.5	1
13072+0435	GRV 863	203	3.1	8.5	0.42	2012.299	775	10.0	11.3	1
13076+1216	HJ 2640	6	0.5	52.9	0.43	2012.299	780	9.25	10.86	1
13077+2401	STT 259	21	0.3	39.7	0.16	2012.403	2266	8.24	8.60	3
13085+0107	STF1721	2	2.5	6.3	0.50	2012.304	696	10.18	10.27	1
13085-0241	S 647	213	0.6	42.3	0.46	2012.299	733	7.91	10.36	1
13092+0848	A 1786	96	1.7	13.9	0.43	2012.304	696	10.10	11.6	1
13109+2114	COU 96AB	309	2.4	11.0	0.43	2012.458	750	6.82	10.8	1
13114+0938	LDS5771	169	0.3	82.1	0.53	2012.307	767	8.74	12.33	1
13115-3508	HJ 4571	266	1.2	23.5	0.48	2012.307	888	6.79	9.13	1
13117-3216	HJ 4572	304	1.2	26.0	0.58	2012.307	864	9.86	10.59	1
13121+1113	HJ 221	187	0.8	49.5	0.62	2012.307	761	8.6	11.1	1
13242-0159	GLP 9	243	0.2	61.9	0.23	2012.402	1798	9.98	10.07	3
13242-0206	STF1741	262	0.5	25.0	0.21	2012.402	2007	8.36	9.78	3
13572-1233	HJ 4637	142	1.6	13.4	0.44	2012.304	705	10.63	11.3	1
13577-1717	HJ 2692AC	226	1.6	29.8	0.66	2012.304	699	10.49	11.60	1
14001+0356	UC 188	138	1.5	21.6	0.57	2012.304	669	10.92	11.87	1
14014-1409	HJ 2696	106	3.4	17.4	1.08	2012.304	682	10.14	13.1	1
14178+4845	HJ 2710AC	321	0.3	24.2	0.09	2012.299	6397	9.47	9.77	6
14189+1812	LDS 956	217	2.2	14.6	0.50	2012.458	736	13.15	14.31	1
14189+3220	HJ 2709	84	1.7	28.8	0.81	2012.458	785	11.46	14.5	1
14190-2549	BU 1246AC	117	0.1	85.9	0.06	2012.458	579	5.93	11.0	1
14245-1608	FOX 183	221	1.2	26.2	0.56	2012.307	777	10.32	12.13	1
14250-0301	BAL 234	5	2.0	16.7	0.60	2012.307	760	10.87	12.8	1
14324+3138	STF1855AB	248	0.7	15.7	0.17	2012.301	2473	9.24	9.94	3
14343+2424	STTA129	67	0.1	77.5	0.17	2012.403	1899	8.43	8.53	3
14427-0558	STF1869	132	0.4	26.3	0.20	2012.403	2072	8.43	9.52	3
14505-0527	HJ 4708	165	2.2	23.8	0.94	2012.463	632	11.46	11.95	1
14589-1109	STF1894AB	39	0.6	19.9	0.23	2012.403	2117	5.87	9.9	3
15006+1606	KU 107	359	0.4	53.6	0.41	2012.458	738	9.82	11.00	1
15010-0831	J 1586CD	346	4.0	9.8	0.66	2012.458	720	11.3	13.7	1
15011-3651	FAL 48	5	1.3	14.0	0.30	2012.458	839	9.00	12.15	1
15016-0310	STF1899	68	0.7	27.9	0.38	2012.460	653	6.69	10.15	1
15017-0707	GIC 123	111	1.4	40.9	1.03	2012.458	636	14.9	17.1	1
15018-3656	HJ 4724	228	2.1	15.0	0.55	2012.460	876	7.97	10.27	1
15019+1547	STF1902	191	0.3	26.6	0.16	2012.301	2944	8.99	9.61	4
15019+2141	GRV 896	240	0.6	46.6	0.48	2012.460	700	10.7	11.9	1
15114-3615	HJ 4745AB	22	1.4	27.2	0.59	2012.463	907	9.40	10.78	1
15114-3615	HJ 4745BC	93	2.0	15.3	0.72	2012.463	898	10.78	11.27	1

Table 2 continues on next page.

Double Star Measures Using the Video Drift Method - III

Table 2 (continued): Results of 242 double stars using the video drift method.

WDS	Discoverer	PA°	σ-PA	Sep"	σ-Sep	Date	No. of (x,y) pairs	mag Pri	mag Sec	No. Drifts
15116-3208	HJ 2765	351	1.1	27.6	0.53	2012.463	894	9.53	10.12	1
15117+1623	BPM 625	64	1.2	72.1	1.28	2012.463	679	14.30	14.32	1
15119-3250	HJ 4743	196	2.4	11.0	0.43	2012.463	933	8.80	9.12	1
15128+2756	H 5 125	228	0.3	32.4	0.14	2012.301	3012	8.43	9.46	4
15287+4215	HJ 1274	310	3.9	6.9	0.33	2012.458	949	10.61	10.8	1
15294+4743	BU 944AB	130	2.8	10.7	0.36	2012.458	1019	6.87	12.8	1
15294+4743	BU 944AC	70	0.9	56.5	0.64	2012.458	863	6.87	12.8	1
15329+0531	STF1953	252	3.2	6.7	0.39	2012.458	707	9.65	10.58	1
15346+4454	HJ 2788	302	0.5	47.1	0.32	2012.458	891	8.50	8.58	1
15375+2325	POU3196	176	2.9	12.5	0.67	2012.463	791	13.4	13.6	1
15376-0147	LDS 533	34	3.0	20.2	0.89	2012.463	767	12.7	15.2	1
15383+2431	ARY 11	327	0.1	151.0	0.16	2012.402	2440	7.03	8.83	4
15509+1441	STF1978	237	1.2	15.1	0.36	2012.463	658	9.19	10.13	1
15517-1109	STF3098	336	1.6	23.0	0.65	2012.463	631	9.47	11.3	1
16087+0210	BAL1913	354	3.2	7.9	0.51	2012.463	783	11.45	12.09	1
16089+1738	BPM 651	215	1.0	33.9	0.56	2012.463	795	11.26	12.58	1
16089+2456	HO 550	297	1.4	17.4	0.45	2012.463	837	8.6	12.8	1
16091+0720	HJ 1286AB	156	1.5	18.8	0.57	2012.463	766	10.51	12.1	1
16091+0720	HJ 1286AC	218	1.3	36.4	0.84	2012.463	745	10.51	12.9	1
16093-0140	BAL 563	142	1.6	22.6	0.78	2012.463	765	10.48	13.1	1
16095+1513	BPM 652	135	0.6	97.1	1.00	2012.463	662	12.53	13.98	1
16308-2820	HJ 4859	265	2.8	11.0	0.69	2012.463	729	10.29	10.30	1
17224-1839	ARA 442	307	4.7	6.2	0.57	2012.463	675	8.69	11.8	1
17229-0223	RAG 9	146	0.8	46.3	0.61	2012.463	604	6.3	12.2	1
17245+3657	STT 329AB	12	0.4	33.5	0.17	2012.482	2512	6.35	9.88	3
17249+1320	STF2159	326	0.4	27.0	0.18	2012.510	2119	8.53	9.44	3
17279+1123	STF2166	282	0.3	27.1	0.14	2012.498	4058	7.15	8.58	6
17346+0935	STFA 34AB	190	0.3	42.2	0.19	2012.485	2072	5.80	7.50	3
17360+2100	STF2190AB	23	0.6	10.4	0.09	2012.555	6739	6.13	9.48	9
17411+2431	STF2194AB	8	0.4	16.3	0.12	2012.530	4660	6.51	9.28	6
17465+2743	STF2220A,BC	247	0.2	35.2	0.10	2012.555	6509	3.49	9.78	9
17503+2517	STF2232	139	0.9	6.7	0.11	2012.530	5404	6.71	8.85	7
17526+2443	POU3318	238	5.0	8.3	0.69	2012.463	715	12.9	13.3	1
17526+2536	LBU 1AB,C	253	0.9	34.6	0.55	2012.463	817	9.17	10.89	1
17526-2108	J 1616	155	1.9	5.7	0.22	2012.463	801	10.6	10.9	1
17527+1459[1]	BPM 705	232	0.7	25.9	0.25	2012.463	762	11.87	14.58	1
17531+1401	HJ 1306	5	0.3	30.8	0.13	2012.563	4324	9.80	10.18	6
17590+3003	STF2259	277	0.4	19.5	0.11	2012.528	4681	7.27	8.44	6
18015+2136	STF2264	256	1.1	6.4	0.12	2012.530	4550	4.85	5.20	6
18057+1200	STF2276AB	256	1.3	7.0	0.16	2012.471	2891	7.09	7.44	4

Table 2 concludes on next page.

Double Star Measures Using the Video Drift Method - III

Table 2 (conclusion): Results of 242 double stars using the video drift method.

WDS	Discoverer	PA°	σ-PA	Sep"	σ-Sep	Date	No. of (x,y) pairs	mag Pri	mag Sec	No. Drifts
18067+1359	FOX 219AD	319	0.1	86.8	0.17	2012.558	4320	10.44	9.08	7
18078+2606	STF2280AB	183	0.7	14.6	0.15	2012.471	2386	5.81	5.84	3
18332+4010	STT 356AB	303	0.4	28.9	0.16	2012.482	2540	7.30	9.23	3
18332+4010	STT 356AC	9	0.2	49.4	0.16	2012.482	2563	7.30	10.90	3
18362+4117	STF2351	161	2.1	4.8	0.17	2012.482	2811	7.60	7.64	3
18373+0732	STF2346	299	0.3	30.2	0.18	2012.510	1994	7.93	10.00	3
18433+3918	BLL 35	191	0.1	62.7	0.12	2012.549	5221	6.64	10.35	6
18448+3736	STFA 38AD	151	0.2	44.3	0.12	2012.533	5067	4.34	5.62	6
18501+3322	BU 293AE	318	0.1	66.3	0.13	2012.597	4298	3.63	10.14	6
18501+3322	BU 293AF	19	0.1	86.9	0.13	2012.597	4546	3.63	10.62	6
18501+3322	STFA 39AB	149	0.1	47.6	0.09	2012.565	9944	3.63	6.69	13
18549+3358	SHJ 282AC	350	0.1	46.2	0.08	2012.565	10774	6.14	7.60	13
18560+3347	STF2421	56	0.3	24.7	0.10	2012.587	5672	8.13	9.34	7
18588+4041	STF2431	233	0.7	19.2	0.15	2012.482	2678	6.17	9.61	3
19020+1907	HJ 2851AC	291	0.2	48.7	0.20	2012.485	1960	7.06	11.35	3
19020+1907	WAL 102AD	137	0.5	47.5	0.37	2012.485	1999	7.06	12.	3
19046+2320	SLE1030AD	118	0.2	56.2	0.20	2012.485	1934	7.25	11.19	3
19046+2320	STF2445AB	262	0.6	12.3	0.11	2012.545	4347	7.25	8.57	6
19046+2320	STF2445AC	109	0.1	143.8	0.14	2012.545	2838	7.25	8.46	6
19046+2320	STF2445BC	107	0.1	154.8	0.19	2012.485	1327	8.57	8.46	3
19069+2210	STF2455AB	27	0.8	9.5	0.12	2012.545	4547	7.42	9.44	6
19069+2210	STF2455AC	20	0.1	101.4	0.18	2012.485	2043	7.42	12.3	3
19071+2235	STF2457	200	0.7	10.4	0.12	2012.545	4546	7.46	9.52	6
19138+3909	STF2487AB	81	0.4	28.7	0.15	2012.584	2603	4.38	8.58	3
19164+3808	SHJ 292AB	70	0.1	100.1	0.10	2012.587	4664	4.48	10.14	7
19210+1909	STF2504AB	282	1.1	8.6	0.17	2012.485	2180	7.00	9.03	3
19210+1909	WAL 111AC	102	0.1	91.8	0.25	2012.485	1616	7.00	12.17	3
19255+1948	HJ 2871AB	90	0.4	14.5	0.15	2012.551	4217	5.16	10.0	6
19255+1948	HJ 2871AC	209	0.2	52.2	0.17	2012.551	3915	5.16	11.7	6
19265+1953	STF2521AB	32	0.4	29.1	0.18	2012.485	2124	5.82	10.5	3
19265+1953	STF2521AC	327	0.1	75.4	0.14	2012.545	3916	5.82	10.54	6
19265+1953	STF2521AD	62	0.1	152.6	0.19	2012.485	1374	5.82	10.57	3
20197+4108	STTA205	321	0.2	46.6	0.12	2012.598	5236	7.19	8.91	6
20230+3913	STTA206AB	255	0.2	43.7	0.11	2012.598	4878	6.72	8.63	6
20474+3629	S 765AC	106	0.1	84.0	0.13	2012.614	4039	4.76	9.65	6
22213+2820	HO 615AB	129	0.1	72.3	0.11	2012.684	6610	4.83	10.73	10
22237+2051	STF2900AC	307	0.1	92.2	0.12	2012.718	4750	6.28	8.54	8
22407+2959	STF3134	76	1.2	6.4	0.11	2012.614	4879	9.59	10.09	6
22415+3003	STF2932AB	283	0.3	22.0	0.11	2012.614	5445	9.32	9.44	7
22430+3013	BU 1144A,BC	339	0.1	94.4	0.11	2012.351	7302	3.02	9.87	10
23304+3050	STF3018AB-C	202	0.4	19.2	0.12	2012.218	4832	7.43	9.75	6
23469+2825	STF3039AB	29	0.2	35.8	0.10	2012.252	7578	7.41	9.39	10

Table 2 Notes

All magnitudes taken from the WDS catalog. All position angle / separation measurements are based on the Equator and Equinox of date.

A PA standard deviation of “0.0 deg represents a standard deviation of less than 0.05 deg.

Column titled “**No. of (*x*,*y*) pairs**” is the total combined no. of (*x*,*y*) pairs (video frames) from all drift runs. All video frames were used, none were discarded.

The last column “**N**” is the number of drift runs made for that double.

[1]17527+1459 – WDS magnitude for primary is listed as +11.87. It is” likely closer to +8.5.

(Continued from page 114)

greater than 25" the average probable error was lower at 0.34°. This is an expected mathematical result explained from Figure 1 of Paper II. Thus the video drift method maintains highly consistent results over multiple drifts and over several nights.

Acknowledgements

This research makes use of the Washington Double Star Catalog maintained at the US Naval Observatory.

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A New Common Proper Motion Double Star in Corvus

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Abstract: In this paper, I report a new visual binary star in the Constellation of Corvus that is not in the current edition of the WDS catalog, the components of which share a common proper motion. On detailed binarity assessments, the two stars seem quite possibly a gravitationally connected pair.

Introduction

This pair first came to my attention in January 2012 in DSS images and I later obtained my own discovery image using the 0.61-meter Cassegrain telescope of the SSON [1] on the night of May 13th 2012 (at 05:28 UTC). The primary has the designation BD-13 3613 and is of visual magnitude +10.5, at ICRS coordinates: 12 53 38.5, -14 27 44 (Epoch 2000.0). I have estimated the brightness of the secondary to be at least 1.5 magnitudes fainter, at V mag. +12.0.

Latest Measurements

My discovery image of this pair is shown in Figure 1.

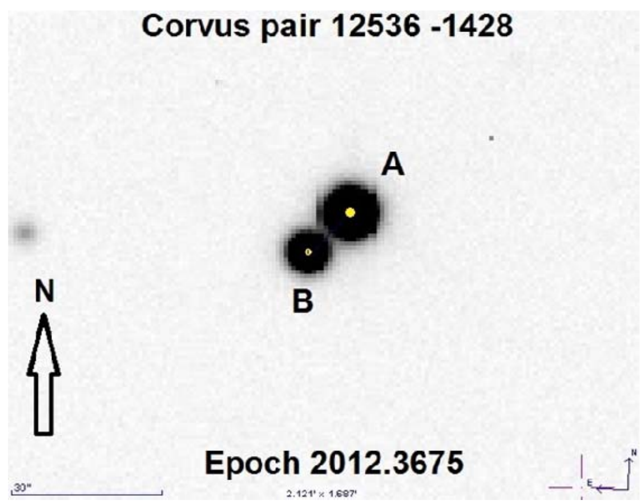

Figure 1: Image of the new cpm pair. Measurements from the above image yield position angle (theta) = 137.0^o and separation (rho) = 11.59" (Epoch 2012.3675)

Proper Motion and Distance

The UCAC3 catalog [2] indicates that the two stars share similar proper motions (PM) in both RA and Dec, in both magnitude and in sign. These are given in Table 1.

The pair as a whole, has a total proper motion of $\{[(-31.5)^2 + (17.6)^2]^{½} + [(-27.0)^2 + (14.9)^2]^{½}\} / 2 \approx 33.5$ milliarcseconds per year. These values are similar to those stated in the PPMXL Catalog (Roeser+ 2010), which may be taken as an additional source of PM for independent verification. In that catalog, the secondary star has proper motions of (-27.7, +18.2) mas/yr which are significantly more similar to the observed proper motions of the primary.

In my report in the Webb Society DSSC19 [4], I showed for purposes of illustration the distances and proper motions of a number of binary systems, and the basic correlation that exists between these two parameters. Referring to that scale, this figure of

Table 1: Proper motion of the components.

Corvus Double Star	Proper Motion in RA	Proper Motion in Dec
A-component	-31.5 mas/year	+17.6 mas/year
B-component	-27.0 mas/year	+14.9 mas/year

Table 2: J and K magnitudes of the components

	J-magnitude	K-magnitude
A-component	+9.575	+9.297
B-component	+10.744	+10.360

33.5 mas/year suggests this Corvus double star is located in the region of somewhere around 400 light-years away from the Earth.

Photometry and Spectral Classification

The 2MASS catalog [3] which was the result of a survey of the sky conducted in the near-infrared, gives the J and K-band magnitudes for the two components in this Corvus double star shown in Table 2.

From these we deduce color indices of (J – K) = +0.28 for the primary and (J – K) = +0.38 for the secondary component.

In 2012, I devised a methodology for deciding the approximate horizontal position in the spectral classification of visual double stars on the Hertzsprung-Russell (H-R) diagram, by working out their 2MASS (J – K) color indices [5]. From the above calculated color index values, and the methodology descrdibed in reference [5], we can infer spectral types of roughly ~G0 for the primary star, and ~K0 for the secondary star in this Corvus double. We can further state, with reasonable confidence, that both stars are likely to be of luminosity class "V" (main sequence dwarves on the H-R diagram) as follows.

Since we already have a basic assumption from the size of their PMs that this pair is located approximately around ~400 light-years away, we can show that the assumptions about their colors and spectral classifications fit the distance modulus. A G0V star placed at a distance of 400 light-years away from the observer will shine at an apparent visual magnitude of around +10.1. For example, the star Chi-1 Orionis is of spectral class G0V, situated at a distance of 28.3 light-years away, shining at apparent magnitude (m) +4.39, and it has an absolute magnitude (M) of +4.67. If Chi-1 Orionis were hypothetically placed 400 light-years away from Earth, it would shine with an apparent magnitude of +10.1. This is not far off from the primary star's +10.5 magnitude brightness we observe in this Corvus double star.

Purely on the basis of the size of its observed proper motion, we can tentatively infer that the secondary star in this double star (B-component) has to be at a similar distance from the Earth as the primary. Its observed apparent brightness and color, therefore, imply it too has to be of luminosity class "V", as a K-type main sequence dwarf on the H-R diagram.

On the assumption that both stars in this pair are in fact at the same distance of 400 light-years away, if their orbit was projected in the plane of the sky, the two stars would be physically separated by:

Tan (11.59") x 400 x 63240 = 1421 Astronomical Units in three-dimensional space.

Conclusions

In the various methods of fitting the observed photometric values to physical properties, distances and proper motions of this pair discussed in this paper, it seems that this is quite possibly a binary star – as opposed to it being merely a line-of-sight optical double star.

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High Speed Astrometry of STF 2848 With a Luminera Camera and REDUC Software

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Abstract: The double star STF 2848 was observed at high speed with a Luminera SKYnyx 2-0m camera controlled with Lucam Recorder software. The observations were reduced using the interferometry feature of REDUC, the software developed by Florent Losse. Some 2000 frames were recorded on the first night, and 7500 on the second night. The sensitivity of the results to reduction settings and number of frames was found to be small. The precision of the results was examined both within and between nights, and also as a function of three integration times: 32, 16, and 8 milli-seconds. Finally, these observations were compared with recent published observations.

Introduction

A recently acquired high speed Luminera SKYnyx 2-m CCD camera was used to observe the double star STF 2848 at high speed. The objectives of these observations were to: (1) gain experience with this camera and its associated Lucan Recorder software, (2) learn how to reduce these observations with the recent interferometry addition to Florent Losse's REDUC program, (3) explore the effects of changing reduction and observational parameters on the precision of the results, and (4) compare my observations with recent past observations.

The Carro Double Star Catalog (Carro 2012) was used to search for an appropriate double for these initial observations. STF 2848 (WDS 21580 +0556, SAO 127196) was well positioned in the sky, and its separation of almost 11 arc seconds made it easy to observe without the complication of using a Barlow lens. While my eventual goal is speckle interfreometry measurements of much closer double stars with larger telescopes, I purposely began with this rather wide double and small telescope (without any Barlow magnification) to simplify these initial observations. As expected, the short effective focal length (only

Figure 1: The author and 10-inch telescope at the Orion Observatory. The laptop on the left controls the telescope and acquisition camera, while the laptop on the right controls the high-speed Luminera camera.

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Figure 2: Instrument cluster on the back of the 10-inch telescope. An Orion Telescopes flip mirror is directly below the telescope, with the Luminera high speed camera to the left of the flip mirror and the SBIG ST-402 camera below it.

about 100 inches—2540 mm) did not bring out true speckles, although one could observe "splotches" dancing about at high speed.

Observations were made on the evenings of September 19 and 21, 2012, at the Orion Observatory near Santa Margarita Lake, just inland from San Luis Obispo on California's central coast. The observatory has 8-, 10-, and 11-inch Schmidt-Cassegrain telescopes

Telescope and Instrument Configuration

Observations were made with the Meade 10-inch, f/10 Schmidt Cassegrain, equatorial, fork-mounted telescope shown in Figure 1. The original LX-200 control system was replaced with a Sidereal Technology (SiTech) control system. SiTech control systems have numerous advanced features, and are utilized on many telescopes large and small. The telescope was controlled from a laptop running the SiTech software, The Sky 6, and CCD Soft (to control the acquisition CCD camera).

The overall instrument layout is shown in Figure 2. An Orion Telescopes 1.25 inch flip mirror was modified by replacing its 1.25 inch female nose piece with an SCT threaded coupler. This not only allowed the flip mirror to be more firmly coupled to the backplane of the telescope, but also provided additional, much needed clearance between the telescope and the equatorial wedge.

There was insufficient clearance below the fork on this telescope to have a "straight through" optical path through the flip mirror leading directly to the Luminera camera. Although it might have been desirable to avoid any distortions introduced by the flip mirror, there simply wasn't enough clearance for this option.

Lumenera Camera and Lucam Recorder Software

A high speed camera, the Luminera SKYnyx 2-0M, was used for the observations. This camera, made in Canada, currently costs $1095 (Oceanside Photo Optical USD). It employs a Sony IXC424 monochrome progressive scan CCD sensor with 480x640 (4.9 x 5.3 mm) square 7.4 micron pixels. Although the camera was designed for astrophotography of the Moon and planets (lucky imaging), it is also useful for scientific observations such as double star speckle interferometry, high speed photometry of variable stars, asteroid occultations of background stars, and lunar occultations of double stars.

The camera's well depth is 40,000 electrons, with a read noise of 10 electrons and a dark noise of < 1 electron/second (the camera is not cooled). Full frames can be read out at 60 frames/second. Both power and communications are provided through a standard USB 2.0 interface. The camera weighs 320 grams and features a solid anodized aluminum body which measures 2.5 x 3.8 x 1.7 inches.

Integration times can be varied from 1 millisecond to many seconds, and the gain, gamma function, and contrast settings can all be varied through the controlling software. Output can be set to 8 or 12 bits, and 2x2 binning can be employed. Of significant interest to double star observers (and those with an interest in high speed photometry) is a completely software settable Region of Interest (RoI). A small RoI not only reduces data storage and transmission requirements, but it allows faster frame rates. For the observations reported in this paper a RoI of only 64x64 pixels was used, allowing frame rates of up to 116 frames/second.

The Lumenera camera is supported by several

High Speed Astrometry of STF 2848 With a Luminera Camera and REDUC Software

third party software suites such as Maxim DL. I used Lucam Recorder, developed by Heiko Wilkens. A free, limited version Lucam Recorder can be downloaded from the Internet. A license for an advanced version can be purchased for a modest fee. The license, which is camera serial number specific, can be used on any number of computers. Lucam Recorder is easy to use, well thought out, and has many fine features.

REDUC Speckle Interferometry Reduction Software

Florent Losse's REDUC double star reduction and analysis software has been refined over the years and is used by many double star observers around the world. This free software is user friendly and well documented. Losse recently added an interferometry reduction capability to his software suite.

The interferometry feature is easy to use. One loads in the observations, which can be in FITS (8, 16, or 32 bit integer, or 32 or 64 bit real), Bitmap, or AVI. REDUC has provisions for converting AVI files to Bitmap before proceeding. One then clicks Auto Correlation. The program automatically conducts a fast Fourier transform (FFT) if the images are square (such as 64x64, 128x128, etc., pixels). If the images are not square, REDUC has a routine to square them. REDUC even has a procedure to take care of non-square individual pixels.

The autocorrelation diagram (image), i.e., the "autocorrelogram," labeled as S0 is difficult to use directly because the peaks are often imbedded in noise and hence are difficult to measure. To overcome this difficulty, the autocorrelogram is repeatedly processed by subtracting a mean mask that uses a growing kernel of 3x3, 5x5, … 19x19 pixels. These are labeled S1 – S9, respectively. One can then choose an autocorrelogram appropriate to the observational situation. Losse suggests that for an Airy disk of 2 or 3 pixels to use S2, an Airy disk of 5 pixels to use S3, etc.

The position angle of the double star as measured from the autocorrelogram normally has an ambiguity of 180°. This ambiguity is inherent in the usual speckle reduction process. The brighter star will always be flanked by two identical dimmer stars exactly 180° apart. If one knows from other (previous) observations the approximate position angle, then this ambiguity is resolved. If not, then one either needs to obtain at least a rough position angle by other means (such as lucky imaging), or one can use the REDUC Cross Correlation feature if the two components of the double star are of significantly different brightness. The ambiguity will then be resolved in the cross correlation autocorrelogram as one of the two flanking stars will be noticeably dimmer than the other.

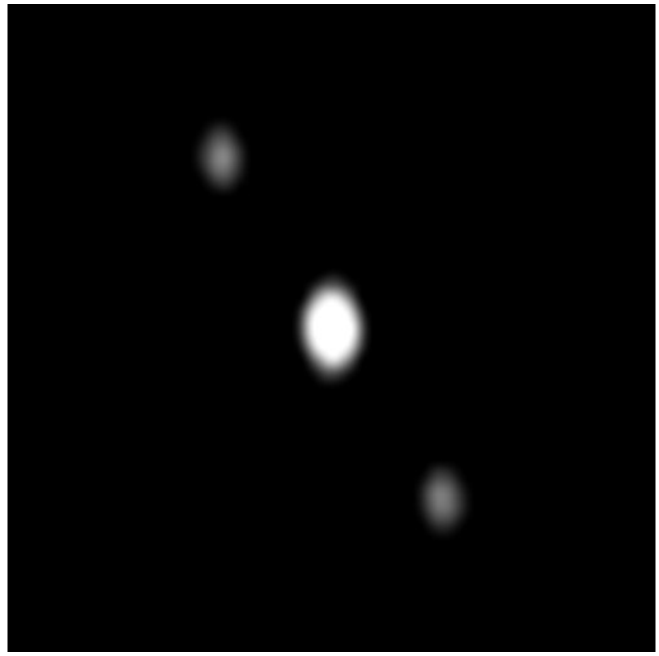

Figure 3: Typical autocorrelogram from REDUC. This one is of STF 2848 from 500 frames taken on the first night. Measurement of the position angle and separation from the centroid of the central image to either of the two flanking images provides the result, albeit with a 180° ambiguity.

Instead of calculating a normal Autocorrelation, the autocorrelation can be calculated with an Enhanced Power Spectrum, which is calculated with the square of the images. This procedure increases the contrast of the fringes during the creation of the power spectrum.

Camera Calibration

The orientation and plate scale of the Luminera camera were determined though astrometry of M-39 on the evening of September 21, 2012 (the camera had remained in place for both nights). Two 20-second images were taken, slightly offset from the center of M-39 to avoid the brightest stars. The two images were offset from each other by about 1 minute of arc to provide independent astrometric solutions.

CCD Soft, linked to The Sky 6, was used to obtain the two astrometric solutions. The solutions both yielded a plate scale of 0.54 "/pixel. CCD soft's plate scale only reports the plate scale to two decimal

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Figure 4: A typical frame from the first set of observations on the second night. The image has been cropped and enlarged from the original 64x64 pixel image.

places—more would have been appropriate. The two camera angles were in close agreement; 271.56° and 271.79°. Although the two values could have been averaged, just the first value was used in the analysis.

STF 2848 Observations

STF 2848 was observed on two evenings, September 19 and 21, 2012. No filter was employed. On the first evening, 2000 frames were obtained. Each frame had an integration time of 32.6 milli-seconds taken at a frame rate of 28.9 frames/second. The total capture time was 64.86 seconds. Data were recorded in an 8-bit AVI format. Gamma was set at 1.0. Subsequent to the observations the data were divided into four sets, each consisting of 500 frames.

On the second night, September 21, 2012, some 7,500 frames were taken of STF 2848 in 15 separately recorded observations of 500 frames each. The 15 observational sets (each consisting of 500 frames) were recorded at three different frame rates as shown in Table 1.

Repeatability of REDUC Calculations

A check was made to determine if, with the same settings and input data set, REDUC always produced the same results. The same data set was repeatedly loaded and analyzed. If the same procedure was used, such as selecting the same mean mask, the results were always identical. Thus, as expected, REDUC is entirely deterministic.

Table 1: Specifics for the 7500 frames captured on September 21st .

Exposure (milli-seconds)	Frame Rate (frames/second)	# Sets	Frames/Set
32.6	28.9	5	500
16.4	57.8	5	500
8.2	116.0	5	500

Sensitivity of Results to REDUC Settings

The first set of 500 frames from the evening of September 19th was used to compare changes in the reduction settings. The baseline setting was an S5 median mask and a pixel area of 5x5. Running Autocorrelation gave a value for STF 2848 of 55.49° position angle and 10.832" separation. Still using Autocorrelation and the S5 result, increasing the pixel area to 15x15 gave 55.55° and 10.822". When the settings were the baseline (S5 and 5x5) and Cross Correlation was run instead of Autocorrelation, the values were 55.29° and 10.872". While changing the settings does change the results, the changes are fairly small. As Florent Losse pointed out, if one considers this from the viewpoint of pixels in rectangular coordinates, all three points are contained in an area of just 0.015x0.070 pixels. The largest distance between the three points is 0.070 pixels or only 38 milli-arc seconds at the camera's plate scale.

Sensitivity of Results to Number of Observations and Enhanced Power Spectrum

As mentioned above, with settings of S5 and 5x5 running Autocorrelation on the first 500 frames gave values 55.49° and 10.832". When all 2000 frames were combined as one observation with the same settings, the result were an almost identical 55.49° and 10.833". With everything the same and Enhanced Power Spectrum checked, the result was 55.37° and 10.759"; as above this is a very small change when one considers the plate scale and pixel size.

Within and Between Night Variations

Observations from the two nights were examined. Both nights had some 32.6 ms exposures, and these were reduced with Autocorrelation (not Enhanced) with settings S5 and 5x5. The first night

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Table 2: Variations within and between nights.

Night	19 Sep	21 Sep	Difference
PA Average (°)	55.50	55.55	0.05
PA Std Dev (°)	0.059	0.007	0.062
Sep Average (")	10.80	10.93	-0.13
Sep Std Dev (")	0.180	0.002	0.178

Table 3: Effects of integration time on position angle and separation precision.

Exposure (ms)	Rate (fps)	Time (sec)	PA Avg (°)	PA SD (°)	Sep Avg (")	Sep SD (")
32.6	28.9	16.22	55.55	0.007	10.930	0.002
16.4	57.8	8.09	55.56	0.044	10.929	0.004
8.19	116.0	4.06	55.54	0.004	10.930	0.003

(September 19) had four observations of 500 frames each, while the second night had five observations of 500 frames each.

As can be seen from Table 2, the differences in the average values between the nights were small. However, the variance (standard deviation) of the position angle on the first night was over 8 times as high as on the second night, while the separation difference was 90 times. The second night appeared to be a much better night—perhaps better seeing and also better focus (the images from the first night were slightly elongated). As frames were not checked individually for errant observations, a few deviant observations on the first night could have caused its larger variance.

Integration Time Variations

On the second night (September 21st), beside the set of observations at 30 frames/second, two additional sets (five observations for each set, with each observation consisting of 500 frames) were made. One set was taken at roughly 60 frames/second, while the other at roughly 116 frames/second. The results are given in Table 3.

As can be seen, shortening the individual frame exposure times did not seem to affect the results. Presumably this would, even for such a wide pair, eventually no longer be the case if one observed significantly fainter stars. For more closely spaced doubles (with the isoplanatic patch), and higher magnification, shortening the exposure times might have significantly improved precision because it would have "frozen" the true speckles.

Comparison with Previous Observations

The position angle and separation of the past 10 observations (from 2001 to 2011) reported in the Washington Double Star Catalog (Mason 2012) were compared with the best night's results (21 Sep with low variances in Table 2 above). Past observations were not corrected for different epochs as the pair has remained essentially unchanged for 200 years. This comparison is shown in Table 4.

Table 4: Past versus current observations.

Observations	Position Angle (°)		Separation (")	
	Mean	Std Dev	Mean	Std Dev
Past	56.25	0.35	10.84	0.04
Current	55.55	0.007	10.93	0.002

The difference in position angle was 0.70º, and in separation was 0.09". In both cases, if one considers the standard deviation of the previous observations, the current observations are about 2 sigma different than the previous observations. As these two stars have similar small proper motions, and the past observations were only over a single decade, one might question whether the camera calibration observations were sufficient. It might have been appropriate to have made calibrations before and after the program observations on both nights and, perhaps to have made the calibrations in the same area of the sky as the program double.

Conclusions

The Luminera camera and associated Lucam Recorder software is easy to use, as is the interferometry feature of the REDUC software. With the same input data and settings, REDUC always gives the same results. Variations of various adjustable parameters do change the results, but not by much.

Within and between night variations were small, suggesting the observations were fairly precise. Changing the integration time on the individual frames did not have much effect on the results.

Although the differences between these observations and past observations were not large, the means did differ by about 2 sigma. This may have been due to insufficient calibration.

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Speckle Interferometry Background Papers

Antoine Emile Henry Labeyrie (1970) is often accredited with initiating speckle interferometry, while Harold A. McAlister (1985) and his many students and associates widely applied speckle interferometry to double stars. Elliott Horch (2006) has summarized the status of speckle binary star research. Nicholas Law (2006), in his doctoral dissertation on lucky imaging also provided much useful information on speckle interferometry. Finally, Nils Turner (2012) reviewed speckle interferometry for small telescopes.

Acknowledgments

Ed Wiley kindly assisted with the REDUC interferometry reduction procedure. Brian Mason provided past observations of STF 2848. Bruce Holenstein and Frank Suits helped in the selection of high speed camera. Heiko Wilkens and Florent Losse provided, respectively, the Lucan Recorder and REDUC software suites and helped in their use. Joseph Carro provided the most recent Excel version of the Carro Catalog. Finally, my thanks to Joseph Carro, William Hartkopf, Florent Losse, Francisco Rica, Tom Smith, Ed Wiley, and Vera Wallen for their reviews of this paper prior to publication.

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TYC 6223-00442-1 Duplicity Discovery from Occultation by (52) Europa

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Abstract: The occultation of TYC 6223-00442-1 by the asteroid (52) Europa observed on 2012 August 12 in Belo Horizonte, Brazil, showed this star to be a double system. The magnitude of the primary component is estimated to be 11.3 ± 0.1, and the magnitude of the secondary component is estimated to be 12.4 ± 0.1. Since the occultation was observed from only one station it was not possible to derive a unique solution to position angle and separation. The four solutions presented in this paper were obtained considering an asteroid shape model.

Observation

On 2012 August 12, Giacchini observed the occultation of TYC 6223-00442-1 by the asteroid (52) Europa from Belo Horizonte, Brazil. According to the prediction, Belo Horizonte was placed 71 km from the central line. The predicted occultation path and observing site are shown in Figure 1. The maximum predicted duration was 81.4 s with a magnitude drop of 1.4.

The observation was made using an 18-cm-aperture clock-driven Newtonian telescope, a Watec 902H2 Ultimate camera and a KIWI-OSD time inserter. The occultation was recorded on digital tape. The light curve obtained (Figure 2) shows two flux drops. Table 1 displays the observatory position, and Table 2 contains the times of the events. The occultation of star A had a duration D_A = (78.78 ± 0.04) s, while star B was D_B = (59.3 ± 0.2) s.

TYC 6223-00442-1 was not listed in the Fourth

(Continued on page 132)

Table 1: Observatory position (WGS-84, MSL)

Longitude	43° 57′ 29.7″ W
Latitude	19° 51′ 20.1″ S
Elevation	823 m

Table 2: Times of the observed events

Event	Time (UT)
Start of observation	$01^h21^m14,0^s$
Star B disappears	$01^h24^m32.0^s$ ± 0.2 s
Star A disappears	$01^h24^m34.68^s$ ± 0.02 s
Star B reappears	$01^h25^m31.34^s$ ± 0.04 s
Star A reappears	$01^h25^m53.46^s$ ± 0.02 s
End of observation	$01^h30^m00.0^s$

TYC 6223-00442-1 Duplicity Discovery from Occultation by (52) Europa

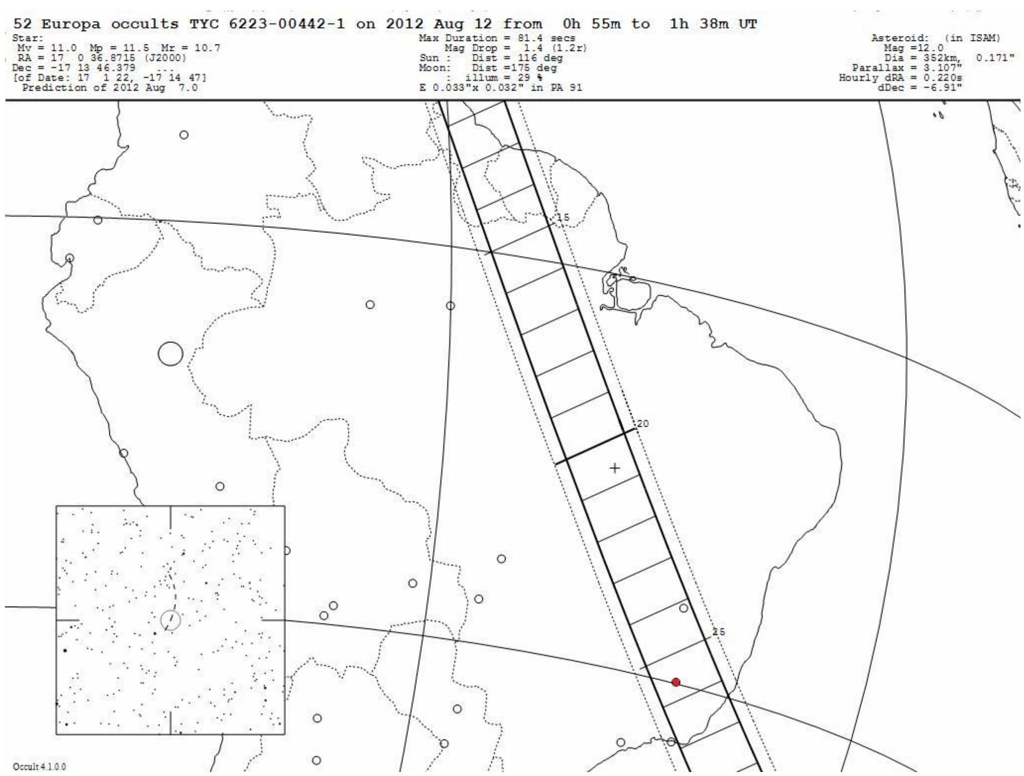


Figure 1: Predicted path and occultation details [Herald, 2012]. Belo Horizonte is marked in red.

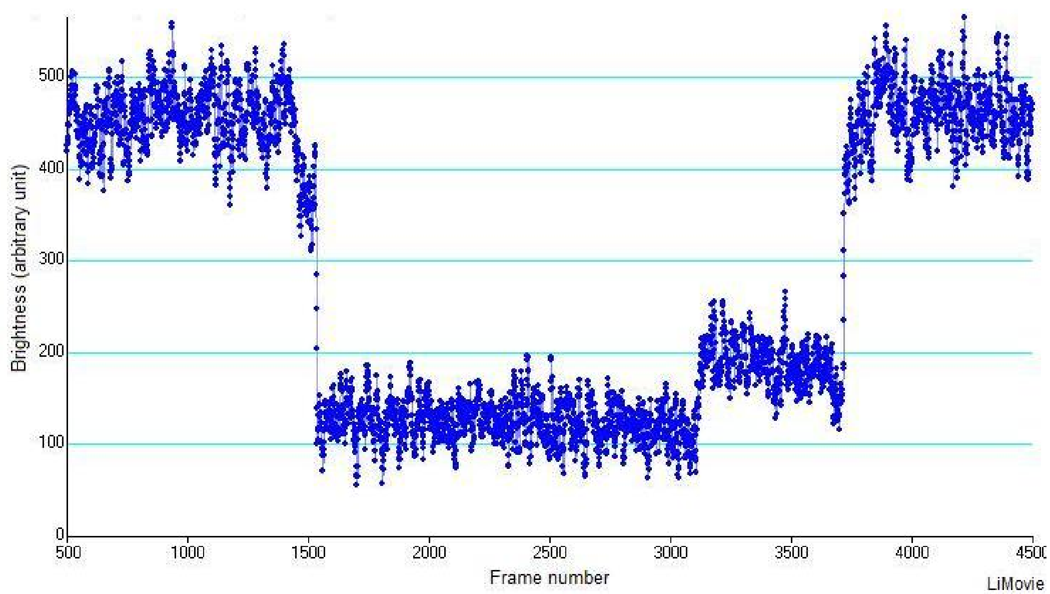


Figure 2: Star's light curve from 1:23:56 to 1:26:58 UT.

TYC 6223-00442-1 Duplicity Discovery from Occultation by (52) Europa

(Continued from page 130)

Interferometric Catalog, nor in the Washington Double Star catalog.

Data analysis

The derivation of the double star parameters that follows are based on [Herald *et al*. 2010] and were carried out using Occult4.1.0 [Herald, 2012]. Since the occultation was observed from only one station, it is not possible to ensure if our observatory was on the north or on the south of the central line. Nor is it possible to distinguish whether the secondary star was on the same side of the asteroid as the primary star. If we consider the asteroid to have a spherical shape, this leads to four different solutions of the pair's position angle and separation.

The asteroid (52) Europa has mean diameter of δ = (350 ± 5) km, according to AcuA [Usui *et al*. 2011]. We combined this information with the asteroid profile at the moment of the occultation (Figure 3) [Marciniak *et al*. 2012] in order to find the possible solutions for the double star parameters. For each of the four possibilities described before, we considered two situations: one in which the asteroid profile could inscribe a circle of diameter δ, the other in which the profile is almost entire contained in such a circle. The first situation supposes the asteroid to be a little larger than the AcuA's mean diameter, while the second considers that the asteroid was a little smaller.

For each of these we derived the pair's separation and position angle. Since the asteroid profile was quite spherical, we expect that between these two extreme situations (*i.e.* in intermediate scales for the profile), separation and position angle would remain between those two values. This allows us to make an estimative of the double star parameters for each of the four possible situations. The graphical reductions are shown in Figures 4-7 and the solutions are presented in Table 3.

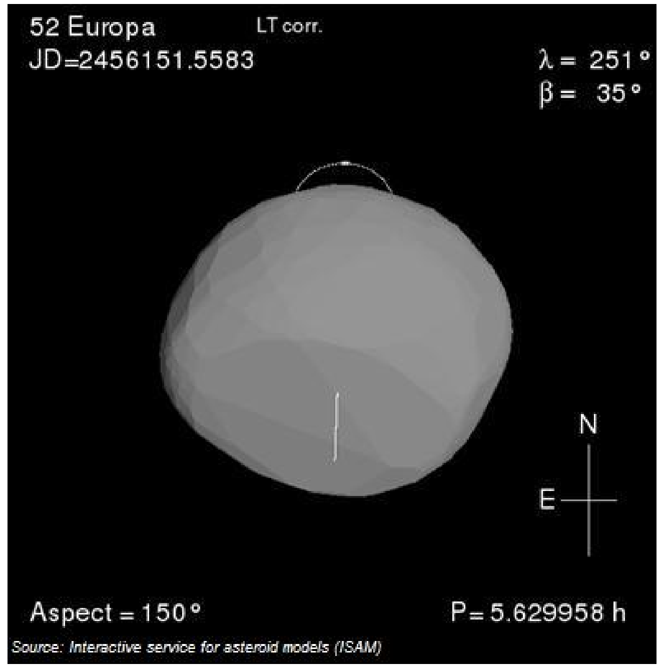


Figure 3: Model of the asteroid at the occultation moment [Marciniak *et al*. 2012].

Occult's magnitude calculator routine [Herald, 2012] allowed us to determine the magnitudes of both stars in view of the brightness levels of the light curve (Figure 2). According to UCAC4 Catalog [Zacharias *et al*. 2012], the (combined) visual magnitude of TYC 6223-00442-1 is V-Mag = (10.943 ± 0.003).

In order to avoid natural flux fluctuations interference, we calculated the average of the brightness during a period of time close to the flux drop. Thus, we considered six levels of brightness, shown on Table 4.This results in two measurements of the stars' mag-

(Continued on page 134)

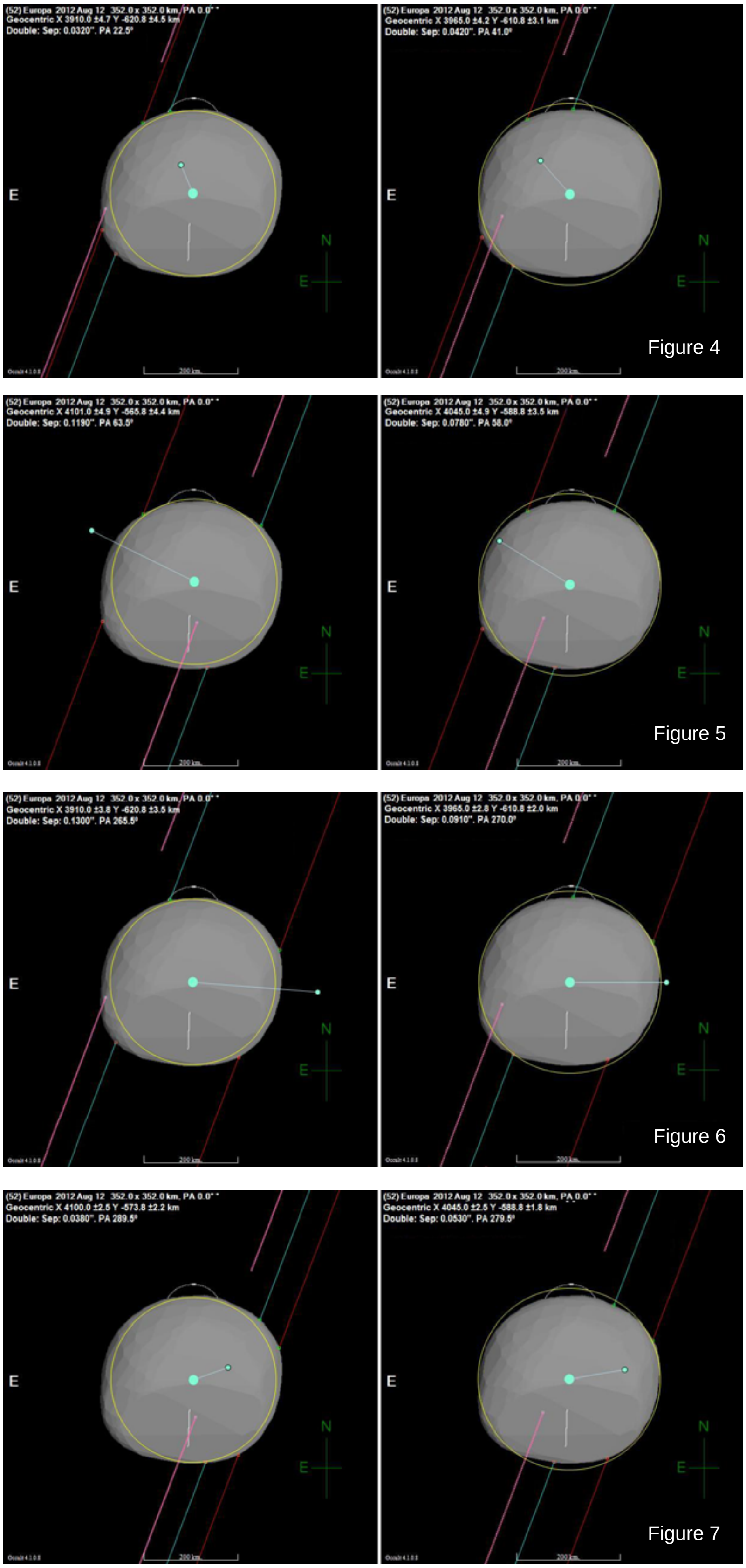
Table 3: Possible values of the double star parameters

Position angle (°)	Separation (mas)
32 ± 10	37 ± 6
61 ± 4	100 ± 20
268 ± 3	110 ± 20
285 ± 6	46 ± 7

Table 4: Average brightness at each level

Period of time (UT)	Average brightness (arb. unit)
$01^h24^m30.0^s$ to $01^h24^m32.0^s$	460
$01^h24^m32.0^s$ to $01^h24^m34.68^s$	374
$01^h24^m34.68^s$ to $01^h24^m36.68^s$	121
$01^h25^m29.34^s$ to $01^h25^m31.34^s$	109
$01^h25^m31.34^s$ to $01^h25^m53.46^s$	187
$01^h25^m53.46^s$ to $01^h25^m55.46^s$	418

TYC 6223-00442-1 Duplicity Discovery from Occultation by (52) Europa



Figures 4-7: Double star graphic reduction of separation and position angle using ISAM profile model. The circle corresponds to the AcuA mean diameter of 350km. The predicted occultation is indicated by the pink line. Figures on the left consider the asteroid profile at the moment of the occultation to be a little larger than the mean diameter; while figures on the right consider that it was a little smaller. Figures 4 and 6 show the solutions assuming that the shadow's path was closer to the predicted one; the other two represent the solution further from the predicted path.

TYC 6223-00442-1 Duplicity Discovery from Occultation by (52) Europa

(Continued from page 132)

nitudes: disappearance steps lead to the values 12.43 and 11.26; and reappearance figures are 12.42 and 11.26. Assuming an asymmetric occultation (*i.e.* the sequence of the stars involved on the events was B-A-B-A), the resulting magnitudes are: Mag_A = (11.3 ± 0.1) and Mag_B = (12.4 ± 0.1).

Based on the data presented is this report, the double star characteristics are:

Star

Tycho-2	6223-00442-1
UCAC2	146-109152
UCAC4	364-078961

Coordinates (J2000)

RA $17^h00^m36.877^s$

Dec -17º13'46.22" [UCAC4]

V-Mag A 11.3 ± 0.1

V-Mag B 12.4 ± 0.1

Separation and Position Angle: Possible solutions shown in Table 3.

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Visual and Photometric Measurements of a Selected Set of Double Stars

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Abstract: The observations and measurements using visual and photometric methods for a selected set of binary stars are reported. These tasks comprised the activities in a special mathematics course devoted to research and observational techniques being taught at the Estrella Mountain Community College in Avondale, Arizona for the fall 2012 semester.

Visual observations and measurements were taken with a Celestron 11" Schmidt Cassegrain Telescope (SCT) using the Celestron MicroGuide™ for binary star separation and position measurements. Photometric measurements were taken utilizing the suite of remote telescopes provided by the iTelescope network. FITs images were obtained and downloaded utilizing the iTelescope system. Analysis of separation and position angle of imaged binary star systems was provided utilizing the AstroImageJ image analysis software package.

Introduction

This observation program is part of a series of special mathematics classes conducted at the Estrella Mountain Community College located in Avondale Arizona. The observations presented here are a result of the class conducted during the fall 2012 teaching semester. This mathematics course is designed to give students an introduction to performing real-world research with the end goal of collecting measurement data which is of sufficient quality to be of value to the scientific community. The selection of researching binary stars was chosen since the observation and measurements of double star systems are an area which can be achieved with the use of small telescopes.[1] This observing program consisted of both visual and photometric observations.

The majority of visual observations were taken at a facility located at 33°30'8.82"N, 112° 21'46.99"W during evening hours which generally consisted of between 6:00 and 9:00 PM local time (01:00 to 04:00 UT). Visual observations and measurements covered the dates from mid September 2012 through early December 2012.

In addition to visual observing, a program of taking photometric imagery and measurements of selected binary stars utilizing a set of online telescopes was conducted. This exercise provided the students the learning opportunity to conduct astronomical observations and measurements utilizing online telescope systems. Online telescope systems in Spain and New Mexico were utilized provided by the iTelescope's network of Internet connected telescopes.

Observing Program and Instrumentation

The observing program consist of instructing the students through a process of learning basis of telescope and observing operations while at the same gaining a better understanding of double star sys-

Visual and Photometric Measurements of a Selected Set of Double Stars

Figure 1: Celestron 11" F/10 Schmidt-Cassegrain

Figure 2: iTelescope Web Interface

tems through research and data collection. Students first gather a list of possible stars from the Washington Double Star (WDS) database and the Cambridge Double Star Atlas (CDSA) which fit a set of observing criteria for place and time. After narrowing down the candidate list, students measure the separation and position angles of the stars both visually and through the use of online telescopes. This allows the students to analyze data manually, as well as with the assistance of computer software. With the continuation of the program, the data collected will be collaborated with data from the WDS and CDSA archives to model the orbital patterns of the stars to investigate the presence of a binary star system.

The instrumentation used for visual observations and measurements consisted of a Celestron 11" LX200GPS F/10 Schmidt-Cassegrain telescope of the type shown in Figure 1. Visual double star measurements were obtained using the Celestron MicroGuide™ eyepiece which is a 12.5 mm F/L Orthoscopic with a reticule and variable LED. The portability of the LX200GPS allowed for observations from a remote site with darker seeing conditions. While the majority of observations were taken at the at 33°30'8.82"N, 112° 21'46.99"W location, additional observations and measurements were obtained from a relatively dark remote location west of Phoenix Arizona at 33°13'1.22"N, 112° 16'47.75"W.

For photometric measurements, a set of three online remote telescopes provided by the iTelescope network was used. iTelescope.Net is a network of Internet connected telescopes allowing members to take astronomical images of the night sky for the purposes of education, scientific research and astrophotography[2]. iTelescope.Net is a self-funding, not for profit membership organization with financial proceeds funding the expansion and growth of the network. iTelescope.Net is run by astronomers for astronomers. The network is open to the public where anyone can join and become a member including students, amateurs and professional astronomers. With 13 telescopes, and observatories located in New Mexico, Australia and Spain, observers are able to follow the night sky around the globe 24x7.

Entry into the iTelescope system and operations of the remote telescopes is via the Launchpad webpage as demonstrated in Figure 2.

The Launchpad portal in the iTelescope system allows access to the telescopes, all sky cameras, and telescope pricing. From here, access to acquired images, reservations and telescopes availability are provided. Signing into a telescope is simple, just clicking the telescope selected will prompt for username and password. Once logged in, access to the reservations currently in the system as well as making additional reservations is provided. The iTelescope system was a good tool in our observational pursuit.

The three online telescope systems consisted of a Planewave 0.51m CDK, Takahashi Epsilon 250mm, and a Takahashi FSQ-ED of 106mm. All of the telescopes utilized are located in Mayhill, in the Sacramento Mountains of New Mexico.

Figure 3: iTelescope Planewave 0.51 m Telescope

The Planewave 0.51m designated as Telescope 11 and is shown in Figure 3.

The telescope system consists of the Planewave 0.51m corrected Dall-Kirkham Astrograph with a focal length of 2280mm, f/4.5 fitted with a 0.66 Focal Reducer. It is mounted on a Planewave Ascension 200HR mount system. The instrumentation package contains a FLI ProLine PL11002M CCD camera with a pixel size of 9um square and a resolution of 0.81 arc-secs/pixel. The CCD array is 4008 by 2672 (10.7 Megapixels) with a FOV of 36.2 x 54.3 arc-mins. Filters of Luminance, Red, Green, Blue, Ha, SII, OIII, U, B, V, R, I are provided as selected.

The Takahashi Epsilon 250 designated as Telescope 5, and is shown in Figure 4.

The telescope system consists of the Takahashi Epsilon 250 with a Hyperbolic Flat-Field Astrograph with a focal length of 850mm, f/3.4. The system is equipped with a SBIG ST-10XME CCD camera with an array of 2184 x 1472 (3.2 Megapixels) with a field of view of 40.4 x 60 arc-mins. It has a pixel size of 6.8um Square, and a resolution of 1.65 arc-secs/pixel. The system is mounted on a Paramount PME. Filters of RGB, Ha, SII, OIII & Clear and photometric BVR By Schuler are available.

The Takahashi FSQ-ED designated as Telescope 20 and is shown in Figure 5.

The telescope system consists of the Takahashi FSQ-ED, an Petzval Apochromat Astrograph optical design, with a focal length of 530mm, f/5.0. The telescope is mounted on a Paramount PME system. The

Figure 4: Takahashi Epsilon 250

Figure 5: Takahashi FSQ-ED

instrumentation consists of a SBIG ST-8300C One Shot Color CCD camera with pixel size of 5.2um square and a resolution of 2.02 arc-secs/pixel. The CCD array is 3326 x 2504 (8.3megapixels) with a field of view of 84.3 x 112 arc-mins. There are no available filters for this telescope.

Selection of Stars

The selection of stars for observation and measurement were taken from the Washington Double Star Catalog [3] and the Cambridge Double Star Atlas [4] cross referencing the standard northern hemisphere sky map provided by Sky and Telescope [5].

The WDS is maintained by the United States Naval Observatory and is the world's principal database of astrometric double and multiple star information. The WDS Catalog contains positions (J2000), discoverer designations, epochs, position angles, separations, magnitudes, spectral types, proper motions and when available, Durchmusterung numbers and notes for the components of 108,581 systems based on 793,430 means. The current version of the WDS is updated nightly. The selection of target stars resulted from reviewing the list of both common observed and neglected double stars referenced on the WDS main web page.

The Cambridge Double Star Atlas (CDSA) was written by James Mullany and published by Cambridge University Press on March 23, 2009. This is the first modern star atlas dedicated to multiple and double stars. The CDSA consists of thirty detailed celestial maps drawn and detailed by celestial cartographer Wil Tirion. In addition to the maps, the author singles out 133 of the best double stars in the sky called, 'Showpiece Double Stars.' It is from this list that we selected some of our double star for observation and measurement.

Visual Measurements of Selected Binary Stars

The visual measurements of the separation distance and position angle of the selected target stars was accomplished using a standard visual observational approach. All measurements were acquired utilizing the Celestron MicroGuide™ [6] In order to produce high quality measurements, care was taken in calibrating the measurement instrument and performing a series of test measurements for validation of results before proceeding to the measurements of the target stars.

Figure 6: Beta Cygni Primary and Secondary Star

MicroGuide Calibration

Previous calibrations of the Celestron MicroGuide™ were via the standard star drift method with the process being carried out over several nights. A different approach was utilized during this semester in that a well known star was chosen and carefully measured using the Celestron MicroGuide™ to determine the number of divisions in the MicroGuide eyepiece to arcseconds. The double star Beta Cygni was chosen for the calibration star.

Albireo, designated Beta Cygni, is a celebrated binary star among amateur astronomers for its contrasting hues. The primary star is an orange-hued giant star of magnitude 3.1 and the secondary is a blue-green hued star of magnitude 5.1. The system is 380 light-years away and is divisible in large binoculars and all amateur telescopes. A typical small telescope image is shown in Figure 6.

Measurements Process

A round robin technique used for taking new measurement data was utilized. Separation was measured by orienting the selected star systems along the Microguide's linear scale, and noting their separation as indicated by the scale's division marks. Position angle was then measured by aligning the binary systems along the linear scale, with the primary star directly on mark 30, and the secondary along the scale between marks 30 and 60. After the stars were aligned, the telescope's tracking system was temporarily hibernated, allowing the binary system to drift

Table 1: Visual Summary Data for WDS Stars

	Magnitudes		Last			Current			Precise Coordinates	
	Primary	Secondary	Epoch	PA	SEP	Epoch	PA	SEP	RA (h m s)	Dec (0 ' ")
18535+7547	6.73	7.35	2010	218	5.6	2012	216	6.1	18 53 33.2	+75 47 14.6
20347+3230	6.99	8.75	2011	285	24.0	2012	284	25.1	20 34 44.6	+32 30 21.1
20264+5638	6.37	8.31	2010	117	26.2	2012	118	26.9	20 26 23.5	+56 38 19.3
18445+3400	7.91	8.66	2003	5	65.2	2012	6	61.2	18 44 30.7	+33 59 46.1
20234+3053	8.59	9.48	2004	176	20.7	2012	174	19.7	20 23 25.5	+30 52 52.8
18015+2136	4.85	5.20	2010	257	9.0	2012	258	6.9	18 01 30.4	+21 35 44.8

out of the eyepiece's field of view. The binary system crossed over the circular scale which runs along the edge of the telescope's FOV, as this happened the position of the secondary star along this circular scale was noted. Based on the orientation, 90 degrees were then added or subtracted from this measurement to achieve the final position angle measurements.

Summary of measurement data are shown in two tables. Table 1 lists the measurements for the stars chosen from the WDS catalog and table 2 for the stars chosen from the CDSA.

Photometric Measurements of Selected Binary Stars

Imagery of Selected Stars

Along with the visual observation program, a set of online telescopes provided by iTelescope were utilized to obtain CCD imagery and corresponding photometric measurements. A set of target stars was assigned to each of the three telescopes. Imagery was acquired and analysis performed using the AstroImageJ software analysis package [7].

AstroImageJ is the ImageJ (ImageJ is a public domain, Java-based image processing program developed at the National Institutes of Health) with some customizations to the base code and a packaged set of astronomy specific plugins. The plugins are based on the Astronomy Plugins package written by Frederic V. Hessman et al. of Inst. f. Astrophysik, Georg-August-Universität Göttingen. The AstroImageJ customizations are by Karen Collins and John Kielkopf of the University of Louisville. The application is open source.

An image of the calibration star Beta Cygni is shown in Figure 7.

Measurements of Separation

Measurements of separation distances on the iTelescope imagery were obtained using a straightforward process of calculating the distance based on image pixel positions provided off the AstroImageJ display window. However, since each telescope utilized had a different camera system with corresponding FOV, imagery distances in terms of pixel positions had to be calibrated using Beta Cygni. Once this was accomplished, positions of the primary and secondary star were obtained using the photometry measuring

Table 2: Visual Summary Data for CDSA Stars

Discover	Magnitudes		Last		Current			Precise Coordinates	
	Primary	Secondary	PA	SEP	Epoch	PA	SEP	RA (h m s)	Dec (0 ' ")
Beta Cyg	3.40	4.70	55	35.0	2012	55	34.7	19 30 43.3	+27 57 34.8
STF 2840	5.60	6.40	196	18.0	2012	189	17.0	21 52 00.0	+55 47 00.0
Gamma Del	4.50	5.00	266	9.0	2012	278	9.4	20 46 38.7	+16 07 38.0
61 Cyg	5.30	6.10	144	31.0	2012	149	31.9	21 06 53.9	+38 44 57.9
Sigma Cas	5.00	7.20	326	3.0	2012	326	2.3	23 59 00.5	+55 45 18.0
8 Lacertae	5.70	6.30	186	22.0	2012	177	21.4	22 35 52.3	+39 38 03.6
Zeta Lyr	4.30	5.60	150	44.0	2012	149	41.1	18 44 46.3	+37 36 18.0
Beta Lyr	3.30	6.70	149	46.0	2012	147	44.8	18 50 04.7	+33 21 46.0
Delta Cep	3.50	6.10	192	41.0	2012	188	39.9	22 29 10.3	+58 24 54.7

Visual and Photometric Measurements of a Selected Set of Double Stars

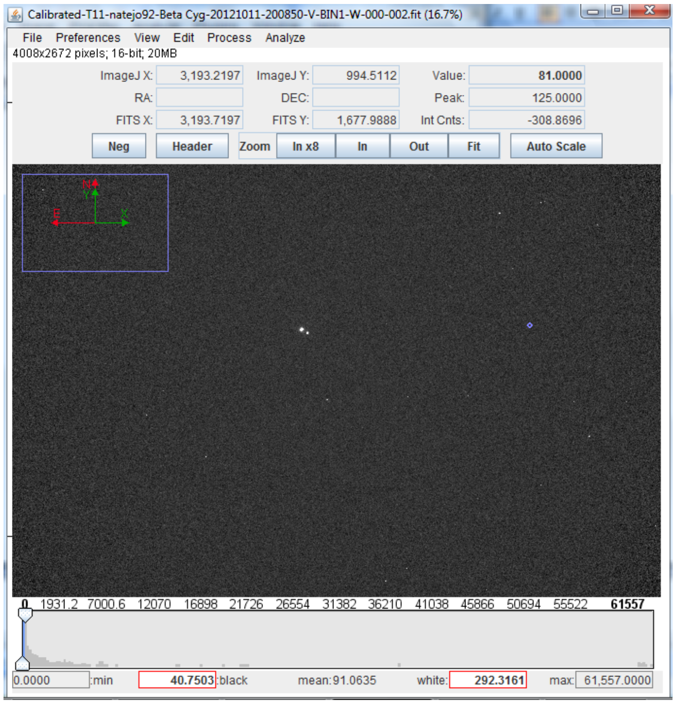

Figure 7: AstroImageJ Image of Binary Star Beta Cygni

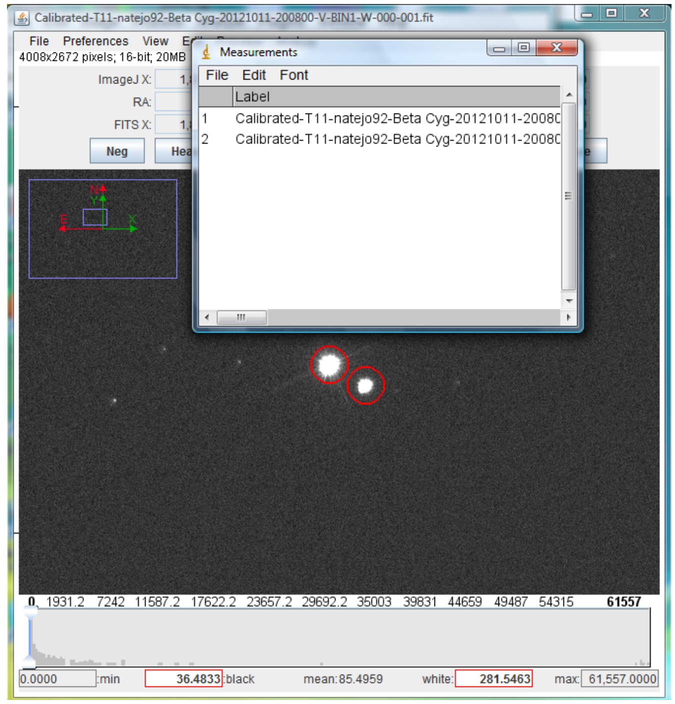

Figure 8: Positions Measurements of Primary and Secondary Stars

tool as shown in Figure 8. From these measurements, separation distances were obtained.

Measurements of Position Angle

Measurements of position angle off the imagery resulted in a set trigonometric calculations being performed in order to establish a baseline angle on the calibration star which could then be used to estimate the position angle of imaged stars. Like in the case for distance separations, baseline calibrations had to be performed for each telescope. However, when this baseline reference line was applied to other stars imaged with the same telescope, calculated angles were not close to previously established position angles. As such, only a few position angles were calculated for imaged stars. Results are shown in Table 3.

Conclusion

These observations provide additional information for researchers to investigate the nature of binary systems.

Acknowledgments

We would to thank Becky Baranowski, Department Chair for Mathematics, Physics, and Astronomy for offering this course for the fall semester year 2012 and to the Estrella Mountain Community College for use of equipment and facilities.

Table 3: Photometric Measurement Data for Measures 2012

WDS ID	Discover	Magnitudes			Last		Current		
		Primary	Secondary	Epoch	PA	SEP	Epoch	PA	SEP
22129+7318	STF2893	6.19	7.91	2010	347	28.8	2012	348	28.7
18433+1100	J_1189	9.80	9.80	2010	16	7.1	2012		6.2
18054-2930	RST2026 (N)	10.70	10.90	1940	321	3.6	2012		4.4
19593+2215	WFC 262	9.64	9.71	2004	32	13.3	2012		13.3
21236+6456	STF2798	8.36	9.93	2010	144	6.4	2012		6.2
19050-0402	SHJ 286	5.52	6.98	2011	210	38.2	2012	263	39.6
18015+2136	STF2264	4.85	5.20	2010	257	6.3	2012		6.1

Visual and Photometric Measurements of a Selected Set of Double Stars

We especially like to thank the iTelescope foundation for providing an education grant to the students in Math 298AC which made the instruction and use of the online telescope systems possible.

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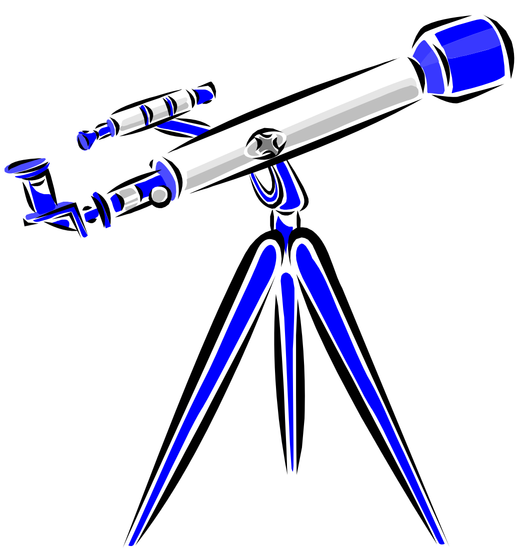

A Pixel Correlation Technique for Smaller Telescopes to Measure Doubles

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Abstract: Pixel correlation uses the same reduction techniques as speckle imaging but relies on autocorrelation among captured pixel hits rather than true speckles. A video camera operating at speeds (8-66 milliseconds) similar to lucky imaging to capture 400-1,000 video frames. The AVI files are converted to bitmap images and analyzed using the interferometric algorithms in REDUC using all frames. This results in a series of corellograms from which theta and rho can be measured. Results using a 20 cm (8”) Dall-Kirkham working at f22.5 are presented for doubles with separations between 1” to 5.7” under average seeing conditions. I conclude that this form of visualizing and analyzing visual double stars is a viable alternative to lucky imaging that can be employed by telescopes that are too small in aperture to capture a sufficient number of speckles for true speckle interferometry.

Most astrophysically interesting visual doubles are less than 5” in separation. Imaging such doubles under less than ideal conditions at many locations is a challenge with smaller telescopes because the number of nights of good seeing is rare and the seeing disc can be large, negating our efforts to obtain clear separation between close pairs. There are two common strategies for beating average to poor seeing conditions. Lucky imaging uses short integration times to freeze seeing. If the investigator takes hundreds or even thousands of frames, there are bound to be a few frames that capture the double under good transient conditions (see Anton, 2012, for a review). Success depends on searching through the available frames, making a judgment as to quality, stacking the best frames in order to measure the resulting seeing disc and using an appropriate technique of finding the centroids of each component (i.e. “centroiding”). There are more automated methods of finding lucky imaging. For example, one could use the REDUC feature “Bestof (Max)” and select some percentage of the best frames. Anton (2012) prefers a more manual technique to pick the best images.

Speckle imaging beats the seeing by taking advantage of the seeing itself. Speckle imaging depends on sampling atmospheric cells that contain an image of the double. The smaller the aperture the fewer the atmospheric cells sampled and thus fewer speckles are captured. Turner et al. (1992) calculates that a 204mm aperture telescope will only gather about 4 speckles and the number of binaries available to measure is rather small (Turner lists only 4 known if a V-filter is used). Florent Losse (pers. comm.) suggests that apertures under 300mm may not collect a sufficient number of speckles to make speckle imaging feasible and that the situation is more optimal with scopes 400mm or more in aperture. This seemed to preclude true speckle imaging from my programs as I am aperture-limited.

I wondered, however, if an approach using lucky imaging camera speeds and autocorrelation might be viable. In 2010 Losse added an interferometric analysis package to his REDUC reduction program (http://www.astrosurf.com/hfosaf/index.htm) that permits reduction of speckle images. His observing program demonstrates that speckle interferometry is quite within the capabilities of astronomers with relatively modest telescopes (Losse, 2010; English summary at http://www.astrosurf.com/hfosaf/uk/speckle10.htm). Could the interferometric subprograms in REDUC could be used with smaller telescopes, perhaps without true speckles but using high speed integrations to capture pixels? Would the pixels captured carry enough information that autocorrelation of the available pixels might yield a measureable autocorrelogram using the autocorrelation subprograms in REDUC? If so, what pairs might I be able to image and measure on an average eastern Kansas night with seeing in the 2/5-3/5 range with a 204mm telescope? And, if results can be obtained, how accurate are those measures? If successful the pixel technique would allow many more nights of measuring astrophysically interesting pairs and I could move on to testing more exotic optical configurations that would increase the effective focal length of my optical train.

Methods

The telescope is a 204mm Dall-Kirkham with a native focal ratio of F/22.5. The cameras used include both the older and newer Image Source DMK21 video cameras, the difference being that the newer version has an upgraded and slightly more sensitive chip. Both cameras have 640x640 chips with 5.6µm square pixels. The optical train was fitted to a Vixen flip mirror to aid in image acquisition. Imaging was performed at prime focus with an effective focal length of 4590mm and a plate scale of 0.250 seconds/pixels without a filter. Integrations ranged from 8ms to 33ms, depending on the magnitude of the pair. The integration time of any one pair was eclectic: I simply reduced the integration time until the stars began "dancing" (the seeing disc began to break up) and then continued to reduce the integration time until the pair (or oblong blob) was barely visible. I then took a minimum of four video files of 400 frames/file of each double. As a safety precaution I then increased the integration time two steps, capturing eight more files. So a typical run might consist of 12 files, four each at 8ms, 11ms, and 16 ms (or 11, 16 and 33 ms) to insure that at least one run would have a sufficient number of pixels to analyze. Two pairs of known theta and rho were imaged at the beginning and end of each observing session. These are relatively wide pairs (8-16arcsec) acquired by normal integrations of 0.25 to 1 second. Four files of 25-50 images each were collected for the calibration pairs. In addition a minimum of two star trails were captured by the drift method.

The uncompressed video files (avi files, Y800 codec) were converted to bitmap images using the open source program VirtualDub (http://www.virtualdub.org/). At faster integration times I did not observe any hot pixels and thus I made no attempt to calibrate the images with darks, flats or bias frames. I did dark, subtract on calibration pairs with longer integration times. Camera orientation was determined by analyzing star trails using subroutines in REDUC. Plate scale is rather constant, but was checked each night using reductions of the angle and separation of rectilinear calibration pairs as detailed in Wiley (2012).

For each pair I began with the set of bitmap images of the shortest integration time. Each file of bitmap images was analyzed using the autocorrelation option in the interferometry menu of REDUC. All frames were included in the analysis regardless of quality. In other words, I made no attempt to sort "lucky images." The analysis result is a series of autocorrelograms (S0-S9). S0 is the unmasked result and while S1-S9 apply a series of masks (kernels of 3x3, 5x5 etc.) to separate the peaks. In general, the smaller the disc, the lower the number of the mask employed. This can be estimated by the measuring aperture; smaller apertures (e.g. 5x5) would call for S1-S2 autocorrelograms, as is the usual case for pairs reported herein. The largest aperture possible was used to insure successful centroiding. As the quadrant of the secondary was known; the relative position of the secondary was unambiguous. Theta and rho were harvested from the autocorrelogram. Each of the total of N=4 (occasionally 5) sets of results were combined to produce an overall average and error for that particular pair. The single exception was 20548+3242STT 418, the closest pair measured where one run resulted in a very different angle and only three measures are reported. Calibration pairs were handled in a similar manner except the images were stacked, then measured by centroiding using the standard REDUC subroutines. A spot check of single runs for selected calibration pairs taken at the end of each session was also made using 40-50 individual frames processed using the automatic reduction routine in REDUC.

Accuracy of the results was judged by comparing

A Pixel Correlation Technique for Smaller Telescopes to Measure Doubles

the results to the entire histories of observation of each pair and O-C calculations for three pairs with orbits and one rectilinear pair not used for calibration. The O-C calculations for the three pairs with orbits were performed using the Excel® program by Workman. (http://www.saguaroastro.org/content/db/binaries_6th_Excel97.zip) with more recent data from the Sixth Catalog of Orbits of Visual Binary Stars (Hartkopf and Mason, 2001 et seq.). The O-C calculation of the rectilinear pairs (including the calibration pairs) were performed using methods in Wiley (2012) derived directly from WDS equations (Mason et al., 2010). An Excel® sheet with worked examples is available on request. Since all doubles measures were STF (F. Struve) and STT (O. Struve) doubles , the history of observations were quite extensive, reaching to the 18th Century. I requested these data from USNO (Mason, 2006). Theta and rho of all historical records were converted to Cartesian (rectangular) coordinates using an Excel spreadsheet provided by Francisco Rica, as detailed in Wiley (2010). I did not weight the observations. I then compared the long-term history to my measure visually and by means of informal line fitting (for example, Figure 1) as implemented in Excel.

Results

Pairs and their measures and errors harvested in this are shown in Table 1. Included in this table are O-C calculations for five pairs with either orbital of rectilinear. Table 2 shows examples of the fit of the cali-

(Continued on page 146)

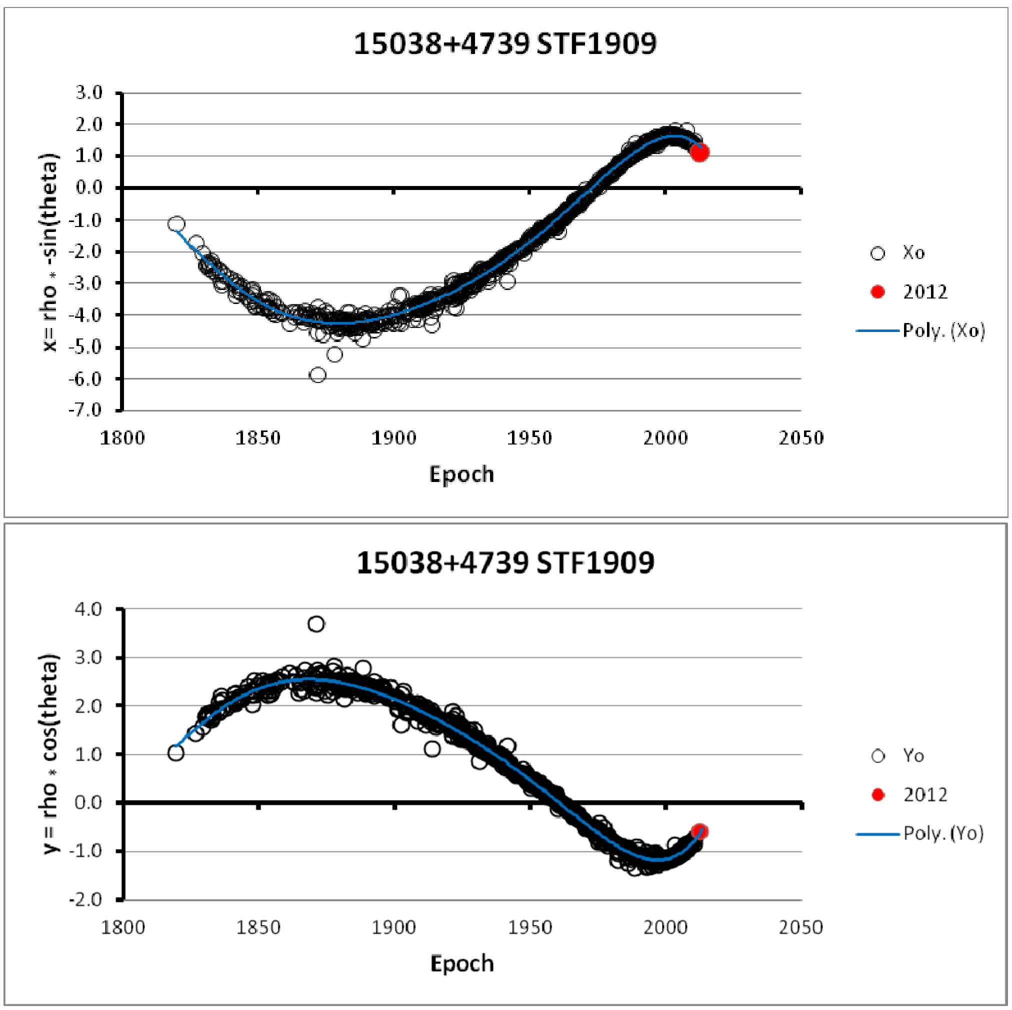

Figure 1: A higher resolution plot of the relative motion of 15038+4739STF1909. Upper: relative motion of the secondary along the x-axis as a function of Epoch. Lower: relative motion of the secondary along the y-axis as a function of Epoch. The blue line is a 6th order polynomial fitted in Excel® to the historical measures, extended to the date of measure herein. The y-axis scale is in arcseconds. Compare to the same pair in low resolution in Plate 2.

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Table 1. Measures reported and O-C analyses in this paper. WDS, Washington Double Star Catalog Number; Disc, discover code; PA(O), reported theta; Sep (O), reported rho; err PA (O) and errSep(O), standard error of theta and rho; Date, epoch of observation reported; N, the number of imaging runs, all taken on the same night; PA(C) and Sep(C),, theta and rho calculated from orbital elements or rectilinear elements; O-C observed versus calculated PA/Sep; O-C reference, author/s of orbital or rectilinear elements. All measures taken with a 204mm F/22.5 Dall-Kirham with a plate scale of 0.25 seconds/pixel.

WDS	Disc	PA (O)	Sep (O)	errPA (O)	errSEP (O)	Date	N	PA (C)	Sep (C)	O-C	O-C Reference
14497+4843	STF1890	45.9	2.55	0.03	0.002	2012.516	4	45.8	2.61	+0.1°/ -0.06"	Hartkopf & Mason, 2011b
15038+4739	STF1909	62.7	1.28	0.13	0.004	2012.516	5	62.5	1.266	0.2°/ -0.04"	Zirm, 2011
16289+1825	STF2052AB	120.3	2.24	0.34	0.042	2012.516	4	119.8	2.47	+0.5°/ -0.03"	Soderhjelm, 1999
16442+2331	STF2094AB	72.5	1.12	0.17	0.001	2012.516	4	72.8	1.16	*	
17237+3709	STF2161AB	320.8	4.14	0.02	0.004	2012.516	5	319.6	4.14	*	*
17564+1820	STF2245AB	290.4	2.59	0.07	0.004	2012.516	4	291.8	2.58	*	*
18101+1629	STF2289	226.2	1.23	0.16	0.001	2012.516	4	218.7	1.23	*	*
19487+1149	STF2583AB	103.2	1.45	0.07	0.017	2012.729	5	104.8	1.41	*	*
20093+3529	STF2639AB	300.9	5.73	0.02	0.011	2012.617	4	300.3	5.73	*	*
20126+0052	STF2644	205.2	2.54	0.05	0.021	2012.729	4	205.8	2.64	*	*
20184+5524	STF2671AB	336.6	3.762	0.26	0.025	2012.617	5	337.2	3.71	*	*
20377+3322	STF2705AB	262.21	3.13	0.49	0.086	2012.617	4	262.3	3.1	*	*
20585+5028	STF2741AB	26.4	1.93	0.05	0.004	2012.617	4	24.7	1.95	*	*
21068+3408	STF2760AB	33.1	4.77	0.21	0.037	2012.617	4	33.2	4.89	-0.1°/ +0.12"	Hartkopf & Mason, 2011b
20548+3242	STT 418	285.0	0.94	1.32	0.013	2012.729	4	284.6	1.12	*	*
21208+3227	STT437AB	20.2	2.38	0.02	0.003	2012.617	4	19.2	2.42	+1°/- 0.04"	Hartkopf & Mason, 2011a

Table 2. Measures reported and O-C analyses of four collimation pairs. WDS, Washington Double Star Catalog Number; Disc, discover code; PA(O), reported theta; Sep (O), reported rho; err PA (O) and err Sep (O), standard error of theta and rho; Date, epoch of observation reported; N, the number of imaging runs, single night; PA(C) and Sep(C),, theta and rho calculated from orbital elements or rectilinear elements; O-C observed versus calculated PA/Sep; O-C reference, authors of rectilinear elements. All measures taken with a 204mm F/22.5 Dall-Kirham with a plate scale of 0.25 seconds/pixel.

WDS	Disc	PA (O)	Sep (O)	errPA (O)	errSEP (O)	Date	N	PA (C)	Sep (C)	O-C	O-C Reference	Notes
15346+4331	STF1961AB	20.09	28.334	0.15	0.165	2012.516	25	20.1894	28.4496	-0.1°/-0.12"	Hartkopf & Mason, 2011b	1
20425+4916	ARG39AB	181.96	14.656	0.37	0.162	2012.6169	42	181.924	14.704	0.036/-0.044	Hartkopf & Mason, 2011b	2
15174+4348	STF1934AB	13.14	9.73	0.32	0.054	2012.516	40	13.185	9.731	-0.05/-.001	Hartkopf & Mason, 2011b	2
20425+4916	ARG39AB	181.86	14.724	0.14	0.011	2012.729	50	181.924	14.704	-.06/+0.02	Hartkopf & Mason, 2011b	2

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bration pairs taken at the end of observations and not used to calculate camera angle and resolution relative to predicted theta and rho derived from The Catalog of Rectilinear Elements (Hartkopf and Mason, 2011b). One example of fitting my observations to previous observations is shown in Figure 1 in high resolution. Example images of raw frames, stacked frames and autocorrelograms are shown in Plate 1 for two of the closer doubles analyzed. The third pair in Plate 1 illustrates some of the challenges to implementing this technique. Comparisons of the histories of observations and my measures as functions of x-values and y-values over Epoch are shown for all pairs reported in Table 1 in Plates 2-4 (in low resolution).

Discussion

The autocorrelogram is the sum result of analyzing all images and no effort was made to select better (or worse) images to analyze. This is because no one image sufficiently samples the seeing disk, making centroiding impossible or highly ambiguous; the use of all images is needed to produce a successful autocorrelation. The fact that I did not calibrate images requires some discussion. Autocorrelation should reject any positive pixel hits caused by random noise given that they are not correlated with pixels in other frames. In fact, in some frames one can see the autocorrelation select random noisy pixels inside the selection window, but those data never appear in the autocorrelogram. I observed no "hot" pixels at high integration speeds that would bias the results with the few darks I took. Never-the-less, it would be prudent to employ darks at all integration times. They are easy to acquire and apply in REDUC.

Figure 1 and Plates 2-4 suggest that this method of analyzing double star data in the 1-5 arcseconds of range of separation is comparable to other methods of measuring doubles as evidenced by the observation that the reported measures fall in line with the histories of observations along both the x-axis/Epoch and y-axis/Epoch plots. The extent to which the overall sum of previous observations portrays something accurate about the actual separation and distance of the pairs at any one time is the extent to which observations reported here can be judged as accurate as most measures and more accurate than some measures. For the four pairs that I could calculate observed versus calculated theta and rho, the O-C differences varied between 0.1° to 1° in theta and 0.12-.03" in rho. The most deviant O-C in theta was the pair 21208+3227STT437AB which had an O-C in theta of 1°. However, the last measure by Cvetkovic et al. (2011: PA=20.19°, Sep=2.381") and my measure differ by only 0.03° in theta and are identical in rho. The history of this pair suggests quite a bit of variation in recent measures. The most deviant O-C in rho was the rectilinear pair 21068+3408STF2760AB which also had the lowest O-C in theta.

The results in Table 2 are an indication of the fit of the camera angle and plate scale to predictions of position and angle derived from the Catalog of Rectilinear Elements. Each of the runs was withheld from modeling camera angle and plate scale and used as a check on O-C calibration fit and to insure that the camera was not moved during the session. Note the higher errors typical of analyzing single frames as compared to errors when the results of pooled runs are averaged (e.g. errors in Table 2 average about twice those in Table 1).

The methods reported herein suggest that this form of autocorrelation using a modest scope of 204mm aperture is quite successful in accurately measuring doubles in the 1.2"-2.0" (and greater) range of separation under seeing that would preclude harvesting measures using other techniques. This vastly increases the number of nights available to measure doubles with a 204mm aperture telescope working at a modest effective focal length, the equivalent of imaging with a 204mm SCT and a 2x-2.5x Barlow. On some nights seeing might be excellent. In such cases autocorrelation techniques may not be needed for many pairs.

There are several challenges to use of this technique. (1) Lack of critical focus, atmospheric dispersion, or collimation can cause distortion of images in the autocorrelogram; they will appear elongated and thus centroiding may be less accurate. How inaccurate is not addressed in this study and would require additional experiments. (2) Imaging at too slow an integration speed will result in an undersampled image. The autocorrelogram may not clearly separate the primary and secondary in the masked images (i.e. the REDUC in all of the S1-S9 autocorrelograms) or the Airy disc may be undersampled. (3) An insufficient number of frames may lead to ambiguous results. I would suggest at least 400 and now take a minimum of 500 frames; 1,000 frames might be better as one reaches the limits imposed by aperture and seeing. (4) Difference in magnitude may result in failure due to not imaging the secondary or saturating the primary. The limits imposed by this challenge are

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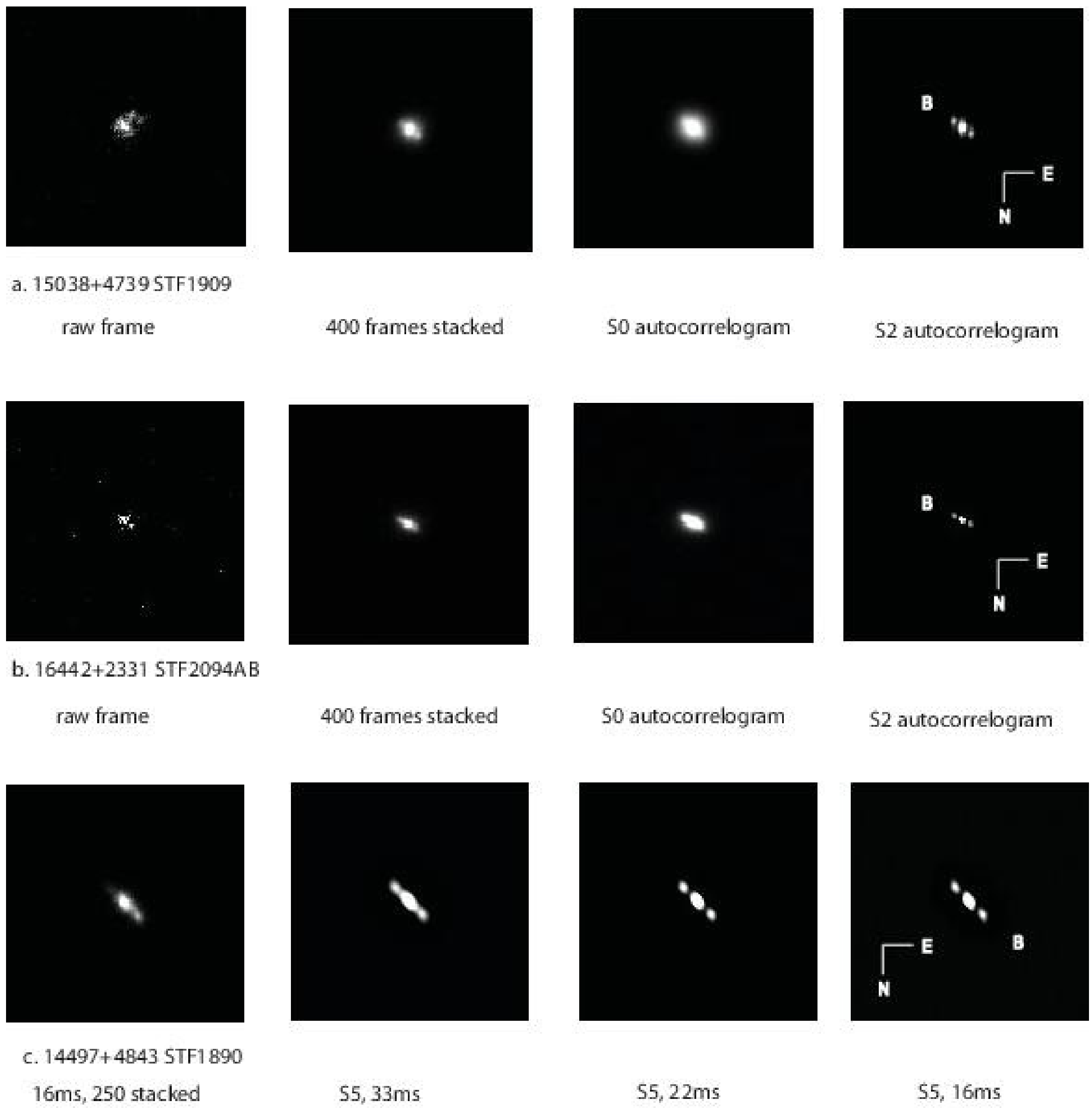

Plate 1. Images of three doubles. The upper two rows (a, b) are examples of two doubles measured in this study. Left to right are: a random raw frame, the entire stack of 400 frames, the unmasked (S0) autocorrelogram and a masked (S2) autocorrelogram. The lower row (c) illustrates the effects of integration time on the quality of the autocorrelogram on a pair not reported; Left to right are: a stack of 250 images of 16ms and S5 autocorrelogram of 250 images at three integration times. Note elongation cause either by miscollimation, lack of critical focus or atmospheric dispersion.

Plates 2-5 (following pages). History of observations of sets of STF and STT pairs as a function of relative motion on the x-axis (right) and y-axis (left) over the history of observations in low resolution. The black circles are previous measures, the solid red dot is the measure reported herein. Blue lines are fitted trend lines. Most are linear, but for orbital pairs STF1909 and STF2052 (Plate 2) lines are 6^{th}-order polynomials and for orbital pairs STT 418 and STT 437.(Plate 5) lines are 2^{nd}-order polynomials. The y-axis scale is in arcseconds. An example in high resolution is shown in Fig. 1.

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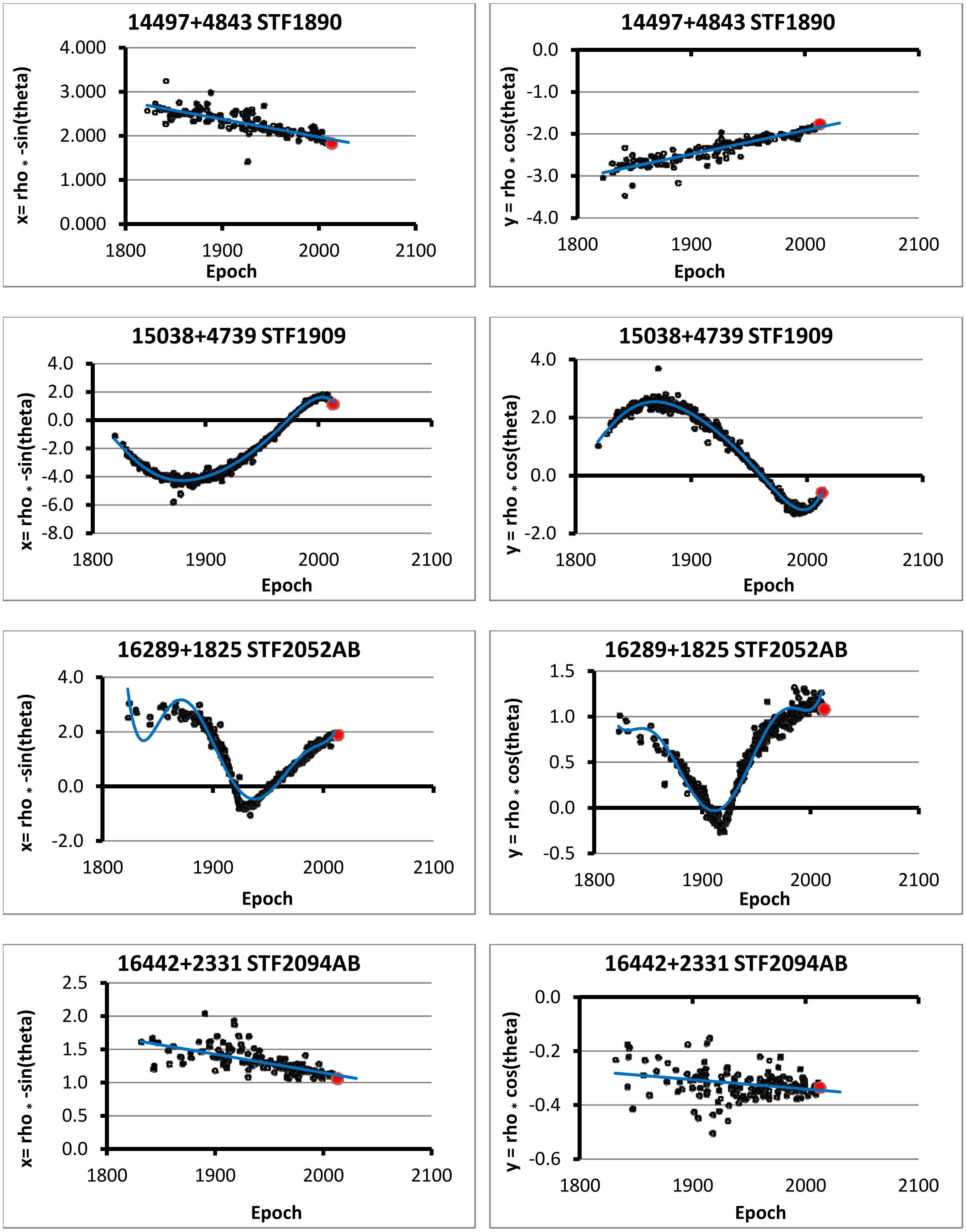

Plate 2.

A Pixel Correlation Technique for Smaller Telescopes to Measure Doubles

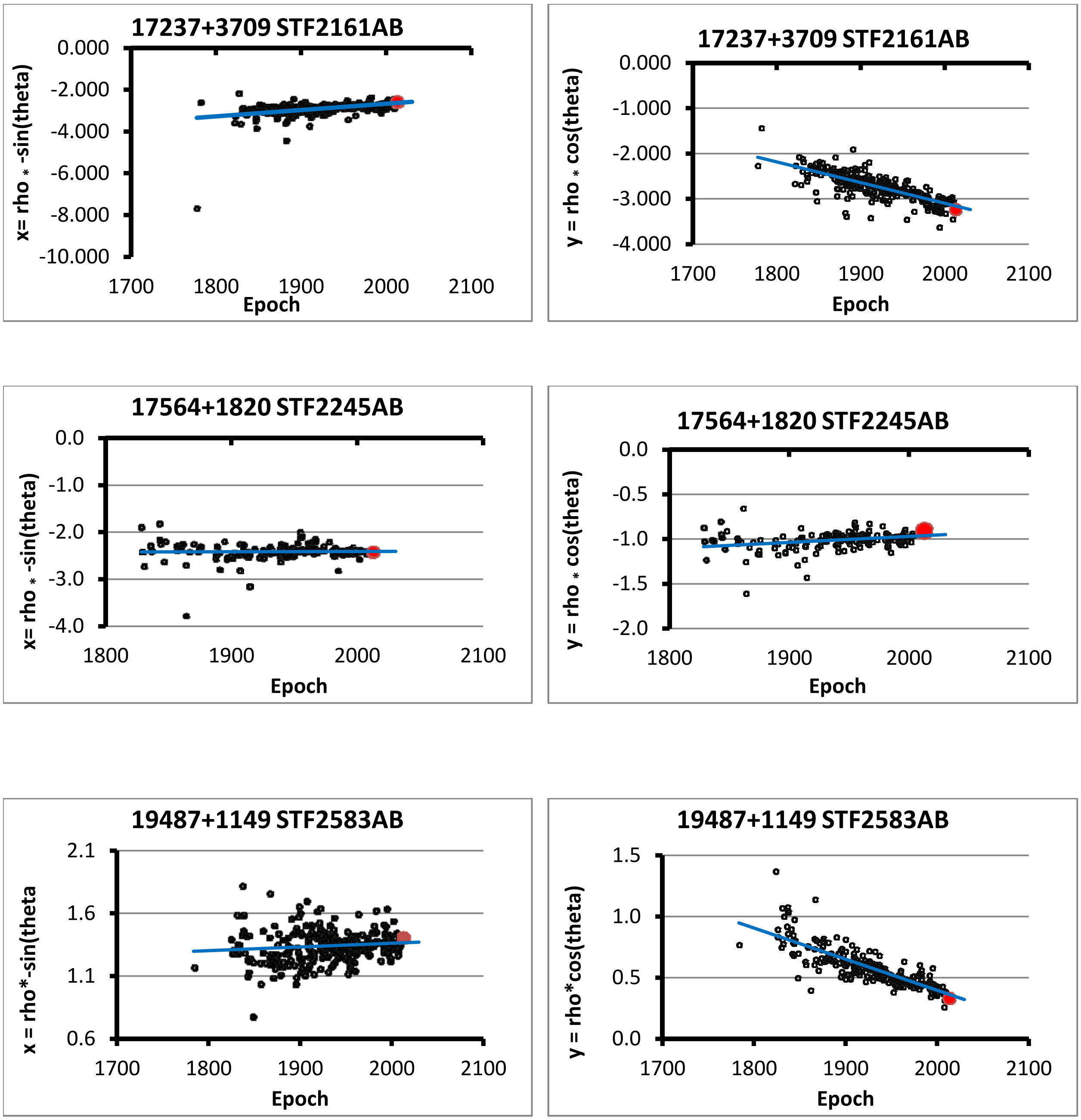

Plate 3.

A Pixel Correlation Technique for Smaller Telescopes to Measure Doubles

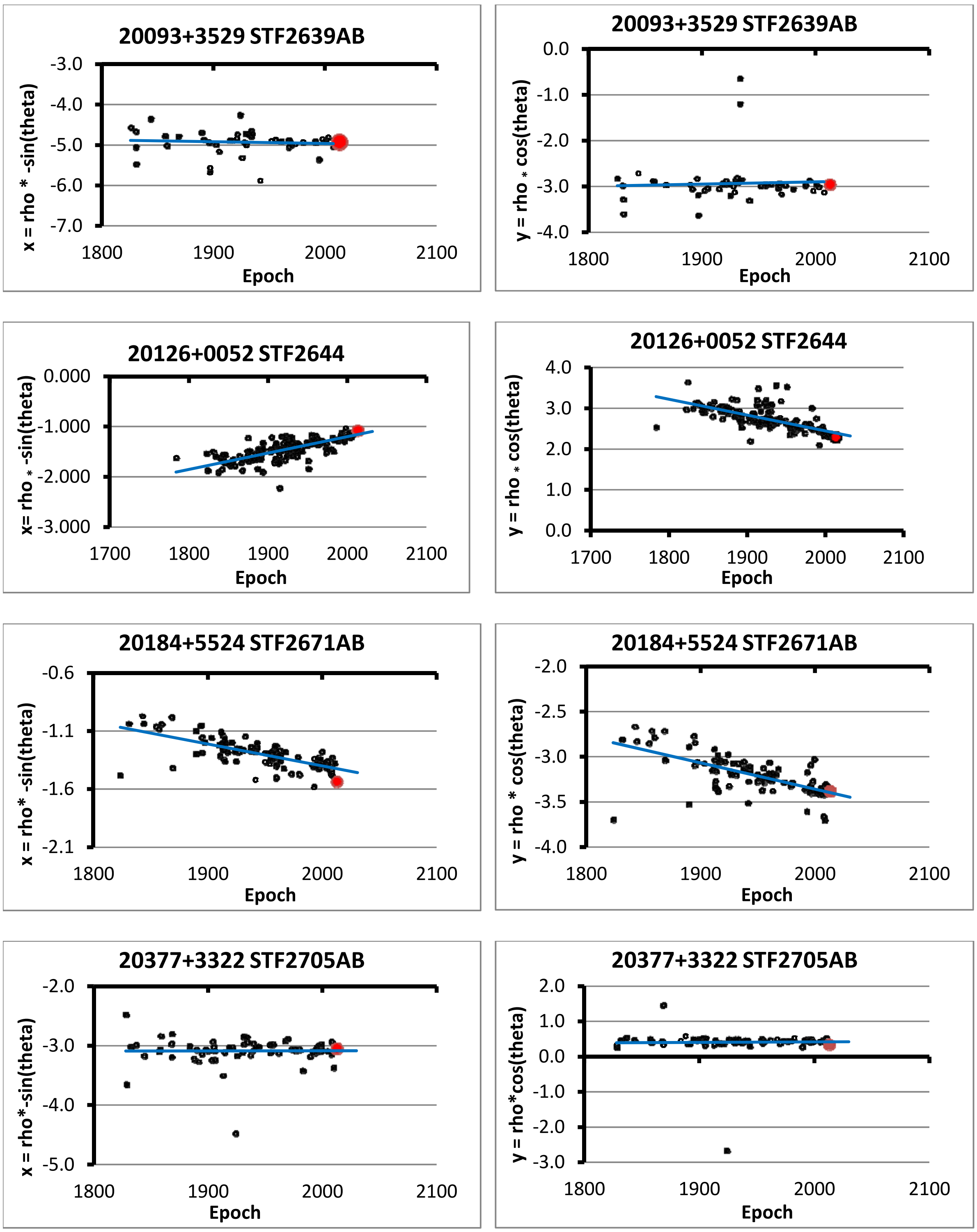

Plate 4.

A Pixel Correlation Technique for Smaller Telescopes to Measure Doubles

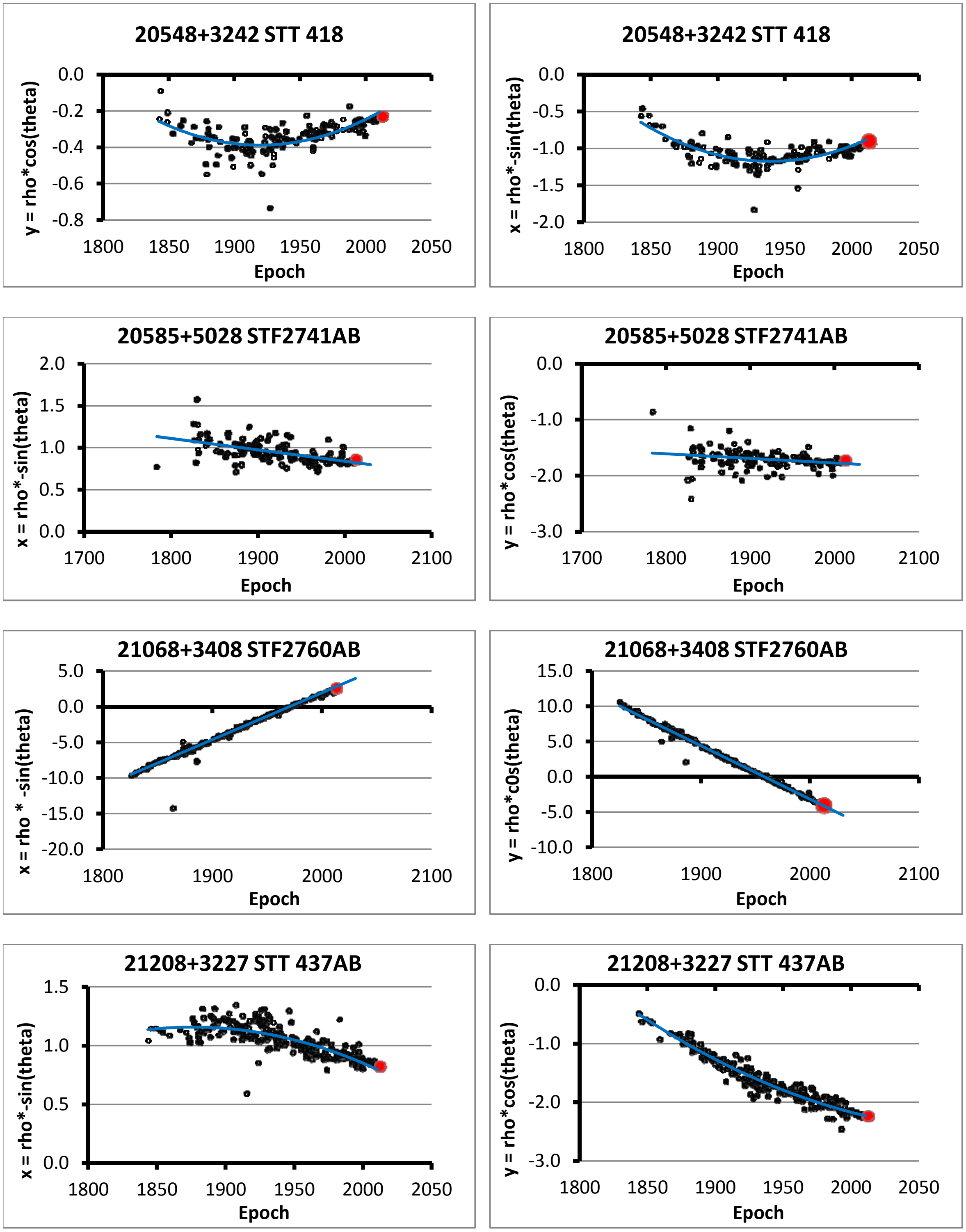

Plate 5.

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not clear and further work is needed. (5) Use of too small a measuring aperture may fail to produce good centroiding of the autocorrelated images. (6) Darks should be employed to guard against hot pixels. One might think that using the smallest aperture (3x3) would really center the position, but this may not be the case; REDUC may have insufficient information to determine a good centroid. This was determined by trial and error during the project. This challenge puts the limits of my 204mm F/22.5 system at about 1.2" using an aperture of 5x5.

An early series of images of STF1890 (39 Boo) shown in Plate 1 row c demonstrates challenges (1) and (2). I chose not to report the measure of this pair because of the small number of frames (imaging done early in the project) and elongation of the image, probably caused either by a slight problem in collimation or uncritical focus. Additionally, we can see the effects of different integration times. From left to right we see the stacked image of 250 frames and autocorrelograms using the same mask (S5) but with three different exposures. Note that the shorter the integration time, the more distinct the separation.

This study suggests that pixel autocorrelation may be a viable approach to imaging and measuring doubles with smaller aperture telescopes. However, this study is just a first step showing the possibility and limits of the technique. Future work includes assessing repeatability, accuracy and precision over multiple nights and different seeing conditions, the effect of using a Barlow to increase focal length and additional tests of the effect of integration time on autocorrelogram quality.

Finally, because this technique does not require true speckles, it might be applicable to even smaller telescopes than mine. It would be interesting to see results with smaller refractors in the 100-180mm range and 180mm reflectors and I encourage others to try this technique.

Acknowledgements

My thanks to Florent Losse for his many emails commenting on interferometric techniques and my attempts to use autocorrelation to measure doubles and for sharing his version of the Workman Excel spread sheet. Thanks to Russ Genet for stimulating discussion of speckle imaging. Thanks to Francisco Rica for sharing his spreadsheets that efficiently converts theta and rho to the Cartesian system using Excel® macros. To these colleagues and the anonymous reviewer my thanks for comments that resulted in substantiate improvements. Thanks to Dr. Brian Mason for answering requests for data in a timely fashion and for his support of our research community. This paper made extensive use of the Washington Double Star Catalog, the Catalog of Rectilinear Elements and the Sixth Catalog of Orbits of Visual Binary Stars, all maintained by the U. S. Naval Observatory Astrometry Department by Drs. Brian Mason and Bill Hartkopf.

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Double Stars at the IAU GA 2012

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Abstract: In August 2012 the 28th General Assembly of the International Astronomical Union was held in Beijing, China. This summarizes some aspects of this meeting relevant to double and multiple star astronomy.

1. Introduction

From 20-31 August 2012 the 28th General Assembly of the International Astronomical Union (IAU) was held in Beijing, China. These triennial meetings provide an opportunity for astronomers from different countries to get together, present results and discuss future plans and collaborations. Examples of the larger policy issues that are discussed in an IAU General Assembly include a reorganization of the IAU Divisional structure, the definition of the astronomical unit or whether to continue the periodic insertion of leap seconds.

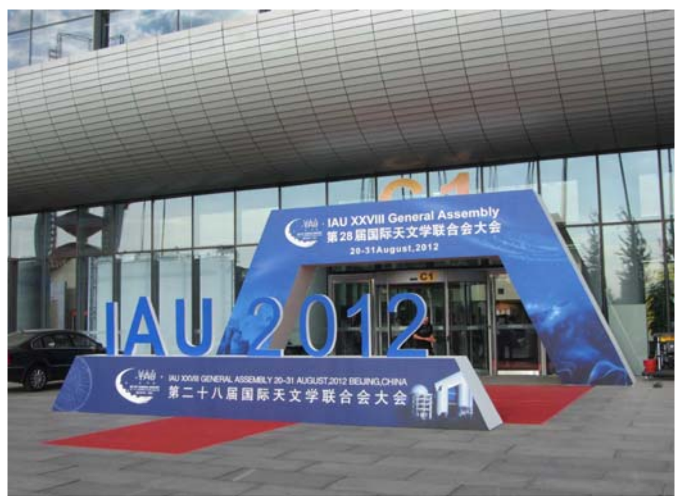

Figure1. IAU entry arch.

2. Commission 26: Double and Multiple Stars

One of the charter commissions of the IAU, Commission 26 (Double and Multiple Stars) has always been a relatively small commission. The study of visual double and multiple stars are typically programs that require many years to come to any sort of fruition and planning observing programs is well-suited to meetings with this sort of regularity.

The Commission 26 meeting was held on Tuesday afternoon from two to six p.m. Seventeen commission members and other interested parties attended the Commission meeting. In the absence of Commission President, Jose Docobo, the meeting was conducted by Vice President Brian Mason. The commission business portion of the meeting was brief. Following the listing of deceased members and the listing of prospective new members a video presentation from Dr. Docobo was shown. The slate of new officers were presented and those members rotating off the organizing committee: Dimitri Pourbaix,

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Terry Oswalt and Colin Scarfe, were thanked for their service. A review of some of the past meetings of relevance to the Commission was given as well as announcements of future meetings. Finally, a few brief points regarding the place of Commission 26 in the new Division structure was presented. We then moved directly into the science presentations.

As a result of the Commission 26 meeting at the Hamburg General Assembly of the IAU in 1964, the double star database was transferred from Lick Observatory to the U.S. Naval Observatory (USNO) and re-designated the Washington Double Star (WDS) catalog. The growth of the WDS and its ancillary catalogs over the triennial period was presented. The changes in the data line format, which many JDSO readers are familiar with, was presented. Also presented at this time were possible future changes in the format of the summary catalog. Difficulties at present include the inadequacy of the current arcminute precision identifier in very dense fields, inadequacies of the multiplicity field for nested hierarchies, the separation precision not sufficient for current techniques, and the need for other codes to clarify the data which are presented. As the base WDS format has been stable for a decade these major changes will not happen quickly. The current USNO observing program was then described. From wider arcsecond pairs observed with our fast readout ICCD in Washington to subarcsecond pairs observed with our standard speckle camera on larger telescopes in Arizona and Chile to collaborative efforts with the NPOI and CHARA Arrays the USNO program is optimized to observe brighter pairs over many decades of separation. These are the pairs which tend to be the most important for navigational (star tracker) purposes.

Gerard van Belle (Lowell Observatory) discussed the binary work that is being done with the Navy Precision Optical Interferometer (NPOI). Work by Jenny Patience and Rob De Rosa is being done to investigate the multiplicity of early-type stars with a volume limited A-star survey while Henrique Schmitt is investigating Be stars and their disks. Christian Hummel is continuing his study of binary stars, typically resolved spectroscopic binaries while Bob Zavala is working on radio stars to tie the optical reference frame to that of the radio. Theo ten Brummelaar continued the interferometry presentations by discussing CHARA Array contributions to double and multiple stars. Optical interferometers like the CHARA Array are now obtaining the same resolution as is capable with VLBA in the radio due to the wavelength at which they work and they are very good at measuring asymmetries caused by companions at milliarcsecond separation. They can also utilize separated fringe packet techniques for the study of wider pairs that can be observed with other more classical techniques. Imaging is now a routine byproduct and stimulating movies of Algol and β Lyrae were shown as well as

Figure 2. Simplified Chinese Armilla. Ming Dynasty.

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the eclipsing cloud of ε Aurigae.

Dimitri Pourbaix gave a report on the current status of SB9: the 9th Catalogue of Orbits of Spectroscopic Binary Stars. The catalog now contains 3866 orbits of 3112 systems and is a comparable size with the USNO 6th Orbit Catalog. However, less than 10% of these respective catalogs have overlap. Like at the USNO, the most significant shortcoming is labor entering the data. This issue will be exacerbated when big survey projects begin the delivery of results. SB9 provides elements and orbit plots as well as lists of measures when available. These can be obtained either through single entry queries or through a downloadable tar ball. Dr. Pourbaix has also been very involved in the non single star activities in preparation for the Gaia launch. Since Gaia will not go brighter than 6th magnitude and will work best fainter than 12th magnitude, it is optimized to work best where we have the poorest historical data. Unlike HIPPARCOS, Gaia will not have an input catalog and will be too large for individual object inspection. It will go through a flowchart of options for non-single star solutions including familiar solution types such as acceleration, orbital, variability induced movers, etc. They are expecting some 500 million binaries to be in the Gaia output catalog. What is unknown at this point is what percentage of them will be detected at some level. The preparation is running smoothly with most of the codes already in the fine tuning stage. By the end of the decade it is expected that millions of orbital solutions will be generated: both astrometric/visual, spectroscopic and photometric. How will these be incorporated in the existing databases is an unanswered question.

Finally, Miguel Monroy, a graduate student of former Commission President Christine Allen, presented work in the preparation of an improved catalog of halo wide binaries and on halo dark matter. The tenuous grip that some of these fragile binaries have on each other can tell us much of Galactic dynamics. While Yoo et al. (ApJ 601, 311; 2004) placed limits on MACHOs based on wide binaries and the observed distribution in their separations, the work here investigates the radial velocities of these wide pairs to determine which are or are not physical. After compiling their refined database of halo wide binaries they found an Öpik distribution worked well with ‹ a › = 10,000 au for those which were most disk-like and ‹ a › = 63,000 au for those which were most halo-like. The interaction with the disk is thus very important. A dynamical model for the evolution of wide halo binaries, subject to perturbations by

Figure 3. Some of the Commission 26 attendees and speakers. Left to right: Chris Corbally, Theo ten Brummelaar, Natalia Shakht, Brian Mason, Miguel Monroy, Frederic Arenou, Gerard van Belle, Dimitri Pourbaix and Ivan Andronov

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MACHOs was developed and validated, and applying this model taking into account time spent in the disk and non-uniformities in the halo density they were able to all but exclude MACHOs in the Galactic halo.

The power point and/or pdf presentations from the Commission 26 meeting are available online at the Commission website: http://ad.usno.navy.mil/wds/dsl/Comm26/Beijing/beijing.html.

The Commission dinner was held at M&E, a Cantonese Restaurant near the venue. Prospective Commission member M.B.N. (Thijs) Kouwenhoven of the local Kavli Institute and Peking University was able to act as interpreter and became, effectively, the dinner host. We turned the item selections over to him and were not disappointed. It was a delicious and quite economical evening. While general double star matters were discussed, among the most interesting aspects of the evening were the impressions of Thijs as a westerner living in China.

Figure 4. IAU member Dimitri Pourbaix discusses the 9th Spectroscopic Binary Catalog

3. Other meetings of relevance

Other commissions and divisions also have interest in the study of double stars. Among these are Commission 8 (Astrometry), Commission 30 (Radial Velocities), Commission 42 (Close Binary Stars) and Commission 54 (Optical and Infrared Interferometry).

The optical and infrared interferometry meeting Gerard van Belle (Lowell Observatory) and Theo ten Brummelaar (GSU) both presented results from their respective interferometers (NPOI and CHARA, respectively) which highlighted some impressive work on resolved spectroscopic binaries.

Due to the high incidence of multiplicity among massive stars it was not surprising to see Joint Discussion 2 (Very Massive Stars in the Local Universe) discuss binaries and multiple systems explicitly as the candidate VMS are multiples. While Massive stars have a good astrophysical definition, a lot of this meeting seemed focused on defining the term "very massive" with the final consensus value (> $100M_\odot$) seeming rather arbitrary.

Among the talks at IAU Symposium 289 ("Advancing the Physics of Cosmic Distances"), results for binaries outside the Milky Way were discussed. Also at this symposium, Dimitri Pourbaix discussed the more recent van Leeuwen Hipparcos solution and finds that for spectroscopic binaries the precision is improved but not the accuracy. The Gaia reduction pipeline will build from Hipparcos and will consider various double star solutions depending on errors. Despite this Gaia results, due to how faint it will go, will not overlap with the most well studied and characterized binary stars. Gaia was discussed at several other meetings such as Joint Discussion 7 ("Space-time Reference Systems for Future Research") where Francois Mignard set the bright magnitude limit for Gaia at V = 6.

At the Commission 30 meeting, Pourbaix presented results of the spectroscopic binary orbit catalog (SB9): 3112 systems (1469 systems in SB8), 3866 orbits, 2113 systems with RV, 635 papers (44 since last General Assembly). This is an orbit catalog. The closest thing to a spectroscopic analog to the WDS is Hugo Levato's massive radial velocity database with over 250,000 radial velocities. There are many large scale radial velocity projects which will produce many, many radial velocities soon.

Symposium 293 ("Formation, Detection, and Characterization of Extrasolar Habitable Planets") introduced some unfamiliar terminology of relevance in discussing extra-solar planets in binary systems. Circumbinary is a more distant planet orbiting a short period binary system (think Tatooine in Star Wars). Circumprimary is where a planet orbits a single star with a more distant stellar companion (think Jupiter/Lucifer in 2010). At present, 20% of known extrasolar planets are in binary star systems.

At the Commission 8 meeting, Gaia was again discussed and Mason presented some results for resolved astrometric binaries and what else you can get out of them. Recall, that both Sirius and Procyon were detected through periodic errors in their proper motion many years (18 and 52 years, respectively) before they were resolved.

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There were also several interesting posters discussing work on, for example, binary stars at Pulkovo and wide physical binaries.

Recent Nobel Prize winner Brian Schmidt gave a talk on "Supernovae, the Accelerating Cosmos and Dark Energy." While I'm sure the cosmologists were bored, for those of us not in that sub-field, he gave a cogent presentation in it's proper historical context.

Overall, the meeting was very exciting and informative. Keeping up with the many presentations where binary stars were discussed required a careful reading of the program, a prioritized scrutinizing of the schedule, and a good pair of cross-trainers!

The author is president of Commission 26 of the International Astronomical Union.

The Maui International Double Star Conference

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Abstract: A three-day double star conference in February, 2013, covered double star observations from simple eyepiece astrometry of wide binaries, with orbital periods of centuries, to amplitude interferometry of binaries with periods measured in days or even hours. A wide range of participants, from students and amateurs to professionals shared their perspectives in panel discussions. This was the first conference of the newly-formed International Association of Double Star Observers (IADSO). PDFs of 22 of the talks and YouTube links to 23 of the talks and panels are available at www.IADSO.org.

The Maui International Double Star Conference was held 8-10 February, 2013, at the University of Hawaii's Institute for Astronomy Makialani, Pukalani, Maui, Hawaii. This was the first conference of the newly formed International Association of Double Star Observers (IADSO).

Many of the conference participants went on a pre-conference Atlantis submarine cruise on February 6^{th}. The Atlantis submarine, which holds 48 people, reached a depth of 129 feet while cruising around reefs and old shipwrecks not far from Lahina. Steve McGaughey, a conference participant and resident of Maui, is one of the submarine's captains.

The submarine tour was followed by lunch at the historic Pioneer Inn and a tour of old town Lahaina, the first capital of Hawaii, and for many years its busiest port.

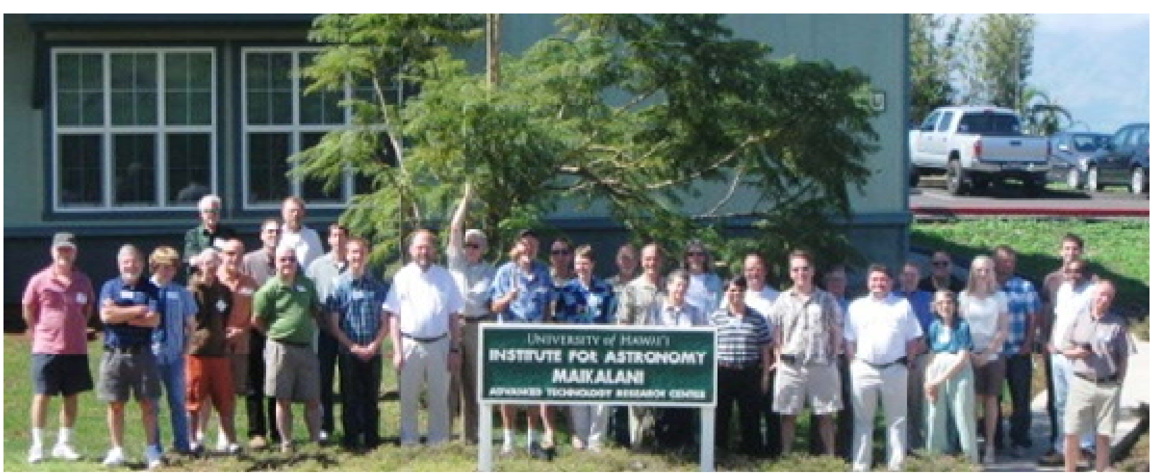

Figure 1: IADSO conference participants pose in front of the University of Hawaii's Institute for Astronomy, Makialani.

The Maui International Double Star Conference

Figure 2: Lined up on the deck before going below. Ellie and Steve McGaughey, Oleg Malkov, and Yury Balega.

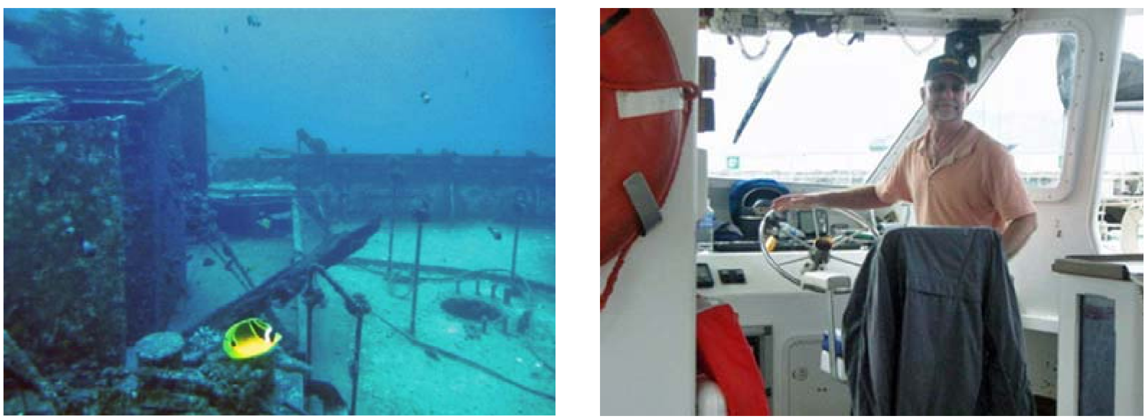

Figure 3: A bright fish swims by a sunken wreck. Captain Steve McGaughey safely brings us back to shore.

Figure 4: Group hug after lunch at the Pioneer Inn. Left to right: Bill Hartkopf, Suzanne & Chris Thueman, Russ Genet (in back), Ellie & Steve McGaughey, the peg-legged sea captain, Oleg Malkov & Irina Arendarchuk (behind), Vera Wallen, and Yuri Balega. An enormous Banyan tree (right) takes up most of a block-sized park in Lahaina. Vera Wallen, Jo Johnson, Cheryl & Russ Genet pose in its shade.

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Figure 5: Bill Hartkopf, Russ and Cheryl Genet in front of Pan-STARRS. Bobby Johnson and Eric Weise at the working end of the 2-meter Faulkes Telescope North.

Another pre-conference tour, this one on February 7th included a Haleakala summit tour of Pan-STARRS (now of Comet Pan-STARRS fame), the 2-meter Faulkes Telescope North (part of the Las Cumbres Observatory Global Network), and the Haleakala Amateur Astronomers observatory (perhaps the highest amateur observatory on the planet).

Pre-conference activities were capped off with a sunset dinner at the famous Kula Lodge on the flank of Haleakala. The wine and food were excellent!

The conference covered many aspects of visual double star astrometry. Invited talks and contributed posters addressed double star instrumentation, observations, orbital analysis, catalogs, organizations, jour-

Figure 6: Sunset dinner at the Kula Lodge on the slopes of Haleakala.

nals, and student research. Observational techniques from simple visual astrometric eyepieces to CCD astrometry of fainter doubles were discussed, along with high resolution techniques including speckle interferometry, amplitude interferometry, and intensity interferometry. Talks on complementary instrumentation included high resolution radial velocity spectroscopy and low cost, portable meter-class "light bucket" telescopes for spectroscopy and intensity interferometry.

Many of the talks were given by student and amateur astronomers on their double star observations made with smaller telescopes. At the other end of the spectrum, there were talks on observations of very close binaries made with the 3.5 meter WIYN telescope at Kitt Peak and the historic 6 meter telescope of the (Russian) Special Astrophysical Observatory. Consideration was given throughout the conference to student education—how undergraduate and even high school students can learn about science by conducting their own double star research. Being a published "scientist" significantly advances educational careers.

The conference was called to order Friday morning, February 8th, by its convener, Russ Genet, who

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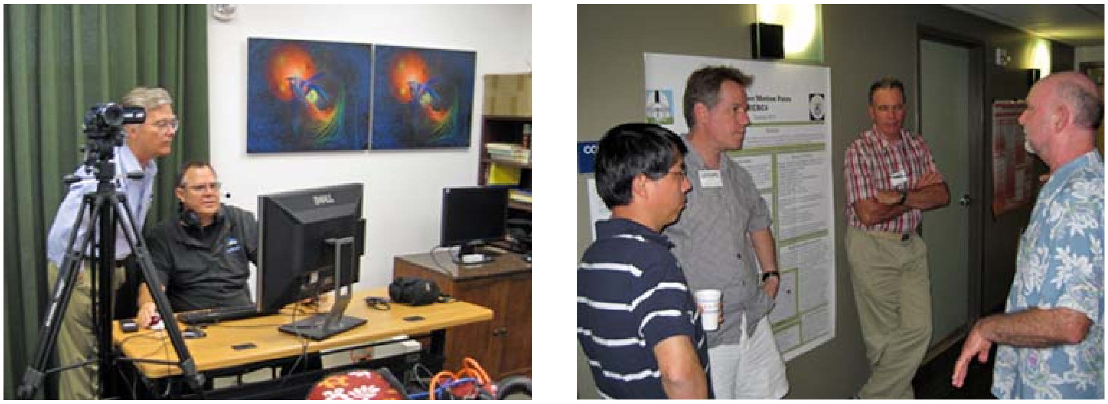

Figure 7: Bob Buchheim and Steph Mohr faithfully record each of the presentations for posterity. PDFs of the power point slides and links to U-Tube videos are available on www.IADSO.org. Jian Ge, Gerard van Belle, Chris Thueman, and Steve McGaughey discuss one of the posters during break.

introduced the Master of Ceremonies, Jolyon Johnson. Joe Ritter, gave a welcome from the University of Hawaii's Institute for Astronomy, while Steve McGaughey did the same for the Haleakala Amateur Astronomers. Steve McGaughey and Cheryl Genet (the Conference Facilitator), provided details on meals and special events.

The first two sessions placed emphasis on student and amateur research at smaller telescopes. Jo Johnson (California State University, Chico) gave the first talk of the conference on undergraduate double star research seminars, followed by a talk by Russ Genet (California Polytechnic State University) on a student speckle interferometry research program. R. Kent Clark (University of South Alabama and Editor of the *Journal of Double Star Observations)* considered the latest trends in double star astronomy in the *JDSO,* which publishes many amateur and student papers. Paul Hardersen (University of North Dakota, Space Studies Program) explained how the development of their astronomical research program led to the unique University of North Dakota graduate distance learning program which offers both masters and doctoral degrees in Space Studies with an astronomy option. Robert Buchheim (Altimira Observatory in California) rounded out the first session by enumerating the support the Society for Astronomical Science (SAS) provides to both amateur and student researchers in many areas, including double stars. The SAS's popular annual late May symposium at Big Bear Lake in southern California is well worth attending.

The second two sessions continued the small telescope double star research theme. Bruce MacEvoy (Black Oak Observatory in northern California) described his visual double star campaign from his well-equipped observatory. Eric Weise (a third year physics and mathematics student at the University of Califor-

Figure 8: The student education panel (left to right): Kent Clark, Bob Buchheim, Eric Weise, Vera Wallen (panel moderator), Jo Johnson, and Russ Genet.

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Figure 9: Social hour at the Maui Beach Hotel. Left to right: Vera Wallen, Deborah and Bill Hartkopf, Russ and Cheryl Genet, and Elliott Horch. Dinner at Tante's Island Cuisine.

nia, San Diego) provided a student-teacher perspective on double star research seminars. Kakkala Mohanan and Rebecca Church (an instructor and student, respectively, at Leeward Community College, Oahu, Hawaii) described double star lucky imaging astrometry with their 0.5-meter telescope. A panel on student research and education, led by Vera Wallen (retired Superintendent of Schools in California), considered various student educational issues. With a good first day under their belts, the attendees retired for a social hour at the Maui Beach Hotel and dinner at Tante's Island Cuisine in Kahului.

Sessions continued on Saturday morning, February 9th, with talks by professional astronomers. William Hartkopf (U.S. Naval Observatory, Astrometry Department) described the Washington Double Star Catalog in terms of "whence it came," and "whither it goeth." Oleg Malkov (Institute of Astronomy, Moscow) described how he formed catalogues of fundamental parameters of orbital binaries. Elliott Horch (Physics Department at Southern Connecticut University) reviewed his speckle interferometry at the 3.5 meter WIYN Telescope at Kitt Peak. Yury Balega (Director of the Special Astrophysical Observatory, Russian Academy of Sciences) described the intriguing puzzles of the young massive binary Theta 1 Ori C. Brian Mason (U.S. Naval Observatory, Astrometry Department) outlined the extensive USNO double star observing program. Observations are made both with the historic Alvin Clark refractor in Washington and as guest observers on many larger telescopes in the USNO's "off campus" program. Brian was unable to attend in person, so Bill

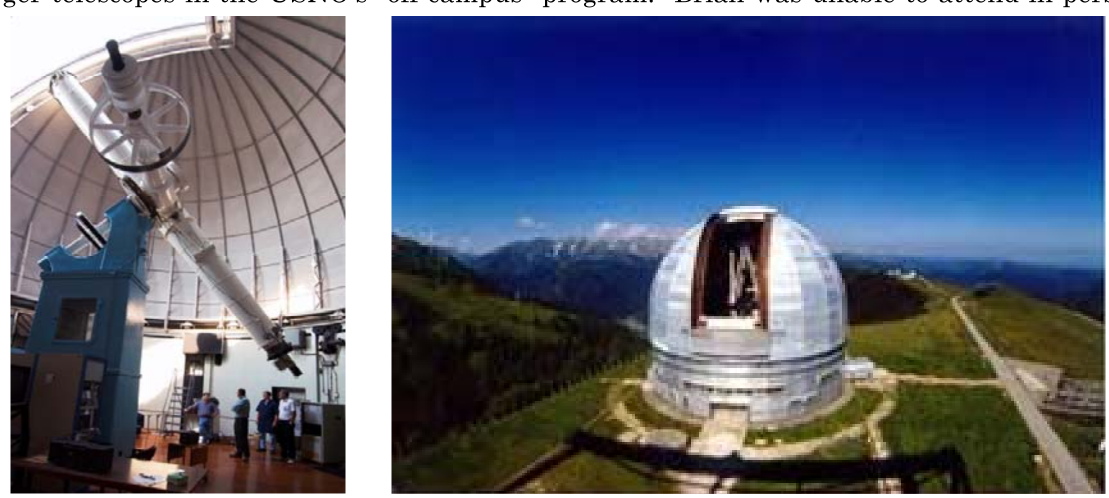

Figure 10: The famous 26-inch (0.66 m) Alvin Clark & Sons refractor at the US Naval Observatory dwarfs Bill Harkopf and Brian Mason as they discuss a speckle interferometry run with their colleagues. The pioneering 6 meter telescope of Russia's Special Astrophysical Observatory, on the right, which Yury Balega directs. Yury spent many 14-hour nights in the prime focus cage.

Figure 11: Elliott Horch and his two-channel speckle interferometer mounted on one of the two Nasmyth foci of the 3.5 meter WIYN telescope at Kitt Peak. One of the two Andor iXon EMCCD cameras can be seen as well as a PC strapped to the bottom of the photometer. Russ and Elliott in the warm room during a recent run.

Hartkopf gave his talk for him. Yury Balega also gave a talk on the pioneering 6-meter azimuthal telescope in southern Russia—formerly the largest telescope in the world.

Saturday afternoon returned to amateur and student talks. Ed Wiley (Yankee Tank Creek Observatory, Kansas) described the autocorrelation techniques he uses on "super speckles" with his small telescope. B. J. Fulton (Institute for Astronomy, University of Hawaii at Manoa) addressed the fundamentals of speckle interferometry reduction. Steve McGaughey described how Maui students—including high school and even middle school students—conduct double star research on the 2-meter Faulks Telescope North. The conference's second panel was moderated by Elliott Horch.

Figure 12: Ed Wiley's f/22 Dall Kirkham telescope he uses to observe double star "super speckles." The second panel (left to right): Bill Hartkopf, Ed Wiley, Elliott Horch (moderator), Steve McGaughey, and B. J. Fulton.

Most of the attendees participated in an evening observing session at Haleakala Amateur Astronomer's Observatory. It was cold and a bit windy but clear, and the seeing was excellent.

Sunday, February 10th, the final day of the conference featured advanced techniques. Gerard van Belle (Lowell Observatory and President of the IAU Commission on Optical and Near Infrared Interferometry) gave talks on the fundamentals of amplitude interferometry and their application at NPOI, CHARA, and elsewhere. David Dunham (President of the International Occultation Timing Association and member of

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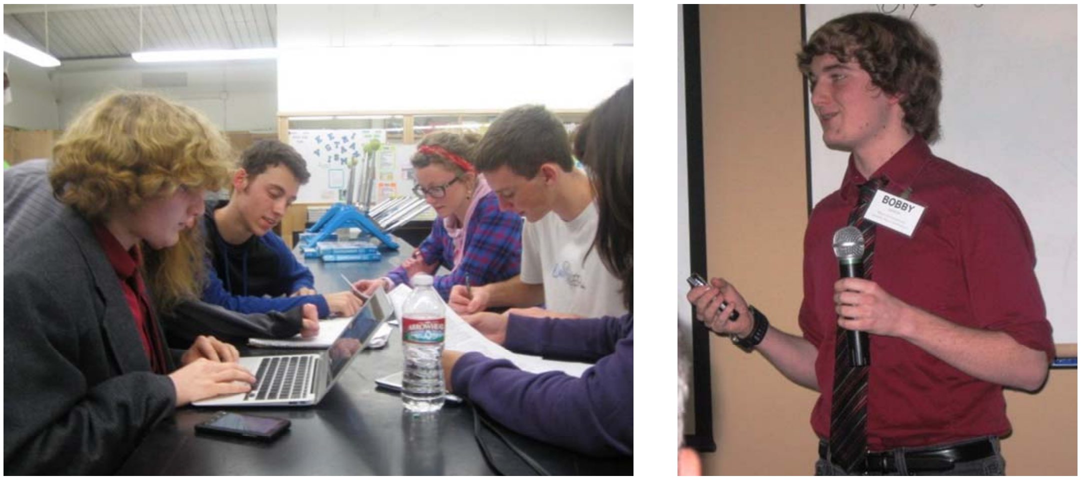

Figure 13: Bobby (left) works with his team at Arroyo Grande High School to analyze lucky images of the double star, 69 And. He presented his results at the conference in Maui (right). Bobby plans on becoming an astrophysicist.

the Moscow Institute of Electronics and Mathematics) explained how to obtain high speed lunar occultations of double stars. Jian Gee (University of Florida Research Foundation) described the development of a low cost, portable, next-generation, extremely high resolution optical /near IR spectrograph.

John Martinez (Las Cumbres Observatory Global Telescope) explained how a global network of telescopes, LCOGTnet, can monitor a variable star around the clock. These telescopes are equipped with high speed EMCCD cameras which could make them useful for double star speckle interferometry.

Bobby Johnson, an Arroyo Grande High School student taking a double star astronomy research seminar at Cuesta College, was, at 16 years old, easily the youngest speaker at the conference. Bobby described his team's lucky imaging of the double star 69 And.

Looking toward the future, Elliott Horch explained how, at Lowell Observatory, he was revisiting (with modern detectors and electronics) the stellar intensity interferometry technique first developed by Hanbury Brown at the Narrarbi Observatory in Australia. Since intensity interferometers only require "light bucket" telescopes of low optical quality, Russ Genet described portable "light bucket" telescopes he is developing with engineering students at California Polytechnic State University. Intensity interferometry experiments with these telescopes are being planned. The final panel on advanced techniques was moderated by Gerard van Belle.

Figure 14: Hanbury Brown's stellar intensity interferometer in Narrarbi, Australia (left). On the right is the portable 1.5 meter light bucket telescope designed and built by Russ Genet and students at California Polytechnic State University.

Figure 15: Tables at the Aloha Dinner. The wine and food were both excellent, as were the spirited conversations.

The final session on intensity interferometry and light bucket telescopes was attended by Joe Ritter and inspired his conception of an array of large-aperture space light bucket telescopes. Joe, Elliott Horch, Gerard van Belle, and Russ Genet had an animated discussion of this concept in the parking lot in front of Tante's Island Cuisine just before the Aloha dinner. Within three days, the four of them had prepared an exploratory study proposal for this nano-arc-second system that Joe sent off to NASA.

The conference concluded with an Aloha dinner, conference memory slides shown by the conference's Master of Ceremonies, Jo Johnson, and an award ceremony.

The award ceremony at the conference recognized William I. Hartkopf's lifetime of double star research and service to the double star community. Bill was presented with a laser-enscribed Hawaiian koa wood paddle for his "Three Decades of Research and Service."

Figure 16: Steve McGaughey (left), besides being an accomplished visual double star observer and ship Captain, is both a visual artist (paintings) and musician. Yury Balega (right), who received a box of Hawaiian chocolate-covered macadamia nuts in recognition of his long journey from Russia to Hawaii, is also a musician. As a young student he earned his way through graduate school playing his guitar and singing Beatles songs.

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Figure 17: Harold McAlister (left), Director of the Center for High Angular Resolution Astronomy (CHARA), Georgia State University, and Director, Mt. Wilson Observatory, and Brian Mason, U. S. Naval Observatory, Astrometry Division, and President of the International Astronomical Union's Commission 26 on Double and Multiple stars. They provided the testimonials for Bill Hartkopf's award.

Although they could not be there in person, Hal McAlister and Brian Mason provided the testimonials to Bill's decades of research and service:

[From Harold McAlister]

I was delighted to learn that you are honoring Bill Hartkopf on Maui this weekend. He certainly deserves recognition for all he's done over the years, and continues to do, to advance the field of binary star studies.

The best thing I ever did was way back in 1981 when I invited Bill, who was then just finishing his PhD at Illinois, to join me at Georgia State in carrying out a long-term program of binary star speckle interferometry I'd started six years before as a post-doc at Kitt Peak. Over the next 18 years, Bill and I spent countless nights at the KPNO 4-m telescope, the Perkins Telescope at Lowell Observatory, and at whatever large telescope on which we could beg, borrow, or steal time to watch our many friends among the binaries do their slow orbital dances. In the process, we discovered a fair number of new systems, published dozens of orbits, measured new masses, honed the speckle reduction methodology to excellent precision and accuracy, compiled catalogs, and generally had a whale of a good time. I like to think that those efforts paid off by enabling speckle techniques to succeed visual micrometry as *the* method for observing visual binaries. As I look back now, those really were the golden years of my career, and Bill's diligence, persistence, attention to detail, devotion to the cause, and all-around good camaraderie were basically what made them so special. During those years, midway through which Bill became the de facto manager of our speckle program as I wandered off mostly into long-baseline interferometry, we wrote more than 50 papers together and amassed a very large collection of fundamental data for binaries. Our partnership held the record in the field for a number of years, but I'm sure that has now been surpassed by Bill and Brian Mason at the USNO. It is also clear that the productivity of our speckle efforts gave us the scientific credibility underlying the NSF support for what would become the CHARA Array. And, Bill played a very major role in our achieving that credibility.

It was quite a blow when Bill decided to move to Washington in 1999, but that hasn't stopped our collaboration, and Bill and Deborah remain dear friends to Susan and me. We see them from time to time, although not often enough. What I miss on a day-to-day basis, though, is Bill's excellent companionship, his great sense of humor—he's a world-class punster—and his overall joy in a job well done.

I wish I could have been there to offer my congratulations in person to you, Bill, and to hear your response that I bet includes a pun or two. No doubt our paths will cross again soon. In the meantime, keep an eye on all our old double star buddies up there in the sky.

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[From Brian Mason]

I have been delighted to work with Bill Hartkopf on a regular basis since 1991. Except for a brief hiatus when I preceded him to the Naval Observatory, we have spent a good bit of each day in each other’s company, and in that I think I have gotten the better end of the stick. We have observed together for a total of a month each at Cerro Tololo and Kitt Peak on the 4m telescopes, for a week on the CFHT an island hop away right now, a few nights at NOFS on the 61", and a month and a half on the Hooker 100" on Mt Wilson. In addition to the many nights observing together, lately we have spent several weeks together completing 360 miles on the Appalachian Trail. Indeed we spend so much time in each other's company, that were it not for each other being happily married, people would talk!

He is my colleague, my collaborator, and I am glad to say, my good friend.

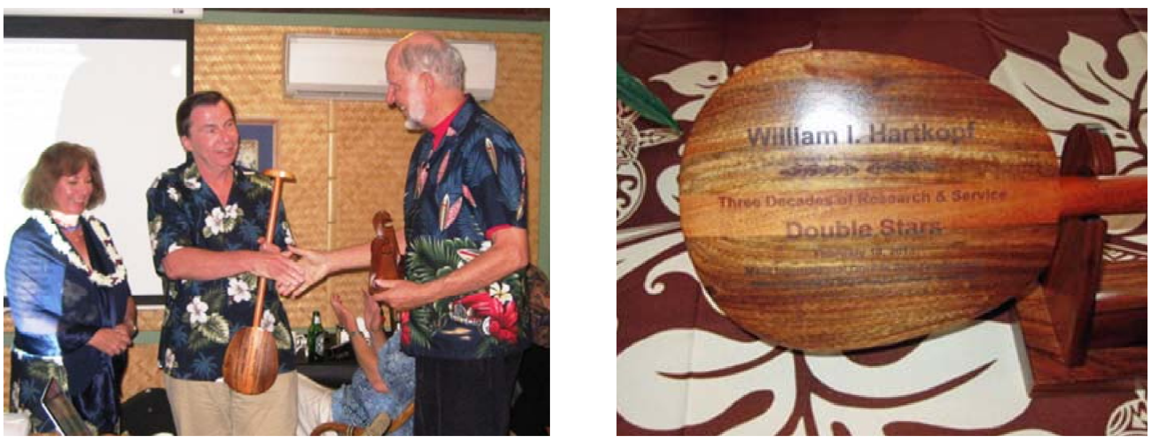

Figure 18: Deborah Cline (Hartkopf), Bill Hartkopf, Russ Genet, and the engraved koa wood Hawaiian paddle award.

Figure 19: Bill Hartkopf (left) and Russ Genet (right) square off with Hawaiian koa wood paddle versus Russian ceremonial mace (the mace was kindly contributed by Oleg Malkov to help keep the conference running on time and in good order). It worked! Not to be outshined by their husbands, Deborah Cline (Hartkopf) and Cheryl Genet (right) pose for a picture.

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The life of a double star astronomer isn't easy, filled as it is with long runs from scenic mountaintops around the planet, not to mention enduring wine and seven course dinners at international astronomical conferences. It's a tough job, but someone has to do it! Bill stepped up to the plate.

Figure 20: Bill's early speckle career included runs at the 4-meter telescope at Kitt Peak National Observatory. Data was logged on an early Osborne microcomputer. The speckle interferometry camera was installed at the Cassegrain focus. That's Bill in the "Cass cage."

Figure 21: Many of Bill's speckle runs were made at the historic Hooker 100 inch telescope on Mt. Wilson. Bill heads for work on the same boardwalk used by Edwin Hubble and Milton Humason on their way to work, not to mention Albert Einstein during his visit to Mt. Wilson. Bill (left), Hal McAlister (rear), and Brian Mason (right) speckle away under the 100 inch telescope. The real fun, however, was installing the calibration slit mask at the top of the telescope!

Figure 22: Attending the tri-annual General Assemblies of the International Astronomical Union was an important duty. Bill served a term as President of IAU Commission 26, Double and Multiple Stars. Did Bill, at the 2006 IAU General Assembly in Prague, vote for the demotion of Pluto? Brian Mason, José Doboco, and Bill Hartkopf in front of the Ramón M^{A}. Aller Astronomical Observatory in Santiago de Compostella, the capital of the autonomous community of Galacia in Spain, which hosted a double star conference replete with a fine dinner.

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The Maui International Double Star Conference was thoroughly enjoyed by all its participants. The exchanges between professionals and amateurs, educators and students, were informative and cordial. Maui's "aloha spirit" imbued the conference with a relaxed, friendly demeanor.

The need for an international organization that would, worldwide, link professional, amateur, and student double star researchers together was discussed repeatedly in the panels and over drinks and meals. As a result, the International Association of Double Star Observers (IADSO) has been formed—an informal organization that has adopted its founding conference's "aloha spirit" of friendly informality and open communications. All those interested in double star observations are invited to join the IADSO as a charter member.

One good conference deserves another, and another, and … Already rumors are circulating about an August 2014 conference in Europe, a June 2015 conference at the Lowell Observatory in Flagstaff, Arizona, and a conference at the 6 meter telescope of the Special Astrophysical Observatory in the Zelenchuksky District on the north side of the Caucasus Mountains in southern Russia. Stay tuned!

International Association of Double Star Observers (IADSO)

The newly formed International Association of Double Star Observers (IADSO) promotes the science of double and multiple stars through astrometric, photometric, and spectroscopic observations, the identification of physically bound or projected pairs, the determination and refinement of binary star orbits, and the publication of these observations and analysis in recognized scientific journals. The IADSO encourages all forms of quantitative, publishable, double as well as multiple star observations and analysis. These include observations made with visual astrometric eyepieces, filar micrometers, and CCD cameras, as well as speckle interferometry, high speed occultation photometry, and high resolution spectroscopy. The IADSO fosters improvements in the accuracy and efficiency of observations, and works to make instrumentation and software practical and affordable for smaller observatories.

The IADSO provides an international forum for the communication of ideas, observations, discoveries, observing techniques, instrumentation, and software by initiating conferences and workshops, hosting the IADSO web site www.iadso.org, publishing books, raising money for student research scholarships, and connecting experienced double star mentors with beginning student and amateur researchers. The IADSO is grateful to the Alt-Az Initiative for providing the IADSO a web site, the Collins Foundation Press for publishing the IADSO's first book, *The Double Star Reader,* the University of Hawaii's Institute for Astronomy for hosting the IADSO's first conference, and the non-profit Collins Educational Foundation for conference management and handling donations for student scholarships.

IADSO-organized meetings and conferences allow professional and amateur astronomers, as well as educators and students, to communicate on a face-to-face basis, foster new ideas, forge new relationships, and promote international collaboration. The IADSO encourages its members to publish their findings in the many excellent double star journals such as *El Observador de Estrellas Dobles, Web Deep Sky Society, Il Bolettino delle Stelle Doppie,* and the *Journal of Double Star Observations.*

Several areas of observational astronomy, including variable stars and double stars, are amenable to making useful, published contributions to science with relatively modest instrumentation and skills. Undergraduate students and even high school students, through published and subsequently cataloged observations of double stars, not only have contributed to science, but have significantly increased their understanding and appreciation of science as well as advancing their educational careers. The IADSO encourages and supports student double star research.

Everyone, world-wide—professional and amateur astronomers, educators and students—with an interest in promoting the science of double star astrometry is invited to join the IADSO as a charter member and receive a charter membership certificate. There are no membership fees, although donations are welcome through the Collins Educational Foundation to support student scholarships and activities. Members will receive an occasional IADSO Newsletter and notification of IADSO conferences, workshops, and books. Please go to the IADSO web site at www.iadso.org to join.

Journal of Double Star Observations

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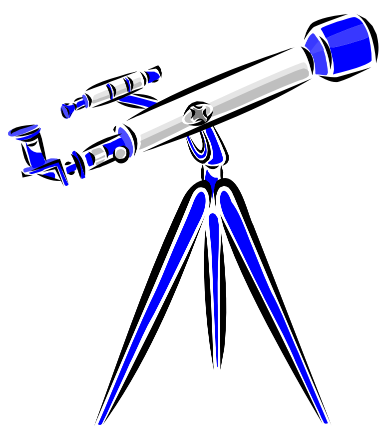
Questions, comments, or submissions may be directed to rclark@southalabama.edu or to rmollise@bellsouth.net

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@southalabama.edu or to rmolise@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.



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