University of South Alabama

Journal of Double Star Observations

VOLUME 7 NUMBER 1 January 1, 2011

Inside this issue:

Double Star Measures Using a DSLR Camera #6

Ernő Berkó

3188-Ludányhalászi,
Bercsényi u. 3.
Hungary

berko@is.hu

Abstract: This article contains measures by the author made with a DSLR camera. The images used for the measures were taken in the period between 2009.874-2009.926. The result is 442 positive and 18 negative measures.

Recently, I have had some problems, causing a short break in measuring, and in publishing measurement data. One of the problems was that in the spring, due to extreme weather, the building of my telescope was flooded twice.

Now, continuing the work, I report here the evaluation of the photos taken in 2009 between 15 November – 4 December.

The equipment used for photographing, and the methods of photo processing and measuring, are the same as those detailed in my first article [1]. Therefore, I would only like to note that I was working with a Canon 350D digital camera with a 35.5cm Newton telescope, and focal length increased to 4200mm. The pictures were measured with Florent Losse's program (Reduc 3.85). I used approximately 3279 photos for the present article. It contains the data of 4184 independent measures of 460 pairs.

A table contains the results of the measures, followed by the notes. I have also attached images of the doubles that I measured, with captions provided. In the first three columns of the table, the WDS coordinates and names of the doubles, as well as the components' brightness can be found. I described the brightness of the components on the basis of WDS, although it seems contradictory sometimes. When there is an Anon. component, I gave the GSC or USNO "R" brightness, if not available, I provided the brightness that I estimated on the basis of the photo.

This is followed by the position angle (PA) and the separation (Sep) measured and calculated by me. In both cases, the value of the standard deviation is also indicated (+/-). The column (Epoch) gives the time when the images was taken. Finally, in every row, the number of individual measures (n), the reference number to the description (Notes), and the reference number of the image belonging to the measures (Img) can be seen.

In the descriptions (notes), you can find the GSC number of the primary star of those doubles that I measured; in case it appears in the GSC catalog. Also, my personal notes about the given double star can be read here. I found the greatest problem with the 10-character identification coordinates of WDS. In many cases it is different from the real position of the double. Although WDS contains more precise coordinates for most of the pairs, at times the double cannot be found at these locations. For the doubles measured by me, I "give suggestions" regarding these closest coordinates in the form of (xxxxx+xxxx!).

In the case of some doubles, when the available

Double Star Measures Using a DSLR Camera #6

measures show a significant deviation in the parameters, I tried to explore the reason for this difference. I downloaded the DSS images of the area (POSS 1 Blue and POSS 2 IR): using these I checked if the doubles under scrutiny changed in the period between the different measures. In some cases it has been proved that the proper motion of one of the components causes this change. I employed the same method when I could not identify a double in or near the position given by WDS.

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

References

1. Berkó, Ernő, "Double Star Measures Using a DSLR Camera", JDSO, **4**, 144-156, 2008.

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Img
20100+2314	POU4238	11.02	11.4	354.56	0.24	15.36	0.05	2009.874	15	1	
20108+2319	POU4247	12.7	12.7	95.73	0.17	10.45	0.04	2009.874	18	2	1
20109+2311	Anon 1	12.0	13.0	143.96		5.46		2009.874	1	3	1
20111+2330	Anon 2	11.5	11.6	255.48	0.24	7.18	0.07	2009.874	4	4	
20112+2330	Anon 3	11.5	11.6	98.92	0.26	5.24	0.06	2009.874	7	5	
20112+2319	Anon 4	13.5	13.5	326.33		4.76		2009.874	1	6	
20113+2333	POU4253	13.8	14.1	50.74	0.14	9.18	0.08	2009.874	5	7	
20113+2314	POU4254	12.7	12.8	314.48	0.13	13.81	0.02	2009.874	16	8	
20114+2331	POU4255	11.63	12.9	43.32	0.10	17.85	0.04	2009.874	16	9	
20115+2328	Anon 5	13.5	13.5	256.63	0.38	2.75	0.14	2009.874	3	10	
20115+2318	Anon 6	14.0	14.0	82.86		4.18		2009.874	1	11	2
20116+2318	Anon 7	13.5	14.0	119.68	0.42	5.77	0.05	2009.874	11	12	2
20117+2320	POU4256	11.04	12.5	249.42	0.21	10.99	0.02	2009.874	15	13	2
20118+2317	Anon 8	14.0	14.0	281.87	0.47	5.64	0.06	2009.874	6	14	2
20118+2316	POU4258	12.6	13.8	176.08	0.18	9.30	0.04	2009.874	16	15	2
20119+2351	POU4262	10.72	11.5	5.84	0.28	7.51	0.04	2009.874	13	16	
20119+2348	POU4260	12.17	13.1	334.60	0.18	14.75	0.06	2009.874	4	17	
20119+2329	POU4261	12.6	14.1	112.17	0.24	6.48	0.06	2009.874	11	18	3
20119+2328	Anon 9	12.2	14.0	34.52		4.56		2009.874	1	19	3
20120+2358	POU4264	12.2	12.7	353.51	0.15	16.77	0.03	2009.874	16	20	3
20120+2357	POU4265	12.5	14.0	238.13	0.22	9.40	0.05	2009.874	16	21	
20120+2350	POU4263	10.7	11.6	293.69	0.25	7.60	0.06	2009.874	14	22	
20121+2429	Anon 10	10.5	12.5	26.06	0.22	8.78	0.07	2009.882	8	23	
20121+2324	Anon 11	12.7	13.5	54.64		6.82		2009.874	1	24	
20122+2359	POU4267	13.0	14.1	172.36	0.30	6.16	0.04	2009.874	12	25	
20123+2404	POU4268	8.81	14.9	41.05	0.18	14.18	0.06	2009.874	5	26	
20123+2348	Anon 12	12.5	13.0	162.43	0.39	4.49	0.07	2009.874	3	27	
20124+2433	POU4269	11.80	12.05	272.09	0.08	13.18	0.02	2009.882	15	28	
20125+2326	POU4270AB	14.0	14.1	219.60	0.33	13.64	0.04	2009.874	13	29	
20125+2326	Anon 13Ax	14.0	14.3	183.61	0.15	5.37	0.03	2009.874	2	29	

Table continues on next page.

Double Star Measures Using a DSLR Camera #6

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Img
20126+2539	DOO 15AB	7.47	11.03	296.48	0.06	117.40	0.06	2009.882	10	30	
20126+2539	DOO 15BC	9.1	10.8	170.28		2.39		2009.882	1	31	
20126+2539	OPI 22BD	11.03	13.5					2009.882		32	
20126+2539	OPI 22BE	11.03	11.72	243.95	0.13	38.43	0.06	2009.882	13	33	
20126+2529	BRT3355	11.30	11.3	206.75	0.29	3.48	0.07	2009.882	7	34	
20126+2326	POU4272AB	12.0	12.4	31.63	0.14	13.61	0.03	2009.874	17	35	
20126+2326	Anon 14Ax	12.0	14.5	58.81		8.52		2009.874	1	35	
20126+2326	Anon 14By	12.4	14.5	19.16		7.10		2009.874	1	35	
20127+2430	POU4273AB	10.95	12.06	233.07	0.25	8.11	0.04	2009.882	15	36	
20127+2430	POU4274AC	10.95	13.91	8.72	0.26	13.32	0.05	2009.882	15	36	
20128+2412	Anon 15	13.0	13.5	249.27		2.68		2009.874	1	37	
20128+2405	POU4277	12.12	13.1	318.42	0.25	12.57	0.08	2009.874	6	38	
20130+2527	Anon 16	12.0	12.0	223.46	0.28	6.87	0.09	2009.882	10	39	
20131+2414	POU4279	14.0	14.1	184.05		2.63		2009.874	1	40	
20132+2328	POU4280	11.04	13.3	47.25	0.27	6.91	0.06	2009.874	8	41	
20133+2411	POU4282	12.7	13.2	14.85	0.32	6.59	0.08	2009.874	6	42	
20135+2325	POU4284	12.6	14.0	342.77	0.18	14.49	0.03	2009.874	15	43	
20136+2334	POU4287	12.2	14.1	62.96	0.26	15.31	0.05	2009.874	15	44	
20137+2333	POU4288	10.6	11.7	105.83	0.11	14.72	0.02	2009.874	14	45	
20137+2330	Anon 17	12.5	13.5	293.30		2.22		2009.874	1	46	
20138+2334	Anon 18AB	13.0	13.5	171.85	0.32	9.93	0.06	2009.874	15	47	
20138+2334	Anon 18AC	13.0	14.0	13.49	0.24	10.22	0.07	2009.874	11	47	
20138+2325	Anon 19	13.1	13.5	83.47		6.58		2009.874	1	48	
20139+2358	POU4290	12.03	14.1	165.27	0.25	13.96	0.04	2009.874	12	49	
20139+2357	NYS 5AB	13.7	13.8	134.51	0.17	17.81	0.05	2009.874	8	50	
20139+2357	NYS 5BC	13.8	15.0	154.00	0.21	8.90	0.06	2009.874	2	50	
20140+2449	Anon 20	11.5	13.0	182.66	0.19	7.09	0.07	2009.882	7	51	
20140+2335	POU4292	13.2	14.1	248.30	0.10	12.39	0.07	2009.874	2	52	
20141+2446	Anon 21	13.5	13.5	249.04	0.28	6.07	0.09	2009.882	7	53	
20141+2443	POU4293	13.17	13.15	204.94		2.84		2009.882	1	54	
20142+2446	POU4295	12.67	14.1	302.54	0.04	3.67	0.11	2009.882	2	55	
20142+2355	Anon 22	14.0	14.0	298.92	0.52	5.61	0.10	2009.874	2	56	
20143+2401	Anon 23	14.3	14.4	162.89	0.23	8.49	0.05	2009.874	7	57	
20143+2352	Anon 24	13.0	13.0	325.77		1.86		2009.874	1	58	
20143+2328	POU4296	13.1	13.7	80.85	0.07	15.54	0.03	2009.874	16	59	
20144+2453	POU4300	12.2	14.0	268.58		24.94		2009.882	1	60	
20144+2358	POU4299AB	12.60	14.3	334.69	0.29	10.47	0.02	2009.874	5	61	
20144+2358	POU4298AC	12.60	14.1	320.40	0.22	12.36	0.06	2009.874	11	61	
20144+2354	Anon 25	13.0	13.2	217.69	0.40	3.43	0.14	2009.874	2	62	
20145+2451	STT 402	7.46	10.73	35.00	0.15	13.97	0.05	2009.882	13	63	
20145+2359	POU4302	11.34	12.4	107.32	0.17	15.62	0.02	2009.874	14	64	
20146+2459	POU4304	12.31	14.3	324.43	0.12	17.76	0.07	2009.882	17	65	
20146+2453	J 1165	10.75	12.4	119.44		1.24		2009.882	1	66	
20146+2334	POU4305	12.39	14.6	316.16	0.25	6.66	0.03	2009.874	13	67	
20147+2355	Anon 26	13.5	13.5	158.69		2.51		2009.874	1	68	

Table continues on next page.

Double Star Measures Using a DSLR Camera #6

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Img
20147+2327	POU4306	12.55	13.2	205.06	0.13	12.81	0.05	2009.874	16	69	
20148+2335	POU4307	11.77	13.7	233.10	0.27	12.26	0.08	2009.874	5	70	
20149+2451	Anon 27	12.5	13.5	264.57		5.57		2009.882	1	71	
20150+2428	POU4311	12.7	14.0	38.83	0.15	11.03	0.05	2009.882	12	72	
20150+2424	POU4309AB	13.2	13.2	71.58	0.29	6.94	0.06	2009.882	16	73	
20150+2424	POU4310AC	13.2	13.2	38.98	0.15	17.84	0.04	2009.882	16	73	
20150+2424	Anon 28Ax	13.2	14.0	313.95	0.29	4.47	0.05	2009.882	4	73	
20153+2432	POU4313	11.5	12.2	329.75	0.27	12.11	0.04	2009.882	18	74	4
20153+2428	POU4312AB	9.78	13.1	220.98	0.14	20.44	0.07	2009.882	18	75	
20153+2428	Anon 29Ax	9.78	14.0	31.22	0.37	6.95	0.10	2009.882	5	75	
20153+2428	Anon 29Ay	9.78	14.0	186.35	0.19	17.98	0.05	2009.882	11	75	
20155+2439	POU4317	12.5	13.9	96.08	0.22	4.72	0.06	2009.882	3	76	4
20155+2437	POU4315	10.48	10.6	92.91	0.58	4.24	0.03	2009.882	4	77	4
20157+2503	POU4318	11.41	12.9	214.04	0.29	14.36	0.05	2009.882	11	78	
20158+2437	Anon 30	14.1	14.1	96.50	0.17	8.23	0.06	2009.882	8	79	
20160+2505	Anon 31	14.0	14.0	9.68	0.39	3.35	0.05	2009.882	2	80	
20162+2506	POU4323	14.0	14.1	21.90	0.34	4.84	0.05	2009.882	9	81	
20162+2437	POU4324	11.02	14.4	189.06		18.07		2009.874	1	82	
20166+2503	POU4329	12.6	13.8	51.10	0.34	8.35	0.06	2009.882	12	83	
20166+2433	POU4330	11.18	12.6	306.98	0.19	15.07	0.03	2009.874	4	84	
20177+2510	POU4344	11.38	13.9	226.33	0.04	6.45	0.07	2009.887	6	85	
20178+3956	HJ 2951	8.80	9.54	124.93	0.11	10.88	0.03	2009.920	16	86	
20179+3712	SEI1071	10.77	11.6	11.42	0.09	27.30	0.05	2009.920	15	87	
20180+2450	Anon 32	13.5	13.5	229.60	0.18	5.29	0.05	2009.887	5	88	
20183+3953	Anon 33	8.80	12.0	58.70	0.19	7.09	0.06	2009.920	9	89	
20183+2539	BU 985AB	6.99	12.8	153.18		5.94		2009.887	1	90	
20183+2539	HJ 1499AC	6.96	10.87	356.72	0.14	21.47	0.07	2009.887	17	91	
20183+2539	WAL 131AE	6.96	8.13	151.17	0.02	123.10	0.05	2009.887	17	91	
20183+2539	BU 985CD	9.7	12.4	65.58	0.36	8.53	0.02	2009.887	3	91	
20183+2449	POU4349	11.47	13.1	13.71	0.18	10.31	0.01	2009.887	16	92	
20184+2511	POU4352	13.25	14.04	280.90	0.08	14.03	0.03	2009.887	15	93	
20184+2501	POU4350	14.1	14.2					2009.887		94	
20187+3720	SLE 995	11.6	11.6	142.77	0.22	8.88	0.04	2009.920	16	95	
20187+3715	SLE 994	11.6	12.3	353.89	0.17	14.57	0.08	2009.920	15	96	
20188+2504	POU4355	13.2	14.0	177.57	0.22	10.70	0.04	2009.887	16	97	
20188+2454	POU4357	14.0	14.2	65.84	0.20	13.73	0.05	2009.887	16	10	
20189+3723	Anon 34	12.0	13.0	202.51	0.11	6.71	0.02	2009.920	3	98	
20192+3938	ES 2051	10.43	12.9	306.12		4.93		2009.920	1	99	
20192+2441	A 391AB	9.82	10.40					2009.887		100	
20192+2441	Anon 35Ax	9.82	13.0	262.80	0.29	6.72	0.01	2009.887	3	101	
20193+2443	POU4361	10.89	14.1	233.83	0.08	20.75	0.04	2009.887	16	102	
20194+2457	GRV 330	12.9	13.6	148.31	0.03	47.34	0.04	2009.887	16	10	
20194+2446	POU4366	11.9	13.1	258.11	0.14	13.20	0.01	2009.887	17	103	
20195+2454	POU4369	11.53	12.5	39.73	0.05	20.40	0.04	2009.887	16	104	
20195+2453	POU4368	12.8	14.2	183.59	0.27	10.75	0.03	2009.887	14	105	

Table continues on next page.

Double Star Measures Using a DSLR Camera #6

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Img
20196+3808	SEI1084AB	10.5	11.0	247.43	0.08	26.30	0.02	2009.920	16	106	
20196+3808	TOB 185AC	11.8	12.3	259.58	0.10	13.64	0.04	2009.920	16	106	
20196+2442	POU4373	14.2	14.3	219.74	0.25	8.74	0.03	2009.887	16	10	
20197+2447	Anon 36	13.0	13.5	245.61	0.15	4.73	0.07	2009.887	7	10	
20198+3958	MLB1014	10.7	11.5	240.72	0.29	7.57	0.05	2009.920	6	107	
20198+3806	Anon 37	13.0	13.5	81.21	0.21	4.93	0.06	2009.920	5	10	
20199+4000	MLB1015	12.0	12.1	86.17		3.96		2009.920	1	10	
20199+3933	SEI1086	9.58	11.3	316.05	0.21	4.83	0.04	2009.920	12	108	
20200+3938	HO 593	9.0	10.8					2009.920		109	
20202+2458	POU4378	13.6	14.0	315.35	0.24	6.82	0.05	2009.887	13	110	
20203+3958	BRT2260	12.55	12.78	7.65	0.27	2.7	0.03	2009.920	5	111	
20203+2501	J 1195	10.01	14.5	105.51	0.07	4.38	0.06	2009.887	6	112	
20205+4122	LI 5AB	10.95	15.9	143.87	0.36	8.34	0.02	2009.920	3	113	
20205+4122	FAB 15AC	10.95	12.81	202.89	0.14	19.50	0.05	2009.920	15	113	
20207+2502	POU4387	12.0	13.8	281.89	0.25	13.06	0.05	2009.887	14	114	
20208+2448	POU4389	12.06	12.7	255.94	0.10	14.76	0.05	2009.887	16	115	
20213+2514	POU4393	12.8	13.8	241.49	0.11	13.09	0.05	2009.887	15	116	
20213+2445	Anon 38	14.0	14.0	106.80	0.32	3.45	0.05	2009.887	3	117	
20213+2443	Anon 39	11.6	13.5	65.58	0.28	7.60	0.06	2009.887	12	118	
20213+2440	POU4394	13.2	14.4	24.09	0.10	15.09	0.02	2009.887	16	10	
20216+3836	SEI1102	9.86	10.1	156.79	0.09	18.96	0.03	2009.920	16	119	
20218+2517	POU4399AB	12.4	13.4	21.24	0.19	10.74	0.03	2009.887	15	120	
20218+2517	POU4400AC	12.4	14.2	72.81	0.14	17.71	0.06	2009.887	15	120	
20219+2510	Anon 40	13.5	14.0	355.62	0.12	5.11	0.04	2009.887	3	121	
20221+3839	Anon 41	12.6	13.7	94.29	0.25	8.25	0.06	2009.920	9	122	
20221+2516	Anon 42	13.5	13.6	85.36	0.25	6.24	0.06	2009.887	5	123	
20223+3837	Anon 43	11.5	12.5	332.11	0.25	5.21	0.05	2009.920	11	124	
20229+3829	MLB 773AB	10.5	11.7	293.85	0.19	9.50	0.06	2009.920	15	125	
20229+3829	Anon 44Bx	11.7	12.5	151.81	0.32	2.52	0.05	2009.920	6	125	
20241+2453	POU4448	13.0	13.0					2009.874		126	
20242+3516	POP1230AC	10.8	11.4	147.64	0.06	46.99	0.05	2009.909	15	127	
20242+2453	POU4450	11.53	11.7	230.69	0.16	17.93	0.04	2009.874	14	128	
20243+2445	POU4455	11.93	13.1	299.05	0.43	6.63	0.02	2009.874	12	129	
20245+3511	POP 202	9.71	12.4					2009.909		130	
20246+2510	POU4463	12.39	13.3	142.83	0.24	12.43	0.04	2009.874	14	131	
20247+3523	SEI1117	11.80	12.15	126.59	0.26	13.01	0.06	2009.909	11	132	
20251+3522	SEI1118	11.1	11.2	149.52	0.20	9.27	0.06	2009.909	17	133	
20252+3522	SEI1120	10.34	10.55	216.53	0.09	27.25	0.03	2009.909	17	134	
20253+2506	POU4483	12.8	13.8	228.40	0.34	5.63	0.04	2009.874	8	135	
20293+3731	WEI 35AB	8.35	8.81	213.26	0.39	3.49	0.01	2009.909	2	136	
20293+3731	WEI 35AC	8.35	9.40	99.92	0.16	87.67	0.09	2009.909	7	136	
20293+3731	WEI 35BC	8.81	9.40	97.89	0.01	89.17	0.03	2009.909	11	136	
20293+3731	WEI 35CD	9.40	10.4	200.81	0.26	12.13	0.06	2009.909	10	136	
20296+4021	STN 50	9.0	10.0					2009.909		137	
20299+4022	HJ 1525AB	9.13	9.58	234.36	0.14	9.09	0.03	2009.909	16	138	

Table continues on next page.

Double Star Measures Using a DSLR Camera #6

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Img
20299+4022	HJ 1525AC	9.13	13.5	38.74		16.78		2009.909	1	138	
20311+3652	SEI1148	12.19	12.9	280.94	0.11	24.62	0.07	2009.909	7	139	
20313+3654	TOB 188	11.8	12.8	261.70	0.15	16.54	0.09	2009.909	5	140	
20317+3831	ES 246AB	10.92	13.4					2009.909		141	
20317+3831	ES 246AC	10.92	12.4	353.56	0.24	10.03	0.05	2009.909	8	142	
20327+3916	SEI1160AB	8.20	10.38	50.85	0.15	14.51	0.05	2009.909	14	143	
20327+3916	SEI1159AC	8.20	10.2					2009.909		144	
20332+3910	SEI1165	9.34	10.8	4.28	0.30	10.81	0.06	2009.909	14	145	
20332+3324	SEI1162	8.89	10.40	91.12	0.11	20.59	0.04	2009.909	15	146	
20333+4119	HJ 1539AB	9.23	10.80	202.12	0.25	9.54	0.08	2009.909	15	147	
20333+4119	HJ 1539AC	9.23	11.8	51.84	0.27	18.32	0.06	2009.909	11	147	
20333+4119	ARN 77AD	9.23	10.14	120.72	0.09	38.16	0.03	2009.909	15	147	
20333+4119	ARN 77BD	10.80	10.14	106.32	0.06	37.92	0.03	2009.909	15	147	
20333+3323	HJ 1535AB	8.29	11.9	245.60	0.25	17.20	0.06	2009.909	7	148	
20333+3323	HJ 1535AC	8.29	11.9	191.79	0.03	30.43	0.09	2009.909	2	148	
20333+3323	HJ 1535AD	8.29	11.03	229.46	0.04	57.81	0.03	2009.909	15	148	
20335+3913	SEI1168	9.80	11.3	117.40	0.21	19.74	0.04	2009.909	15	149	
20340+3737	SEI1170	12.36	13.4	28.82	0.17	17.45	0.05	2009.909	10	150	
20349+4143	STU 13	7.57	10.13	195.68	0.21	27.27	0.08	2009.920	14	151	
20351+3914	MLB 777	11.0	11.1	185.37	0.29	6.09	0.01	2009.909	2	152	
20355+3749	SEI1184	10.59	11.98	35.96	0.28	27.23	0.05	2009.909	9	153	
20357+3747	TOB 190	9.8	12.6	68.68	0.20	17.78	0.09	2009.909	4	154	
20362+3737	SEI1188AB	10.64	11.29	78.20	0.13	15.49	0.04	2009.909	13	155	
20362+3737	SEI1187BC	9.0	11.0	272.40	0.22	22.74	0.05	2009.909	7	155	
20362+3737	TOB 191BD	11.9	12.7	134.74	0.07	37.38	0.06	2009.909	9	155	
20363+3854	MLB 953	11.70	12.2	6.12		6.10		2009.909	1	156	
20383+3814	SEI1202	11.0	11.0					2009.909		157	
20390+3804	SEI1204	11.0	11.0	294.79	0.30	7.80	0.09	2009.909	3	158	5
20391+3759	SEI1208	10.58	11.8	10.46	0.33	7.41	0.08	2009.909	5	159	
20411+2322	Anon 45	12.0	13.5	210.44	0.29	7.39	0.06	2009.901	12	160	
20411+2321	POU4864AB	12.20	15.0	212.51	0.20	13.78	0.04	2009.901	18	161	
20411+2321	Anon 46Bx	15.0	14.0	300.73	0.32	10.47	0.05	2009.901	8	162	
20412+2322	POU4866	14.3	14.4	38.82	0.24	10.17	0.05	2009.901	11	163	
20415+2318	Anon 47	12.0	13.8	239.84	0.23	10.72	0.05	2009.901	18	164	
20415+2317	Anon 48	13.8	13.8	32.80	0.31	8.73	0.07	2009.901	5	165	
20416+2323	POU4871	13.5	13.6	68.51	0.11	15.46	0.06	2009.901	18	166	
20417+2318	Anon 49	13.0	13.5	345.75	0.24	8.10	0.06	2009.901	16	167	
20418+2321	Anon 50	13.9	14.2	76.80	0.25	7.74	0.03	2009.901	6	168	
20418+2317	Anon 51	11.0	13.0	262.06	0.25	9.87	0.06	2009.901	10	169	
20420+2317	POU4884AB	12.58	13.3	286.81	0.18	6.43	0.03	2009.901	16	170	
20420+2317	POU4885AC	12.58	13.5	227.32	0.10	20.19	0.04	2009.901	18	170	
20420+2317	Anon 52Ax	12.58	14.0	12.16	0.31	15.06	0.05	2009.901	11	170	
20420+2317	Anon 52Ay	12.58	13.8	95.27	0.12	22.32	0.03	2009.901	18	170	
20421+2319	Anon 53AB	12.5	13.5	299.07	0.29	4.76	0.04	2009.901	3	171	
20421+2319	Anon 53AC	12.5	13.0	344.76	0.22	9.59	0.06	2009.901	15	171	

Table continues on next page.

Double Star Measures Using a DSLR Camera #6

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Img
20423+2352	POU4893	11.09	14.3	248.21	0.17	14.83	0.05	2009.901	11	172	
20425+2352	Anon 54	14.0	14.0	311.50	0.12	9.01	0.03	2009.901	4	10	
20425+2350	POU4900	13.5	14.4	3.73	0.32	10.63	0.04	2009.901	13	173	
20427+2355	POU4907AB	11.77	11.76	220.04	0.30	5.73	0.05	2009.901	13	174	
20427+2355	POU4906AC	11.77	13.79	159.48	0.19	12.10	0.04	2009.901	15	175	
20429+2356	Anon 55	12.5	13.6	311.50	0.18	9.05	0.05	2009.901	3	176	
20430+2421	POU4910	12.3	12.4	114.07	0.10	16.01	0.03	2009.901	16	177	
20432+2353	POU4912AB	13.0	13.1	27.84	0.10	16.28	0.04	2009.901	16	178	
20432+2353	Anon 56Bx	13.1	14.0	77.51	0.27	6.63	0.04	2009.901	3	178	
20432+2349	POU4913	10.46	15.3	26.97	0.22	18.14	0.06	2009.901	9	179	
20435+2420	Anon 57	12.0	13.6	346.49	0.32	10.42	0.05	2009.901	16	180	
20435+2415	POU4922	12.00	10.90	190.59	0.09	18.63	0.05	2009.901	12	181	
20436+2420	BRT2481	10.99	11.1					2009.901		182	
20439+2416	POU4928	12.8	14.3	208.67	0.25	8.61	0.04	2009.901	13	183	
20445+2420	Anon 58	12.5	13.5	69.14		4.11		2009.901	1	184	
20445+2402	POU4935	13.9	14.4	79.19	0.21	2.84	0.08	2009.901	5	185	
20445+2356	STF2724	8.97	9.00	150.98	0.29	2.07	0.12	2009.901	3	186	
20446+2423	POU4936	11.4	12.3	256.85	0.24	9.46	0.03	2009.901	16	187	6
20446+2423	Anon 59	13.0	13.2	62.76	0.37	4.78	0.09	2009.901	2	188	6
20446+2403	Anon 60	12.5	13.5	130.27		3.85		2009.901	1	189	
20446+2358	POU4941	13.9	14.4	328.43	0.27	9.73	0.04	2009.901	17	190	
20447+2424	POU4943	13.4	13.6	295.50	0.31	11.65	0.03	2009.901	10	191	6
20447+2356	Anon 61	13.5	14.0	13.46	0.25	11.39	0.02	2009.901	3	192	
20450+2423	POU4950	12.0	12.2	137.31	0.11	13.91	0.03	2009.901	14	193	
20450+2356	POU4949	12.50	13.44	271.67	0.24	13.48	0.08	2009.901	16	194	
20451+2414	POU4967	13.7	14.0					2009.901		195	
20459+2344	POU4962	13.4	13.7	0.26	0.43	2.95	0.02	2009.901	5	196	
20460+2349	POU4965	14.5	14.5	113.80	0.32	7.69	0.05	2009.901	5	197	
20460+2343	POU4963AB	13.7	13.9	297.60	0.22	7.82	0.06	2009.901	15	198	
20460+2343	Anon 62Bx	13.9	14.5	220.52	0.10	4.11	0.01	2009.901	2	198	
20461+2358	POU4970	14.5	14.5	1.88	0.22	14.69	0.06	2009.901	12	199	
20461+2354	POU4969	13.4	13.8	146.36	0.18	18.53	0.03	2009.901	14	200	
20462+2358	POU4971	9.53	13.3	74.12	0.21	13.28	0.05	2009.901	14	201	
20463+2343	POU4973	14.3	14.5	331.64	0.29	4.06	0.05	2009.901	10	202	
20465+2403	POU4975	12.14	14.8	159.40	0.25	18.53	0.07	2009.901	11	203	
20469+2342	POU4983	11.53	14.1	245.04	0.19	16.20	0.06	2009.901	14	204	
20471+2343	POU4984	12.4	14.1	154.34	0.24	9.67	0.07	2009.901	10	205	
20471+2341	POU4985	12.25	14.2	110.13	0.08	16.26	0.03	2009.901	16	206	
20475+2342	Anon 63	13.0	14.0	127.77	0.20	6.55	0.07	2009.901	9	207	
20476+2518	POU4996	12.27	14.3	126.84	0.20	12.30	0.05	2009.884	15	208	
20476+2339	POU4993	13.3	13.5	114.26		3.23		2009.901	1	209	
20476+2322	Anon 64	13.6	14.0	314.80	0.24	9.63	0.07	2009.901	11	210	
20477+2339	POU4997AB	12.4	14.2	194.89	0.25	12.29	0.04	2009.901	10	211	
20477+2339	Anon 65Ax	12.4	12.5	235.40	0.77	1.66	0.01	2009.901	2	211	
20478+2519	BUP 218AB	11.27	11.29	36.73	0.03	49.48	0.01	2009.884	15	212	

Table continues on next page.

Double Star Measures Using a DSLR Camera #6

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Img
20478+2519	BUP 218AC	11.27	11.2	142.78	0.22	5.74	0.02	2009.884	2	213	
20478+2519	BUP 218AD	11.27	10.78	252.49	0.01	154.66	0.02	2009.884	15	214	
20478+2320	POU4999	12.23	13.2	125.73	0.07	21.28	0.04	2009.901	14	215	
20479+2519	Anon 66	13.4	13.5	177.43	0.26	9.26	0.05	2009.884	10	216	
20480+2428	Anon 67	13.7	13.9	148.97	0.31	8.25	0.05	2009.884	10	217	
20480+2321	Anon 68	13.9	14.1	208.35	0.26	9.74	0.04	2009.901	9	218	
20480+2319	POU5000	14.1	14.2	6.59	0.19	10.96	0.04	2009.901	15	219	
20482+2624	STF2728AB	7.92	10.38	25.93	0.25	10.36	0.04	2009.884	17	220	
20482+2624	STF2728AC	7.92	13.6	210.62	0.27	19.31	0.06	2009.884	6	220	
20483+2515	POU5004	13.4	13.2	325.25	0.14	15.04	0.06	2009.884	18	221	
20484+2426	Anon 69	13.5	13.5	264.07	0.26	8.81	0.03	2009.884	8	10	
20484+2422	POU5005	11.9	13.0	61.29	0.25	13.90	0.06	2009.884	13	222	
20485+2444	POU5007	14.5	14.6	155.86	0.33	3.62	0.04	2009.884	11	223	7
20486+2444	Anon 70	13.5	13.5	299.93	0.18	8.58	0.07	2009.884	17	224	7
20486+2428	POU5009AB	13.5	13.8	185.15	0.13	14.63	0.07	2009.884	5	10	
20486+2428	Anon 71Bx	13.8	14.0	224.75		1.98		2009.884	1	10	
20487+2507	Anon 72	13.0	14.0	59.62	0.22	7.49	0.06	2009.884	5	225	
20487+2442	Anon 73	13.5	14.0	275.23	0.31	3.85	0.03	2009.884	9	10	
20488+2449	POU5010	13.1	13.4	217.43	0.31	2.60	0.04	2009.884	6	226	7
20488+2446	POU5013	13.4	14.0	353.79	0.13	14.65	0.03	2009.884	17	10	7
20488+2427	POU5014	12.7	13.5	140.91	0.16	13.51	0.04	2009.884	16	227	
20490+2637	COU 828AC	10.66	13.3	96.34	0.16	25.59	0.05	2009.884	11	228	
20490+2504	Anon 74	11.0	14.0	315.60	0.33	8.84	0.04	2009.884	5	229	
20490+2439	POU5018	11.10	13.28	282.91	0.05	22.31	0.05	2009.884	16	230	
20491+2509	Anon 75	13.9	14.0	100.92	0.30	8.53	0.07	2009.884	7	231	
20491+2442	Anon 76	13.3	13.5	114.15	0.21	2.25	0.02	2009.884	2	232	
20492+2510	POU5021	12.0	13.4	359.70	0.14	5.75	0.02	2009.884	5	233	
20492+2504	POU5020	13.1	13.6	70.28	0.49	3.83	0.07	2009.884	2	10	
20493+2440	Anon 77	11.3	13.0	350.88	0.11	4.56	0.05	2009.884	2	234	
20494+2405	POU5022	13.4	13.6	45.07	0.30	10.62	0.09	2009.884	10	10	
20494+2359	POU5023	13.0	13.2	291.03	0.22	13.34	0.05	2009.884	13	235	
20496+2444	POU5027	11.4	13.6	179.12	0.17	14.43	0.03	2009.884	16	236	
20496+2404	POU5026	11.94	13.9	92.65	0.15	17.01	0.04	2009.884	15	237	8
20497+2507	Anon 78	13.1	13.5	275.72	0.24	9.71	0.07	2009.884	7	238	
20497+2358	Anon 79	13.5	13.7	299.71	0.19	9.73	0.04	2009.884	4	10	
20499+2510	POU5029	12.15	13.53	19.75	0.15	12.53	0.04	2009.884	16	239	9
20499+2508	POU5030	12.2	12.4	345.58	0.34	4.03	0.05	2009.884	11	240	9
20499+2456	Anon 80	13.3	13.5	237.65	0.22	8.26	0.03	2009.884	6	241	
20499+2454	POU5035	12.8	13.4	54.37	0.32	9.60	0.05	2009.884	12	242	
20499+2412	POU5031AB	11.74	11.88	318.49		17.72		2009.884	1	243	
20499+2412	POU5032AC	11.74	12.3	310.83		16.47		2009.884	1	243	
20499+2408	Anon 81	13.5	13.9	266.84		11.81		2009.884	1	10	
20499+2407	Anon 82	12.1	13.9	93.34	0.21	11.61	0.06	2009.884	14	244	
20499+2402	POU5034	13.65	13.8	127.43	0.27	4.40	0.06	2009.884	5	245	8
20499+2401	Anon 83	13.5	13.5	290.26	0.22	11.34	0.06	2009.884	8	246	8

Table continues on next page.

Double Star Measures Using a DSLR Camera #6

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Img
20500+2508	Anon 84	13.5	14.0	256.52	0.27	12.59	0.08	2009.884	9	10	
20500+2412	Anon 85	13.5	13.6	146.34		5.62		2009.884	1	247	
20501+2512	POU5038	12.15	13.7	342.31	0.06	16.55	0.04	2009.884	3	248	9
20503+2518	POU5040	10.45	12.4	290.65	0.06	18.34	0.04	2009.884	17	249	
20503+2507	POU5039	11.1	13.5	84.37	0.18	10.68	0.05	2009.884	14	250	9
20506+2512	POU5041	12.5	12.7	176.96	0.23	14.52	0.06	2009.884	16	251	
20507+2527	POU5042	12.00	12.4	344.25	0.21	7.36	0.04	2009.884	13	252	
20507+2525	Anon 86	13.5	14.0	66.61	0.32	7.91	0.08	2009.884	8	253	
20510+2320	POU5043	11.02	12.5	157.91		5.07		2009.901	1	254	
20513+2426	Anon 87	12.2	13.5	269.55	0.02	5.14	0.07	2009.884	2	255	
20514+2329	POU5047	13.5	13.6	145.24	0.29	6.97	0.06	2009.901	7	256	
20514+2326	POU5046	12.4	13.6	268.36		3.41		2009.901	1	257	
20515+2444	POU5048AB	10.85	11.0	303.74	0.18	8.42	0.02	2009.884	16	258	
20515+2444	Anon 88Bx	11.0	13.0	226.75		7.30		2009.884	1	258	
20516+2440	Anon 89	12.5	12.5	157.65	0.24	5.20	0.05	2009.884	11	259	
20516+2429	POU5049	11.61	13.9	107.00	0.06	14.95	0.03	2009.884	14	260	
20516+2426	Anon 90	13.2	13.5	219.99	0.35	6.20	0.07	2009.884	4	10	
20517+2323	Anon 91	13.5	13.6	79.81		2.22		2009.901	1	10	
20522+2353	POU5051	11.8	11.9	349.67	0.18	6.49	0.03	2009.901	15	261	
20523+2352	Anon 92	13.5	13.5	308.63	0.24	4.38	0.03	2009.901	7	262	
20526+2353	Anon 93	13.6	13.6	8.44	0.24	8.98	0.05	2009.901	10	263	
21110+2353	POU5224	12.61	14.8	32.07		15.86		2009.882	1	264	
21110+2345	Anon 94	12.0	13.0	16.18	0.34	4.29	0.02	2009.882	2	265	
21112+2353	POU5227	11.90	14.6	323.91	0.18	14.93	0.05	2009.882	16	266	
21112+2351	Anon 95	12.4	14.5	89.71	0.23	13.91	0.04	2009.882	12	267	
21112+2347	POU5228	12.3	14.0	238.95	0.16	17.40	0.08	2009.882	13	268	10
21113+2349	POU5230	14.1	14.4	21.42	0.16	11.01	0.04	2009.882	6	269	10
21114+2348	POU5232	11.5	12.8	143.15	0.07	17.74	0.03	2009.882	16	270	10
21118+2348	POU5240	13.5	14.2	43.11	0.34	8.12	0.05	2009.882	3	271	
21122+2556	SLE 368	11.18	13.0	267.61	0.30	13.20	0.07	2009.882	7	272	
21124+2333	POU5247	13.8	14.0	21.84	0.21	14.16	0.06	2009.882	8	273	
21125+2619	STF2774AB	8.55	10.6	335.84	0.11	27.25	0.05	2009.884	15	274	
21125+2619	SLE 369AC	8.55	12.9	337.86	0.07	51.66	0.06	2009.884	15	275	
21128+2516	POU5251	11.2	13.8	302.85	0.11	18.26	0.04	2009.882	17	276	
21129+2457	POU5257	12.4	13.8	157.09		14.87		2009.882	1	277	
21129+2330	POU5252AB	11.24	12.8	226.75	0.23	13.24	0.04	2009.882	16	278	
21129+2330	POU5253AC	11.24	13.0	207.45	0.21	17.14	0.04	2009.882	16	278	
21129+2330	POU5254AD	11.24	13.2	217.89	0.06	30.86	0.04	2009.882	16	278	
21129+2330	Anon 96Ax	11.24	14.0	141.95		6.99		2009.882	1	278	
21129+2329	Anon 97	11.19	13.7	114.49	0.09	42.60	0.03	2009.882	16	279	
21130+2513	POU5260	11.30	11.9	193.36	0.22	6.54	0.02	2009.882	16	280	
21132+2503	POU5263	12.2	12.3	298.88		1.37		2009.882	1	281	
21133+2515	POU5265	12.5	13.7	34.02	0.15	21.04	0.04	2009.882	10	282	
21133+2501	POU5266	13.8	13.9	328.80	0.13	12.20	0.05	2009.882	9	10	
21134+2457	POU5267	14.0	14.1	113.24	0.06	6.06	0.05	2009.882	2	283	

Table continues on next page.

Double Star Measures Using a DSLR Camera #6

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Img
21135+2512	POU5269	11.4	11.6	269.58	0.26	4.29	0.06	2009.882	10	284	
21136+2508	Anon 98	14.7	14.8	286.96		5.51		2009.882	1	285	
21136+2503	POU5272	12.7	13.4	37.60	0.23	7.59	0.05	2009.882	8	286	
21137+2510	POU5273	10.24	13.6					2009.882		287	
21138+2333	POU5274	13.3	13.4	323.69	0.09	17.51	0.04	2009.882	16	288	
21138+2329	Anon 99	14.7	14.0	14.39	0.03	8.05	0.03	2009.882	3	289	
21139+2512	POU5276	11.28	13.9	110.62	0.26	5.52	0.05	2009.882	3	290	
21139+2329	Anon100	15.0	15.0	189.82	0.18	9.07	0.01	2009.882	2	291	
21143+2522	POU5283AB	10.0	11.0	85.90	0.07	15.99	0.03	2009.882	12	292	
21143+2522	POU5284AC	10.0	12.4					2009.882		293	
21143+2519	POU5286	11.94	13.2	159.47	0.18	18.10	0.07	2009.882	17	294	
21143+2333	POU5282	12.81	13.5	358.91	0.22	7.39	0.03	2009.882	13	295	
21145+2523	Anon101	13.1	14.0	117.35	0.26	9.60	0.06	2009.882	2	296	
21153+2527	SLE 375	11.35	13.1					2009.882		297	
21160+2524	POU5301	12.9	13.0	61.85	0.36	10.00	0.08	2009.882	7	298	
21170+2452	POU5310	10.37	12.4	12.75	0.18	15.07	0.04	2009.884	15	299	
21174+2445	POU5313	12.23	13.2	314.86	0.12	15.34	0.03	2009.884	17	300	
21174+2332	POU5314	11.53	11.8	125.48	0.09	17.23	0.02	2009.884	15	301	
21174+2330	POU5312	12.72	14.3	292.81		4.10		2009.884	1	302	
21176+2556	SLE 380	12.01	12.9	272.79	0.28	10.89	0.06	2009.884	13	303	
21176+2453	POU5317	12.4	14.0	336.95		14.63		2009.884	1	304	
21177+2449	POU5318AB	10.60	12.9	231.69	0.19	8.76	0.04	2009.884	16	305	
21177+2449	POU5319AC	10.60	14.4	154.46	0.30	17.04	0.07	2009.884	16	305	
21178+2449	POU5320	10.60	11.8					2009.884		306	
21185+2428	POU5327	12.12	13.7	248.28	0.24	20.01	0.05	2009.884	15	307	
21190+2423	POU5331	11.75	13.4	233.06	0.29	11.75	0.05	2009.884	12	308	
21194+2513	POU5332AB	12.86	13.1	53.81	0.26	9.40	0.04	2009.884	9	309	
21194+2513	POU5333AC	12.86	14.6	191.46	0.46	9.60	0.10	2009.884	2	309	
21198+2435	Anon102	14.4	14.5	89.07		5.79		2009.901	1	310	
21199+2432	POU5337	12.0	13.6	191.01	0.24	10.87	0.05	2009.901	8	311	
21200+2440	POU5338	12.66	13.9	267.77	0.32	11.61	0.03	2009.901	8	312	
21203+2453	POU5341	11.67	14.1	73.08	0.11	14.43	0.03	2009.901	11	313	
21205+2448	Anon103	14.5	14.5	9.21		2.55		2009.901	1	314	
21209+2426	POU5343	13.6	13.9	137.58	0.32	6.67	0.09	2009.901	4	315	
21210+2435	POU5347	12.49	13.2	19.41	0.10	17.87	0.01	2009.901	2	316	
21210+2428	POU5345	13.4	14.0	263.89	0.29	4.06	0.04	2009.901	8	317	
21216+2344	POU5350	11.2	12.9	342.75	0.27	11.51	0.07	2009.901	8	318	
21217+2420	POU5351	12.09	12.7	145.01	0.11	17.29	0.05	2009.901	16	319	
21218+2241	HLM 40	10.7	11.0					2009.901		320	
21220+2350	COU 132	8.85	10.33	201.04	0.19	13.34	0.04	2009.901	12	321	
21229+2346	POU5355	13.2	13.3	12.41	0.29	14.04	0.06	2009.901	11	322	
21237+2519	Anon104	11.5	12.5	252.77		4.85		2009.901	1	323	
21240+2416	HJ 1641	5.71	10.5	301.88	0.09	61.52	0.05	2009.901	5	324	
21240+2352	J 3137	11.2	11.5	238.98	0.26	7.24	0.06	2009.901	10	325	11
21241+2519	BU 447AB	6.20	12.2	313.92	0.38	9.24	0.05	2009.901	7	326	

Table continues on next page.

Double Star Measures Using a DSLR Camera #6

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Img
21241+2519	BU 447AC	6.20	11.7	191.41	0.07	57.80	0.06	2009.901	12	326	
21241+2519	BU 447AD	6.20	11.8	83.85	0.08	46.88	0.06	2009.901	11	327	
21241+2519	BU 447AE	6.20	10.96	115.74	0.06	66.59	0.06	2009.901	13	326	
21241+2519	BU 447AF	6.20	10.7	217.27	0.05	83.17	0.06	2009.901	13	326	
21490+2456	POU5512AB	12.35	12.9	5.05	0.26	11.41	0.05	2009.901	10	328	
21490+2456	POU5513AC	12.35	13.76	66.92	0.27	11.32	0.06	2009.901	11	328	
21494+2509	POU5517	12.5	12.6	233.02	0.30	6.43	0.06	2009.909	3	329	
21495+2458	POU5519	13.7	13.9	250.33	0.10	8.07	0.01	2009.901	2	330	
21495+2334	BU 1306AB	8.43	13.2	301.85	0.25	31.04	0.07	2009.901	14	331	
21495+2334	BU 1306A-CD	8.43	13.0	271.53	0.21	34.53	0.06	2009.901	11	331	
21495+2334	POU5518B-CD	13.2	13.0	208.04	0.12	17.54	0.08	2009.901	7	332	
21495+2334	BU 1306CD	13.6	14.0					2009.901		333	
21496+2431	POU5520	11.76	12.4	307.31	0.19	19.20	0.05	2009.901	12	334	
21498+2503	POU5521	13.0	13.2	75.48	0.21	15.51	0.07	2009.909	7	335	
21500+2437	POU5522	12.7	13.8	137.63	0.32	4.22	0.09	2009.901	3	336	
21501+2433	GRV 512	10.9	13.1	190.84	0.04	69.06	0.06	2009.901	15	337	
21504+2519	POU5524AB	12.4	13.6	126.58	0.07	14.24	0.08	2009.909	2	338	
21504+2519	POU5525AC	12.4	13.8	302.19	0.16	15.69	0.06	2009.909	2	338	
21506+2447	POU5527AB	12.10	13.8	97.29	0.17	8.01	0.04	2009.909	4	339	
21506+2447	POU5528AC	12.10	13.9	157.70	0.38	8.98	0.01	2009.909	5	339	
21507+2449	POU5529	13.9	14.0	19.39	0.28	9.03	0.09	2009.909	6	340	
21507+2422	POU5530	10.44	11.95	50.04	0.05	35.20	0.06	2009.901	14	341	
21508+2451	POU5532	12.1	13.7	322.83	0.30	9.16	0.05	2009.909	7	342	
21510+2437	GRV 514	11.9	13.0	115.01	0.22	42.93	0.07	2009.909	9	343	
21510+2420	POU5533	13.2	13.7	234.17	0.27	10.62	0.07	2009.901	7	344	
21516+2434	POU5537	11.69	14.6	95.51	0.21	18.36	0.06	2009.909	14	345	
21517+2437	POU5538	10.93	12.1	277.79	0.32	6.63	0.05	2009.909	16	346	
21524+2348	POU5540	12.1	13.7	283.53	0.26	11.15	0.06	2009.926	16	347	
21529+2354	POU5545	10.26	12.4	124.40	0.17	19.13	0.03	2009.926	13	348	
21535+2347	POU5550	10.49	13.2	125.10	0.26	9.49	0.03	2009.926	11	349	
21556+2406	POU5572	12.7	13.3	277.36	0.24	20.29	0.04	2009.926	10	350	
21565+2613	ES 526	9.25	13.4	98.21	0.33	10.01	0.03	2009.920	7	351	
21568+2357	POU5580	12.13	14.0	140.81	0.25	15.02	0.05	2009.926	12	352	
21571+2509	POU5582	12.9	13.3	338.09	0.25	7.74	0.04	2009.926	7	353	
21572+2457	POU5583	12.6	13.2	15.55	0.24	13.64	0.05	2009.926	4	354	
21574+2458	POU5587	11.8	13.1	329.65	0.21	12.95	0.06	2009.926	10	355	
21574+2354	POU5585	12.7	13.3	73.58		5.42		2009.926	1	356	
21575+2457	POU5588	12.6	13.3	11.51	0.21	5.44	0.01	2009.926	2	357	
21576+2440	POU5589	11.9	13.1	26.18	0.31	13.09	0.07	2009.926	6	358	
21578+2437	POU5590	11.12	13.2	136.39	0.28	10.25	0.04	2009.926	10	359	
21582+2507	POU5591	11.7	13.3	323.65	0.17	14.71	0.04	2009.926	13	360	
21583+2440	POU5592	11.6	12.9	99.26	0.23	9.21	0.05	2009.926	14	361	
21584+2510	POU5593	12.39	13.6	325.24		4.64		2009.926	1	362	
22049+2158	GAU 18	11.29	11.83	132.05	0.03	53.68	0.04	2009.926	16	363	
22052+2158	HJ 3088	9.46	12.98	193.54	0.19	23.33	0.03	2009.926	16	364	

Table concludes on next page.

Double Star Measures Using a DSLR Camera #6

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Img
22053+2156	HJ 3089	9.1	13.43	110.78	0.11	22.02	0.06	2009.926	16	365	
22063+2423	POU5636	11.54	14.3	42.98	0.17	18.57	0.06	2009.874	15	366	
22066+2427	POU5638	10.16	13.68	164.59	0.28	18.40	0.08	2009.874	8	367	
22077+2421	POU5641	11.2	13.3	238.65		6.47		2009.874	1	368	
22081+2419	POU5643	13.1	13.3	284.82	0.28	3.85	0.08	2009.874	9	369	12
22082+2418	GRV 541	8.4	13.6	269.00	0.07	45.48	0.06	2009.874	14	370	12
22082+2416	Anon105	10.2	13.5	151.17	0.23	9.47	0.05	2009.874	11	371	12
22084+2525	POU5644	11.5	13.8	321.89	0.24	16.16	0.03	2009.874	15	372	
22087+2342	Anon106	13.0	13.2	316.34	0.31	9.32	0.04	2009.884	8	373	
22089+2347	POU5646	11.68	13.0	119.50	0.27	3.41	0.03	2009.884	2	374	
22090+2518	POU5647	9.92	13.5	114.07	0.18	22.22	0.08	2009.874	9	375	
22092+2510	POU5648	12.3	13.9	210.97	0.38	9.24	0.08	2009.874	6	376	
22096+2425	POU5650	13.4	13.6	293.65	0.15	16.43	0.08	2009.874	5	377	
22102+2418	POU5653	11.94	12.54	310.41	0.09	21.71	0.06	2009.874	11	378	
22105+2421	POU5655	13.4	13.8	223.52	0.13	13.71	0.05	2009.874	15	379	
22106+2342	POU5656	14.10	13.95	280.18	0.29	8.44	0.05	2009.926	11	380	
22109+2417	POU5657	12.1	13.8	325.56	0.13	11.89	0.03	2009.874	13	381	
22112+2359	POU5658	11.8	11.9	17.89	0.13	9.25	0.03	2009.884	17	382	
22112+2335	ARY 63	9.68	10.14	188.75	0.03	93.19	0.07	2009.874	13	383	
22113+2353	CBL 100	13.0	14.5	348.61	0.15	21.79	0.05	2009.884	17	384	
22115+2356	POU5659	12.01	13.67	92.06	0.11	13.29	0.05	2009.884	17	385	
22131+2351	HJ 1743	11.4	11.4	297.62	0.18	10.43	0.05	2009.874	15	386	
22132+2358	POU5667	11.7	13.1	232.12	0.22	3.95	0.02	2009.874	3	387	
22133+2352	HJ 1744	11.64	13.4	345.47	0.18	14.75	0.04	2009.874	15	388	
22134+2402	ARY 57	7.93	10.75	55.28	0.03	92.79	0.06	2009.874	9	389	

Table Notes

1. A=GSC 2154 374.
2. A=GSC 2154 1130 non star (20108+2314!).
3. AB=GSC 2154 1497 non star.

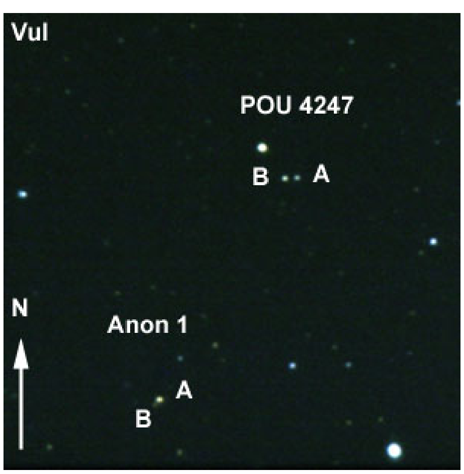


Figure 1: See Notes 2 and 3.

4. AB=GSC 2154 3324 non star.
5. AB=GSC 2154 3396 non star.
6. AB=GSC 2154 1371 non star.
7. A=GSC 2154 3310 non star.
8. A=GSC 2154 1205.
9. A=GSC 2154 3352.
10. Does not appear in GSC.
11. AB=GSC 2154 377 non star.
12. AB=GSC 2154 707 non star.
13. AB=GSC 2154 1010 non star.
14. AB=GSC 2154 356 non star.
15. AB=GSC 2154 1495 non star.
16. AB=GSC 2154 3278.
17. A=GSC 2154 2130.
18. AB=GSC 2154 650 non star.
19. A=GSC 2154 104.
20. A=GSC 2154 335.
21. AB=GSC 2154 912 non star.
22. AB=GSC 2154 1386 non star.
23. AB=GSC 2158 243 non star.

Double Star Measures Using a DSLR Camera #6

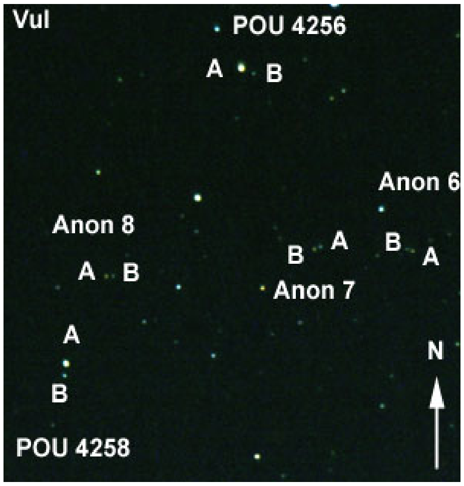


Figure 2: See notes 11 - 15.

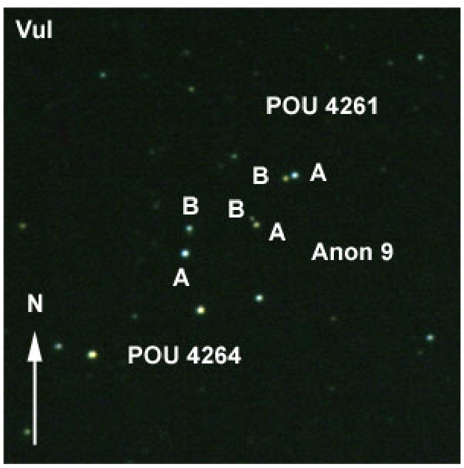


Figure 3: See notes 18 - 20.

24. AB=GSC 2154 68 blended object.
25. AB=GSC 2154 1194 non star.
26. A=GSC 2154 1014.
27. AB=GSC 2154 2368 non star.
28. A=GSC 2158 1903 (20123+2433!).
29. Ax=GSC 2154 1951 non star.
30. A=GSC 2158 1023. The proper motion in PA 10 direction of component A accounts for the changes of the measured parameters. This however is of small scale, therefore the 1900 measures could be PA302, in my opinion.
31. BC=GSC 2158 1438. The proper motion in PA 40 direction of components B and C accounts for the changes of the measured parameters. Cpm pair?
32. I cannot find component D. It cannot be identified in the DSS images, either.
33. BC=GSC 2158 1438.
34. AB=GSC 2158 1516.
35. Bxy=GSC 2154 1287 non star.
36. A=GSC 2158 369.
37. AB=GSC 2154 1742.
38. A=GSC 2154 2872.
39. AB=GSC 2158 1381 non star.
40. AB=GSC 2154 1236 non star. Uncertain measures.
41. AB=GSC 2154 1079.
42. AB=GSC 2154 1107 non star.
43. A=GSC 2154 1449. The proper motion in PA 210 direction of component B accounts for the changes of the measured parameters.
44. A=GSC 2154 2968.
45. A=GSC 2154 2884.
46. AB=GSC 2154 3468.
47. AC=GSC 2154 2942 non star.
48. A=GSC 2154 899 blended object.
49. A=GSC 2155 1877.
50. A=GSC 2154 1454 non star.
51. AB=GSC 2159 401 non star.
52. A=GSC 2155 1941.
53. AB=GSC 2159 339 non star.
54. AB=GSC 2159 807.
55. AB=GSC 2159 25 non star (20142+2447!).
56. AB=GSC 2155 1751 non star.
57. A=GSC 2155 1917 non star.
58. AB=GSC 2155 1217.
59. A=GSC 2155 1503.
60. A= J1165AB! (20145+2453!). Very different parameters. The images available do not show significant proper motion of the nearby stars.
61. A=GSC 2155 1215 non star.
62. AB=GSC 2155 703 non star.
63. A=GSC 2159 483.
64. A=GSC 2155 513.
65. A=GSC 2159 91.
66. AB=GSC 2159 941 (20145+2453!). Uncertain measures.
67. AB=GSC 2155 1295 non star.
68. AB=GSC 2155 1730 non star.
69. A=GSC 2155 1433 non star.
70. A=GSC 2155 1169.
71. A=GSC 2159 183 blended object.
72. A=GSC 2159 461.
73. AB=GSC 2159 2001 non star.
74. A=GSC 2159 2063 (20152+2432!).
75. A=GSC 2159 459.
76. AB=GSC 2159 619 non star.
77. AB=GSC 2159 129 non star.

Double Star Measures Using a DSLR Camera #6

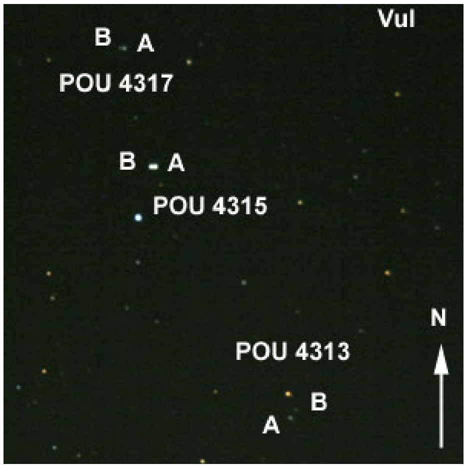


Figure 4: See notes 74, 76, 77.

78. A=GSC 2159 1379.
79. A=GSC 2159 655.
80. AB=GSC 2159 1311 non star.
81. AB=GSC 2159 1372 non star.
82. A=GSC 2159 919.
83. AB=GSC 2159 1497 non star (20162+2507!). Far from the indicated position (6').
84. A=GSC 2159 593.
85. AB=GSC 2159 1354 non star (20176+2509!).
86. A=GSC 3155 1860.
87. A=GSC 2684 951.
88. AB=GSC 2159 307 non star.
89. A=GSC 3155 1332.
90. A=GSC 2159 108. Very difficult to measure.
91. A=GSC 2159 108.
92. A=GSC 2159 317 (20183+2448!).
93. Does not appear in GSC. The proper motion in PA 200 direction of component A accounts for the changes of the measured parameters.
94. AB=GSC 2159 1524. According to DSS images, the members are getting closer. At present star-like, impossible to measure.
95. AB=GSC 2684 1827 non star.
96. A=GSC 2684 1415.
97. Does not appear in GSC. (20187+2504!). According to DSS images, the members are becoming more distant.
98. AB=GSC 2684 1779 non star.
99. AB=GSC 3155 242.
100. AB=GSC 2159 497. Cannot be measured.
101. AB=GSC 2159 497.
102. A=GSC 2159 725 (20192+2443!). The proper motion in PA 30 direction of component A accounts for the changes of the measured parameters.
103. A=GSC 2159 837.
104. A=GSC 2159 615.
105. A=GSC 2159 281 (20195+2452!). The proper motion in PA 40 direction of component B accounts for the changes of the measured parameters.
106. A=GSC 3151 3207.
107. A=GSC 3155 80 blended object. The proper motion in PA 200 direction of component B accounts for the changes of the measured parameters.
108. AB=GSC 3155 298.
109. A=GSC 3155 348. I cannot find component B. It cannot be identified in the DSS images, either. In my opinion, it is the same as SEI 1086.
110. AB=GSC 2159 121 non star.
111. AB=GSC 3156 2170 (20205+4000!).
112. A=GSC 2159 1513.
113. A=GSC 3160 391.
114. A=GSC 2159 1505 (20206+2502!).
115. A=GSC 2159 901.
116. A=GSC 2159 1092 (20212+2514!).
117. AB=GSC 2159 147 non star.
118. AB=GSC 2159 635 non star.
119. A=GSC 3152 1159.
120. A=GSC 2159 1219.
121. AB=GSC 2159 1251 non star.
122. A=GSC 3152 1261.
123. AB=GSC 2159 1211 non star.
124. AB=GSC 3152 1059 non star.
125. A=GSC 3152 624 blended object.
126. It is the same as POU 4450, but with a difference of 180 degrees. I cannot find any other double.
127. AB=GSC 2693 181 (20243+3517!).
128. A=GSC 2160 1144.
129. AB=GSC 2160 1219 non star (20243+2446!).
130. A=GSC 2693 421 I cannot find component B. It cannot be identified in the DSS images, either.
131. A=GSC 2160 300.
132. A=GSC 2693 562.
133. AB=GSC 2693 445 non star.)20251+3521!).
134. A=GSC 2693 924.
135. AB=GSC 2160 1203 non star.
136. A=GSC 3152 824 1.
137. I cannot find such double in the vicinity. It cannot be identified in the DSS images, either. The images available do not showsignificant proper motion of the nearby stars.
138. A=GSC 3156 1942 1.

Double Star Measures Using a DSLR Camera #6

139. A=GSC 2697 1159.
140. A=GSC 2697 1353.
141. A=GSC 3153 1233 I cannot find component B. It cannot be identified in the DSS images, either. It may have got too close to component C.
142. A=GSC 3153 1233
143. A=GSC 3153 1235.
144. I cannot find component C. It cannot be identified in the DSS images, either.
145. A=GSC 3153 317.
146. A=GSC 2690 774.
147. A=GSC 3161 1325 1.
148. A=GSC 2690 833. The proper motion in PA 40 direction of components A and B accounts for the changes of the measured parameters. Cpm pair?
149. A=GSC 3153 289.
150. A=GSC 3153 340 non star.
151. A=GSC 3161 880.
152. AB=GSC 3153 239 non star (20351+3913!).
153. A=GSC 3153 56.
154. A=GSC 3153 112.
155. A=GSC 3153 890.
156. AB=GSC 3153 677 non star.
157. I cannot find such double in the vicinity. It cannot be identified in the DSS images, either. The images available do not show significant proper motion of the nearby stars.
158. AB=GSC 3153 674 non star (20392+3805!). The proper motion in PA 700 direction of component A accounts for the changes of the measured parameters. B are brightness star.

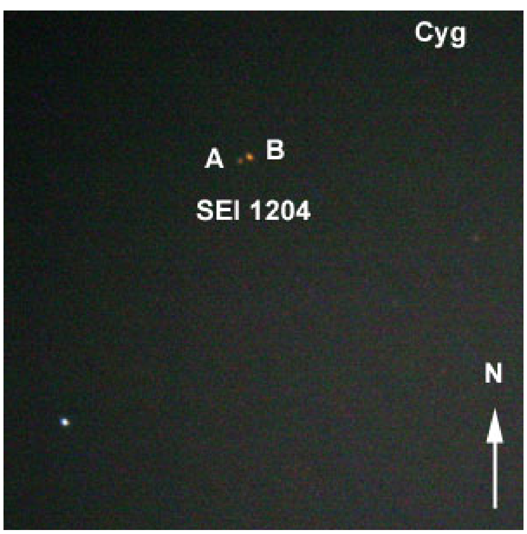


Figure 5: See note 158.

159. A=GSC 3153 86.
160. AB=GSC 2170 307 non star.
161. A=GSC 2170 69.
162. B=GSC 2170 372 non star (13,3m).
163. A=GSC 2170 19 non star.
164. A=GSC 2170 193.
165. A=GSC 2170 2039 non star.
166. A=GSC 2170 1897.
167. AB=GSC 2170 137 non star.
168. A=GSC 2170 2011.
169. AB=GSC 2170 321 non star.
170. AB=GSC 2170 163 non star.
171. AB=GSC 2170 711 non star.
172. A=GSC 2170 1411 (20423+2353!).
173. A=GSC 2170 621 non star.
174. AB=GSC 2170 1856 non star (20426+2354!). PA136 value might have been a typo in earlier WDS. The images available do not show significant proper motion.
175. AB=GSC 2170 1856 non star.
176. AB=GSC 2170 1616 non star.
177. A=GSC 2170 625 non star (20429+2421!).
178. A=GSC 2170 714 (20431+2353!).
179. A=GSC 2170 783 (20432+2348!).
180. A=GSC 2170 1376 non star.
181. A=GSC 2170 716.
182. I cannot find a double for these data. The images available do not show significant proper motion of the nearby stars. In my opinion, it is the same as POU 4928.
183. AB=GSC 2170 1808 non star.
184. AB=GSC 2170 514 non star.
185. AB=GSC 2170 1452 non star.

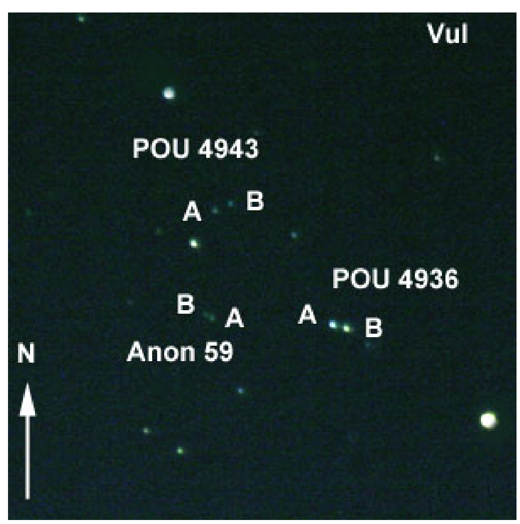


Figure 6: See notes 187, 188, 191.

Double Star Measures Using a DSLR Camera #6

186. A=GSC 2170 1648 1.
187. AB=GSC 2174 2220 non star (20445+2423!).
188. AB=GSC 2174 1534 non star.
189. AB=GSC 2170 1328 non star.
190. A=GSC 2170 1396 non star.
191. A=GSC 2174 2330 (20446+2424!).
192. A=GSC 2170 1634.
193. A=GSC 2174 575 non star.
194. A=GSC 2170 1682 (20449+2355!).
195. I cannot find such double in the vicinity. It cannot be identified in the DSS images, either. The images available do not show significant proper motion of the nearby stars.
196. AB=GSC 2170 1905.
197. AB=GSC 2170 1511 non star.
198. ABx=GSC 2170 537 non star.
199. B=GSC 2170 1582 non star (20461+2359!).
200. A=GSC 2170 630.
201. A=GSC 2170 1488.
202. AB=GSC 2170 2430 non star.
203. A=GSC 2170 1258.
204. A=GSC 2170 1513.
205. A=GSC 2170 1231 non star.
206. A=GSC 2170 1393.
207. AB=GSC 2171 912 non star.
208. A=GSC 2175 1403 non star = BUP 218D.
209. AB=GSC 2171 116.
210. A=GSC 2171 300 non star.
211. Ax=GSC 2171 34 non star.
212. A=GSC 2175 1431.
213. Actually this is BUP 218BC! I measured it accordingly.
214. A=GSC 2175 1431.
215. A=GSC 2171 20.
216. A=GSC 2175 1215 non star.
217. A=GSC 2175 246 non star.
218. A=GSC 2171 818 non star.
219. A=GSC 2171 1367.
220. A=GSC 2179 1370.
221. A=GSC 2175 1551. The proper motion in PA 80 direction of component A accounts for the changes of the measured parameters.
222. A=GSC 2171 371 (20487+2420!). Mirror image? I cannot find any other double. The images available do not show significant proper motion of the nearby stars.
223. AB=GSC 2175 1731 non star.
224. AB=GSC 2175 1826 non star.

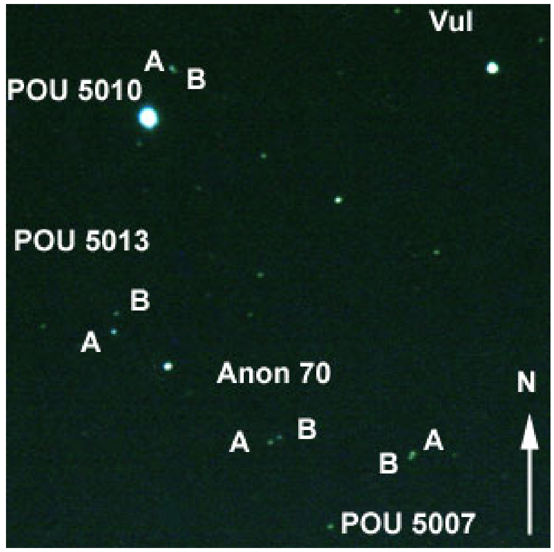


Figure 7: See notes 223, 224, 226, 10.

225. AB=GSC 2175 1863 non star.
226. AB=GSC 2175 1560 (20487+2449!).
227. A=GSC 2175 738 non star.
228. AB=GSC 2179 1668. The proper motion in PA 100 direction of component C accounts for the changes of the measured parameters.
229. AB=GSC 2175 1883 non star.
230. A=GSC 2175 6. The proper motion in PA 50 direction of component A accounts for the changes of the measured parameters. In my opinion the 1999' measure are correct in earlier WDS.
231. A=GSC 2175 1466 non star.
232. AB=GSC 2175 1824 non star.
233. AB=GSC 2175 1408 nonstar. The proper motion in PA 210 direction of component B accounts for the changes of the measured parameters.
234. AB=GSC 2175 1929.
235. A=GSC 2171 7.
236. A=GSC 2175 1792 non star (20496+2445!).
237. A=GSC 2171 199. The proper motion in PA 10 direction of component B accounts for the changes of the measured parameters.
238. A=GSC 2175 1041.
239. A=GSC 2175 1666 (20498+2510!).
240. AB=GSC 2175 1085 non star (20498+2509!).
241. A=GSC 2175 1144 non star.
242. AB=GSC 2175 1652 non star. The proper motion in PA 180 direction of component A accounts for the changes of the measured parameters.
243. A=GSC 2171 325 non star (20499+2413!).
244. A=GSC 2171 385 non star.
245. AB=GSC 2171 235 non star (20500+2402!).

Double Star Measures Using a DSLR Camera #6

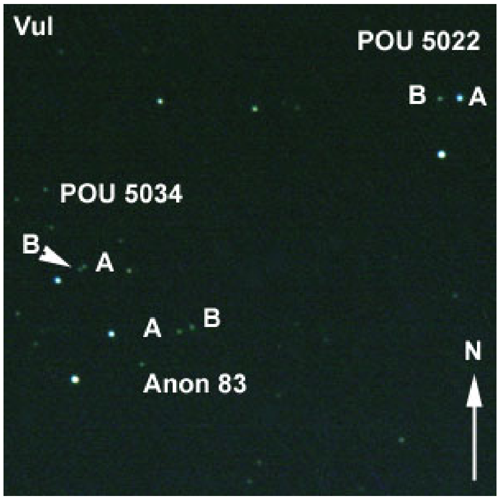


Figure 8: See notes 237, 245, 246.

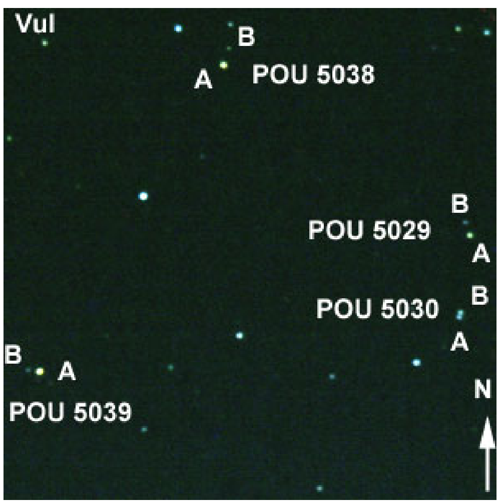


Figure 9: See notes 239, 240, 248, 249.

246. B=GSC 2171 49.
247. AB=GSC 2171 283 non star.
248. A=GSC 2175 965.
249. A=GSC 2175 1360 (20504+2518!).
250. A=GSC 2175 1689 non star (20503+2508!).
251. A=GSC 2175 1068 non star.
252. AB=GSC 2175 731 non star.
253. AB=GSC 2175 1052 non star.
254. AB=GSC 2171 424. The proper motion in PA 20 direction of component B accounts for the changes of the measured parameters.
255. AB=GSC 2175 309 non star. The proper motion in PA 200 direction of component A accounts for the changes of the measured parameters.
256. AB=GSC 2171 962 non star.
257. AB=GSC 2171 1638 non star (20514+2327!).
258. AB=GSC 2175 1867 non star.
259. AB=GSC 2175 1954 non star.
260. A=GSC 2175 45 non star. Mirror image? I cannot find any other double.
261. AB=GSC 2171 877 non star.
262. AB=GSC 2171 707 non star.

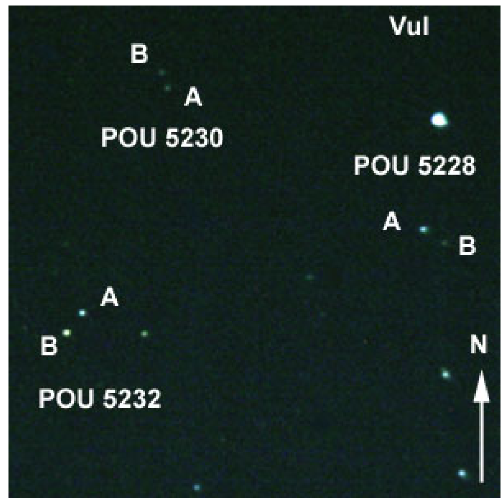


Figure 10: See notes 268 - 270.

263. A=GSC 2171 635 non star.
264. A=GSC 2173 1149 (21109+2353!).
265. AB=GSC 2173 1831 non star.
266. A=GSC 2173 1331 (21111+2352!).
267. A=GSC 2173 1758.
268. A=GSC 2173 1229 (21111+2347!).
269. A=GSC 2173 2239.
270. A=GSC 2173 1641 non star (21114+2346!).
271. AB=GSC 2173 1910 non star.
272. A=GSC 2177 2622 non star.
273. A=GSC 2173 1217 (21124+2332!).
274. A=GSC 2181 1268.
275. C=GSC 2181 1508. Could PA be a typo in WDS? I cannot find any other double.
276. A=GSC 2190 1825 (21128+2515!).
277. A=GSC 2190 1860.
278. Ax=GSC 2186 269.
279. A=GSC 2186 2248. The proper motion in PA 220 direction of components A and B accounts for the changes of the measured parameters. Cpm pair?
280. AB=GSC 2190 1600 non star.
281. AB=GSC 2190 2441. Uncertain measures.
282. A=GSC 2190 1206.
283. A=GSC 2190 2080 non star.

Double Star Measures Using a DSLR Camera #6

284. AB=GSC 2190 37 non star. The proper motion in PA 340 direction of component A accounts for the changes of the measured parameters.
285. A=GSC 2190 283 non star.The proper motion in PA 200 direction of component A accounts for the changes of the measured parameters.
286. A=GSC 2190 1120 non star.
287. A=GSC 2190 1556. I cannot find component B. It cannot be identified in the DSS images, either.
288. A=GSC 2186 2060 non star.
289. A=GSC 2186 647.
290. A=GSC 2190 1776. The proper motion in PA 270 direction of component B accounts for the changes of the measured parameters.
291. A=GSC 2186 197.
292. A=GSC 2190 968.
293. I cannot find component C. It cannot be identified in the DSS images, either.
294. A=GSC 2190 1955 (21144+2519!).
295. A=GSC 2186 2128 non star.
296. A=GSC 2190 1659 non star.
297. A=GSC 2190 2410. I cannot find component C. It cannot be identified in the DSS images, either.
298. A=GSC 2190 1262 non star.
299. A=GSC 2190 2174 (21170+2453!).
300. A=GSC 2190 1894.
301. A=GSC 2186 2134.
302. AB=GSC 2186 1537 non star. The proper motion in PA 80 direction of component B accounts for the changes of the measured parameters.
303. A=GSC 2190 413. There's nothing else nearby. Very different parameters. The images available do not show significant proper motion of the nearby stars.
304. A=GSC 2190 2443 (21177+2453!).
305. A=GSC 2190 2002.
306. I cannot find such double in the vicinity. It cannot be identified in the DSS images, either.
307. A=GSC 2190 729.
308. A=GSC 2190 378.
309. A=GSC 2190 1646 non star (21195+2514!). The proper motion in PA 100 direction of component A accounts for the changes of the measured parameters.
310. AB=GSC 2190 399 non star.
311. A=GSC 2190 591.
312. A=GSC 2190 2217.
313. A=GSC 2190 1697 non star. The proper motion in PA 220 direction of component B accounts for the changes of the measured parameters.
314. AB=GSC 2190 1802 non star.
315. AB=GSC 2191 1717 non star (21212+2427!).
316. A=GSC 2191 1856 (21210+2436!).
317. AB=GSC 2191 1669 non star. The proper motion in PA 120 direction of component A accounts for the changes of the measured parameters.
318. A=GSC 2187 1626.
319. A=GSC 2187 1277.
320. I cannot find such double in the vicinity. It cannot be identified in the DSS images, either. The images available do not show significant proper motion of the nearby stars.
321. A=GSC 2187 2180.

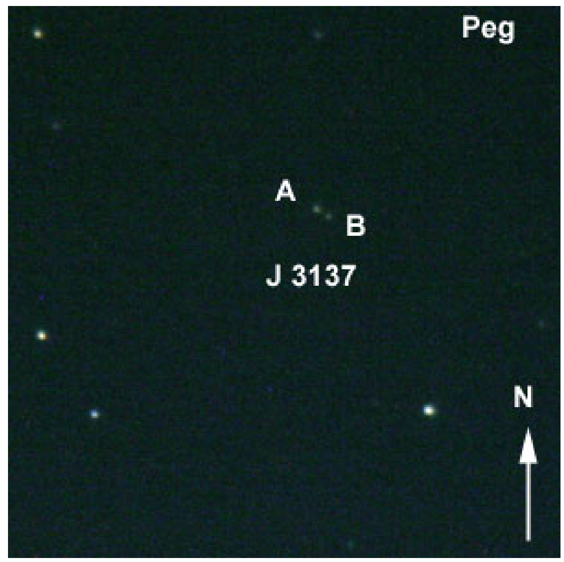


Figure 11: See note 325.

322. A=GSC 2187 2122. The proper motion in PA 170 direction of component A accounts for the changes of the measured parameters.
323. AB=GSC 2191 2186 non star. The proper motion in PA 30 direction of component A accounts for the changes of the measured parameters.
324. A=GSC 2187 2177. The proper motion in PA 90 direction of component A accounts for the changes of the measured parameters.
325. AB=GSC 2187 1077 non star (21239+2351!).
326. A=GSC 2191 2228.
327. A=GSC 2191 2228. The proper motion in PA 250 direction of component D accounts for the changes of the measured parameters.
328. A=GSC 2206 1862 (21489+2456!).
329. AB=GSC 2206 877 non star. The proper motion in PA 210 direction of component A accounts for the changes of the measured parameters.
330. A=GSC 2206 1445 non star.

Double Star Measures Using a DSLR Camera #6

331. A=GSC 2202 34.
332. CD= GSC 2202 584. The proper motion of components accounts for the changes of the measured parameters.
333. CD=GSC 2202 584. The duplicity can be seen, but cannot be measured.
334. A=GSC 2206 1266.
335. A=GSC 2206 432.
336. AB=GSC 2206 1164 non star.
337. A=GSC 2206 1404.
338. A=GSC 2206 1259 non star (21503+2519!).
339. ABC=GSC 2206 1786 non star.
340. A=GSC 2206 809 (21509+2449!).
341. A=GSC 2202 693 (21506+2422!). The proper motion in PA 220 direction of component A accounts for the changes of the measured parameters.
342. AB=GSC 2206 1600 non star.
343. A=GSC 2206 1380 (21511+2438!).
344. AB=GSC 2202 429 non star.
345. A=GSC 2206 1242.
346. AB=GSC 2206 1143. The proper motion in PA 150 direction of component B accounts for the changes of the measured parameters.
347. A=GSC 2202 945.
348. A=GSC 2202 348.
349. A=GSC 2202 70.
350. A=GSC 2203 2272.
351. A=GSC 2207 2049.
352. A=GSC 2203 2225 (21568+2356!).
353. AB=GSC 2207 2533 non star. The proper motion in PA 250 direction of component B accounts for the changes of the measured parameters.
354. A=GSC 2207 2221.
355. A=GSC 2207 1750 (21574+2457!).
356. AB=GSC 2203 2162 non star.
357. AB=GSC 2207 1766 non star.
358. A=GSC 2207 2325.
359. AB=GSC 2207 1843 non star.
360. A=GSC 2207 1780 (21582+2506!).
361. A=GSC 2207 2001 non star.
362. AB=GSC 2207 1878 non star.
363. A=GSC 1692 1687.

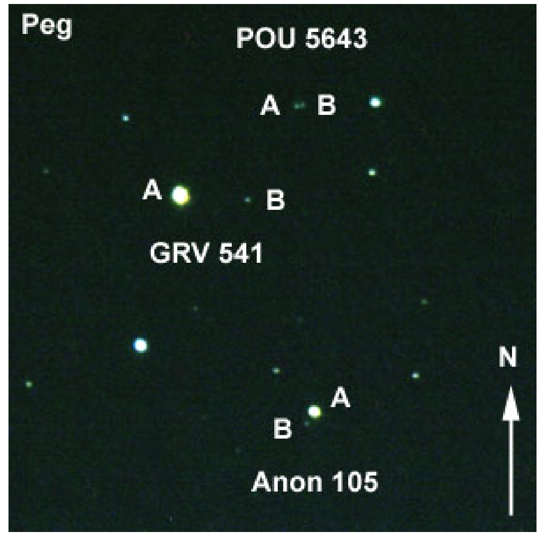


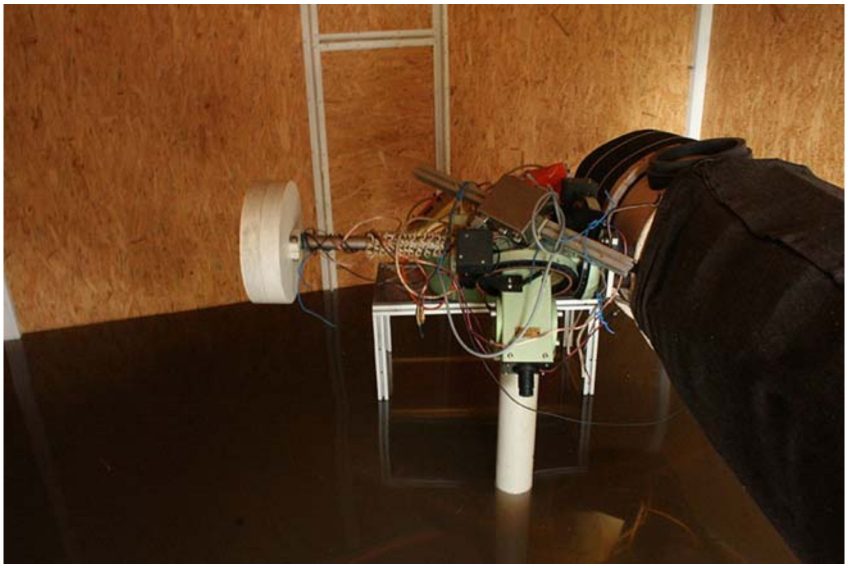
Figure 12: See notes 369 - 371.

364. A=GSC 1692 1717. The images available do not show significant proper motion.
365. A=GSC 1692 1885. The images available do not show significant proper motion.
366. A=GSC 2208 564.
367. A=GSC 2208 1472 (22068+2428!).
368. AB=GSC 2208 2006 non star (22078+2520!). A little proper motion can be observed.
369. AB=GSC 2204 112 non star (22082+2420!).
370. A=GSC 2204 259 (22083+2419!)
371. A=GSC 2204 562.
372. A=GSC 2208 807.
373. A=GSC 2204 486.
374. AB=GSC 2204 1364 non star.
375. A=GSC 2208 1147. The proper motion in PA 230 direction of component A accounts for the changes of the measured parameters.
376. A=GSC 2208 1905 non star.
377. A=GSC 2208 1422 (22095+2426!).
378. A=GSC 2204 271 (22102+2419!).
379. A=GSC 2204 448. The proper motion in PA 150 direction of component B accounts for the changes of the measured parameters.
380. A=GSC 2204 1649 (22106+2341!).
381. A=GSC 2204 127 non star.
382. A=GSC 2205 989 non star.

Double Star Measures Using a DSLR Camera #6

Editor's Note: Ernő Berkó made reference to extreme weather and the flooding of his observatory at the beginning of this article. He sent us pictures showing his flooded facility, which we show below. You can see that he came very close to experiencing a disastrous loss. At its highest, the water was 30 cm from his telescope. Considering this, it is remarkable that Mr. Berkó was able to do any double star observations at all.

Outside Ernő Berkó's observatory during the flooding.



Inside the observatory. You can see that water came to within a few inches of his telescope.

New Suspected Common Proper Motion Pairs

Massimiliano Martignoni
Stazione Astronomica Betelgeuse (SAB)
Via Don Minzoni 26/d
20020 Magnago (Milano)
Italy

massimiliano.martignoni@alice.it

Abstract: This article describes the identification of 9 new suspected pairs of stars with common proper motion. I provide position measurements and proper motion values using data from NOMAD and PPMXL catalogs.

Introduction

During the analysis of CCD images taken for the purpose of photometry of variable stars and of astrometry of minor planets of our solar system, I have identified serendipitously 9 new suspected pairs of common proper motion stars not previously reported by observers and not enclosed in the last edition of the Washington Visual Double Star Catalog (Mason, 2001).

Analysis

In order to search for new pairs of common proper motion stars I analyzed images collected during the year 2009 and the first half of 2010 with the instruments of the "*Stazione Astronomica Betelgeuse* (SAB)" located in Magnago, Italy (a Schmidt-Cassegrain 0.20m-F/10.0 Telescope with a KAF-0402ME CCD Camera).

For each suspected pair identified, I checked the NOMAD (Zacharias, 2005) and the PPMXL (Roeeser, 2010) catalogs in order to establish a similarity in the proper motion components (not exceeding 5 mas/yr).

In Table 1, for each pair of stars with suspected common proper motion are reported the position (RA and declination) and magnitude as measured with the software Astrometrica (Raab, 2010), epoch, separation and position angle derived as described by Buchheim (2008), proper motion in right ascension (pm RA) and proper motion in declination (pm Dec) for both components (A and B) as derived from NOMAD and PPMXL, as well as their mean values.

Table 2 shows the images of fields containing the suspected double stars; the orientation of the images is north up and east left.

References

Buchheim R.K., "CCD Double-Star Measurements at Altimira Observatory in 2007", JDSO 4, 27, 2008.

Mason B.D., Wycoff G.L., Hartkopf W.I., Douglass G.G., Worley C.E., "The Washington Visual Double Star Catalog (WDS), Version 2010-07-03", A.J. 122, 3466, 2001.

Raab H., Astrometrica (Version 4.6.1.385), 2010, http://www.astrometrica.at.

Roeeser S., Demleitner M., Schilbach E., "The PPMXL catalog of positions and proper motions on the ICRS. Combining USNO-B1.0 and the two Micron All Sky Survey (2MASS)", Astron. J. 139, 2440, 2010.

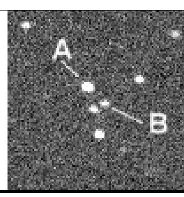
Zacharias N., Monet D.G., Levine S.E., Urban S.E., Gaume R., Wycoff G.L., "Naval Observatory Merged Astrometric Dataset (NOMAD)", San Diego AAS Meeting, January 2005.

New Suspected Common Proper Motion Pairs

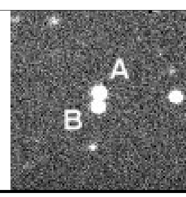
Table 1: Analysis Results

Identifier	R.A. h m s	Dec. ° ' "	Mag.	Epoch	Rho "	Theta °	NOMAD pm RA mas/yr	NOMAD pm Dec mas/yr	PPMXL pm RA mas/yr	PPMXL pm Dec mas/yr	AVERAGE pm RA mas/yr	AVERAGE pm Dec mas/yr
MMA001 A	5 31 7.05	+ 9 43 9.4	12.4	2009.116	25.66	225.13	2.0	-10.3	-3.8	-7.9	-0.9	-9.1
MMA001 B	5 31 5.82	+ 9 42 51.3	14.1				0.8	-9.7	-0.4	-8.6	0.2	-9.2
MMA002 A	16 30 7.97	+13 26 3.1	12.3	2009.122	15.10	173.34	-4.3	-8.8	-5.2	-11.9	-4.8	-10.4
MMA002 B	16 30 48.09	+13 25 48.1	12.6				0.4	-10.9	-0.1	-16.8	0.2	-13.9
MMA003 A	20 19 39.66	+41 51 10.6	12.2	2009.122	10.63	106.96	-4.9	-8.7	-0.9	-10.8	-2.9	-9.8
MMA003 B	20 19 40.57	+41 51 7.5	14.0				-10.0	-11.1	-5.5	-10.2	-7.8	-10.7
MMA004 A	8 13 28.38	+20 4 3.6	12.3	2009.124	22.51	309.10	-6.9	-13.7	-2.0	-15.4	-4.5	-14.6
MMA004 B	8 13 27.14	+20 4 17.8	14.8				-7.5	-14.1	-5.2	-5.9	-6.4	-10.0
MMA005 A	16 44 33.00	+19 19 39.7	14.4	2009.189	28.34	324.59	-9.3	7.1	-10.5	-1.4	-9.9	2.9
MMA005 B	16 44 31.84	+19 20 2.8	15.0				-7.2	6.4	-12.1	-2.7	-9.7	1.9
MMA006 A	14 9 4.31	- 4 57 35.8	11.9	2010.307	10.72	53.99	-45.7	10.6	-45.8	10.7	-45.8	10.7
MMA006 B	14 9 4.89	- 4 57 29.5	11.9				-47.1	11.5	-46.6	11.7	-46.9	11.6
MMA007 A	14 39 0.43	+30 2 4.3	11.2	2009.291	17.47	156.33	8.0	-2.5	7.2	-2.8	7.6	-2.7
MMA007 B	14 39 0.97	+30 1 48.3	13.7				12.9	-3.4	8.2	-4.7	10.6	-4.1
MMA008 A	19 17 23.46	+37 11 38.5	10.1	2009.729	27.16	298.36	17.1	42.6	17.7	41.4	17.4	42.0
MMA008 B	19 17 21.46	+37 11 51.4	10.9				17.1	42.6	23.3	39.6	20.2	41.1
MMA009 A	5 0 54.08	+49 25 10.9	11.3	2009.786	17.75	47.46	-1.1	-13.5	-1.0	-10.6	-1.1	-12.1
MMA009 B	5 0 55.42	+49 25 22.9	12.3				-4.4	-18.3	-3.9	-5.6	-4.2	-12.0

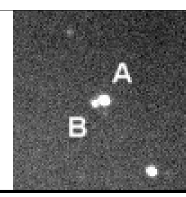
Table 2: Identification Charts



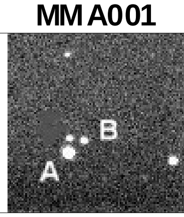
MMA001



MMA002



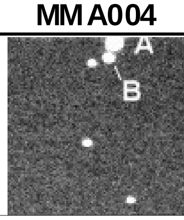
MMA003



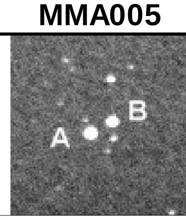
MMA004

MMA005

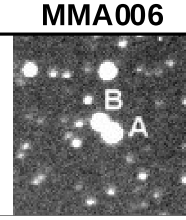
MMA006



MMA007



MMA008



MMA009

The Rapid Convergence of 44 Boötis with Revised Orbit and Updated Ephemerides

Henry Zirm

Jena, Thuringia, Germany

henryzirm@gmx.de

Abstract: In this article I investigate the apparent orbital motion for the visual double star 44 Boötis (WDS 15038+4739, *i* Boötis) near periastron. Observations from about 200 years and the comparison with recent orbit references from the literature show systematic increasing differences between observed and calculated positions in polar coordinates. The current separation of the components of 1.6 arcsec is expected to approach 0.2 arc seconds in the next 10 years. Based on the calculation of a new and improved orbit and updated ephemeris, the expected positions are predicted more accurately.

Introduction

The visual double star 44 Boötis, also known as *i* Boötis, ADS 9494, WDS 15038+4739, STF1909 AB, HD133640, HIP73695, HR5618, is a 4.8 magnitude (visual) bright star located in constellation Boötes. The coordinates in IRCS epoch 2000 are right ascension 15h 03m 47sec and declination +47° 39' 14". Sir William Hershel discovered this pair in 1781 and a few decades later, Friedrich Georg Wilhelm Struve confirmed the visual duplicity. The supposed variability in brightness was investigated by Schilt (1926) and he established variability with a period of about 6.4 hours. Recently detailed results of an investigation into this eclipsing binary component, located in component 44 Boötis B, were given by Liu, *et al*. (2001) and Pribulla (2001). The corresponding weakening in brightness due to the variability of 44 Boötis B is less than 0.2 magnitudes from the combined light. The difference in brightness between the visual components is about 0.8 magnitude.

Motivation

44 Boötis is one of the relatively bright interesting systems for visual double star observers; the apparent motion of both components is nearing a phase of rapid change. Presently, the distance is near 1.6 arc seconds and is just possible to resolve with a small aperture telescope. But in the coming 10 years, the components will approach to about 0.2 arc seconds, which will lead to increasing requirements on telescope resolution power. Therefore, this pair offers the opportunity to check the resolution of one's equipment.

With the separation nearing distances of 0.2 arc seconds, techniques such as speckle interferometry will be increasingly more important. A good overview of the application of speckle interferometry with amateur means was given by Joerg Schlimmer (Schlimmer, 2008).

For checking the quality of these measurements, it's necessary to use ephemerides from a recent orbit calculation. This information can be easily obtained from the *Sixth Catalog of Orbits of Visual Binary Stars* (Hartkopf & Mason, 2010). If one can accept the ephemeris as trustworthy, it is a good way to check the one's own measurements.

In case of 44 Boötis, I don't trust the orbit quality from the two latest published orbits, especially due

The Rapid Convergence of 44 Boötis with Revised Orbit and Updated Ephemerides

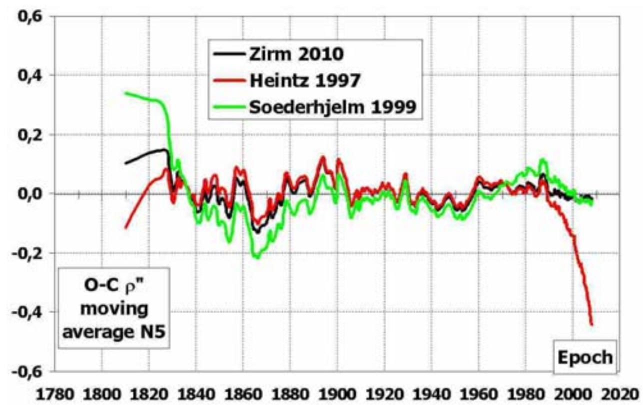


Figure 1: 44 Boötis, residuals in Rho vs. time

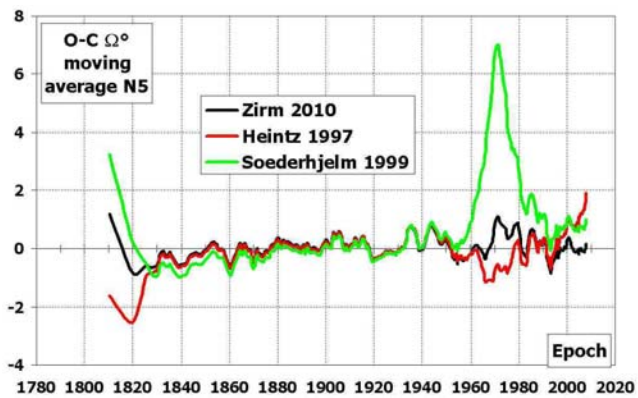


Figure 2: 44 Boötis, residuals in Theta vs. time

to the rapid motion for next decade and the definitely decreasing separations since 2000. Before year 2000, the end of growing distances was not clear enough.

I have calculated residuals from the large observational data (see the section titled Preparation), based on the two most recent orbits (Soederhjelm, 1999 and Heintz, 1997). For evaluating the quality of these orbits and consequently the plausibility of needed ephemerides for the next decade, I've checked the residuals via graphical representation in Theta vs. time and in Rho vs. time.

In case of Heintz orbit, particularly since 1990, the residuals in distance are especially enlarged and for recent measures the residuals |O-C r"| have increased up to about -0.4 arc seconds (Figure 1, moving average).

The residuals from Soederhjelm's orbit shows a large error, surprisingly especially in the time interval about 1960 to about 1990. Since 1960 a clear systematic growing error in position angle |O-C W°| is visible (Figure 2, moving average), after the maximum error with 7° (Theta) in 1972, the residuals decreasing to "normal" in year 1990. One important fact should be noted, the author had in all probability used measurements up to Epoch 1999. So I suppose any mistakes in orbit computation, particularly in estimation of weightings (see Preparation). This fact leads to a probable overestimated eccentricity in the Soederhjelm orbit and accordingly the time of closest approach is 1 year earlier than estimated by me.

As a result to get more probability estimation for positions on the apparent orbit for the next 10 years, I have decided to calculate a new orbit. Below I described shortly the steps to get a new orbit for 44 Boötis.

Preparation

Most observations I used were from the Washington Double Star Catalog, obtained via email request from Brian D. Mason and his colleagues. Other measurements were recently reported in the *Journal of Double Star Observations* (Anton 2010 and Schlimmer 2010).

Initially, all position angles were corrected for precession to epoch 2000 (Heintz, 1978).

In case of 44 Boötis the influence of proper motion was ignored.

Furthermore, I divided all observations in three classes: visual observations, photographic and CCD observations and speckle measures (including Hipparcos). For each class it's useful to create normal points, in case of 44 Boötis, all observations from the same year have to be merged into a weighted average. An example is shown in Figure 3.

The extracted information for a single visual normal point at Epoch 1879 is:

t	1879.488
Theta	240.5
Rho	4.90
Observers	Sp_6 Hod4 Sbk3 Prc2 Sbk3 Je_3

Date	P.A.	Sep.	Mag-a	Mag-b	#	RefCode	Aperture	Method
.								
.								
.								
1879.18	240.4	4.76	.	.	6	Sp_1888	09	A
1879.44	240.1	4.80	.	.	4	Hod1881	8	A
1879.55	241.9	5.04	.	.	3	Sbk1881	8	A
1879.59	238.2	4.88	.	.	2	Prc1887	12	A
1879.63	241.4	5.01	.	.	3	Sbk1881	8	A
1879.66	241.5	4.97	.	.	3	Je_1882	06	A
.								
.								

Figure 3: 44 Boötis, example observation data file extraction from WDS

The Rapid Convergence of 44 Boötis with Revised Orbit and Updated Ephemerides

I'll not describe here the topic of calculating weights. But, I recommend publications from well known double star observers such as Wulff D. Heintz, (Heintz 1967, Heintz 1978), J.D. Docobo (Docobo & Ling, 2003), and from the CHARA team (Mason, *et al.*, 1999).

All computed normal point observations and combined with calculated residuals, are shown in Table 4, Appendix A.

Orbit calculation

Numerous methods for orbit computation exist in the literature as well as many methods to improve a given (more or less preliminary) orbit. In *Observing and Measuring Visual Double Stars* (Argyle, ed., 2004) chapters 7 and 8 by A. Alzner, are detailed and clearly arranged information about the fundamentals of orbit and ephemerides computation and references to further readings.

In case of 44 Boötis, I used the method of least squares. I have two important reasons for this decision: first, the observation data set is large and consistent and second, on basis of the two recent orbits (Heintz, 1997 and Soederhjelm, 1999) the residuals showed systematic trends and affected only single parts of the apparent orbital path.

So I tried an improvement on the basis of existing orbits using the well-described method of least squares in polar coordinates by Heintz (1967, 1978). On basis of weighted normal equations (see literature references in the section Preparation), I obtained differential corrections and transformed into the dynamical orbital elements for period **P** in years, the time of periastron passage **T**, the numerical eccentricity **e**, the semi major axis **a** in arc seconds and finally the elements from apparent orbit: the position angle of node **Ω** in degrees, the inclination **i** in degrees and the argument of periastron **ω**. The uncertainties were derived from the covariance matrix of normal equations and the sum of residuals in both polar coordinates.

Figure 4 shows the retrograde apparent orbital motion on basis of the new elements and the normal points of used observations. The scale is 1 arc second per large tic.

The resulting (so called Campbell-) elements are listed in Table 1, combined with the previously discussed recent orbit results.

Ephemerides: I'll give a brief overview how to compute ephemerides respectively residuals on basis of present measurements (t_i, ϑ_i, ρ_i) and the desired orbital elements (P, T, e, a, i, ω, Ω_{2000}).

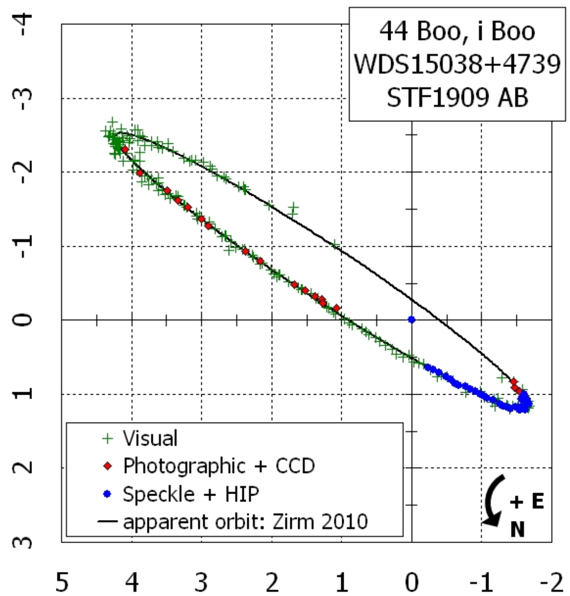


Figure 4: 44 Boötis, apparent orbit from new orbital elements, normal points visible for visual, photographic/CCD and speckle measures.

The Kepler equation is the correlation between mean anomaly M and eccentric anomaly E and is calculated by:

$$M = E - \sin E$$

M is defined as:

$$M = \mu(t_i - T) = 360° \, (t_i - T) \, / \, P$$

Heintz (1978) gave an easy, iterative, method to determine the eccentric anomaly E:

$$E_o = M + e \sin M + (e^2 / M) \sin(2M)$$

With E_0 calculate M_0:

Table 1: 44 Boötis, new orbital elements and uncertainties

	Zirm 2010		Hei1997	Sod1999	unit
P	209.8	±3.3	220.0	206	years
T	2012.04	±0.26	2017.0	2013	
e	0.5111	±0.0065	0.451	0.55	
a	3.666	±0.021	3.70	3.8	arcsec
i	83.55	±0.05	83.7	84	degree
ω	39.86	±0.68	37.5	45	degree
Ω_{2000}	57.14	±0.06	57.7	57	degree

The Rapid Convergence of 44 Boötis with Revised Orbit and Updated Ephemerides

$$M_o = E_o - e \sin E_o$$

The next step is calculating E_1 from E_0 and M_0:

$$E_1 = E_o + (M - M_o)/(1 - e \cos E_o)$$

Using the last two formulas for four more iterations, the accuracy should be sufficient for ephemerides calculation in case $e \le 0.95$.

For a given epoch, the theoretical positions in polar coordinates can then be calculated. The value ν is the true anomaly and r is the radius vector:

$$\tan(\nu/2) = \sqrt{(1+e)/(1-e)}\,\tan(E/2)$$
$$r = a(1-e^2)/(1+e\cos\nu)$$
$$\tan(\theta - \Omega) = \tan(\nu + \omega)\cos i$$
$$\rho = r\cos(\nu+\omega)\sec(\theta+\Omega)$$

With this simple "tool" it is quick and easy to compute theoretical positions for each time. Calculate residuals for Epoch *i* via:

$$\text{O-C } \vartheta_{2000\ i} = \vartheta_{\text{observed (corrected for precession) } i} - \vartheta_{\text{calculated I}}$$
$$\text{O-C } \rho_i = \rho_{\text{observed } i} - \rho_{\text{calculated } i}$$

The estimated ephemerides for the new and the two recent 44 Boötis orbits are listed for comparison in Table 2. The probable year of closest approach is characterized by bold letters.

A detailed view of the apparent orbit is given in Figure 5, additionally included are points of coming yearly ephemerides for the new orbit and those from Soederhjelm orbit:

For clarity, alternatively in Figure 6 the theoretical evolution of separations (ρ in arc seconds) in the next two decades is shown.

The Heintz orbit (1997) is definitely not in line with actual measurements. A clear indication that the new calculated orbit is a better interpretation than Soederhjelm's, seems to be the discussed systematic errors during the last approach phase 1960 – 1990.

Table 2: 44 Boötis, Ephemerides from 2011 to 2030

	Zirm 2010		Heintz 1997		Soederhjelm 1999	
t	$J°_{2000}$	r"	$J°_{2000}$	r"	$J°_{2000}$	r"
2011.0	61.4	1.502	58.7	2.083	60.6	1.490
2012.0	62.5	1.386	59.2	2.028	61.6	1.359
2013.0	63.7	1.260	59.8	1.963	63.0	1.216
2014.0	65.3	1.125	60.4	1.890	64.7	1.061
2015.0	67.3	0.983	61.0	1.807	67.0	0.896
2016.0	70.0	0.835	61.7	1.716	70.4	0.725
2017.0	73.9	0.684	62.5	1.617	75.9	0.551
2018.0	80.0	0.533	63.4	1.511	86.4	0.382
2019.0	90.8	0.390	64.4	1.397	111.1	0.241
2020.0	112.2	0.273	65.7	1.277	**161.4**	**0.207**
2021.0	**150.4**	**0.230**	67.2	1.152	196.9	0.319
2022.0	185.1	0.297	69.0	1.022	211.4	0.482
2023.0	203.0	0.424	71.4	0.889	218.3	0.658
2024.0	212.2	0.571	74.7	0.754	222.3	0.835
2025.0	217.6	0.725	79.4	0.620	224.9	1.011
2026.0	221.1	0.880	86.7	0.489	226.8	1.184
2027.0	223.5	1.034	98.9	0.370	228.2	1.352
2028.0	225.3	1.186	120.5	0.281	229.2	1.517
2029.0	226.7	1.335	**152.7**	**0.255**	230.1	1.677
2030.0	227.9	1.482	181.5	0.311	230.8	1.832

Discussion

I will now compare the new orbit with the older orbits. One of the main reasons why astronomers calcuate visual (and spectroscopic) binary orbits is that in combination with a good estimate of the distance, it is one of the most direct routes to obtain stellar masses. However, to get the information about the masses of each component we need the mass ratio (M_B/M_A). Many techniques are available, for instance: mass ratio from double lined spectroscopic orbits or astrometric or photocentric motion of main component from long time photographic investigations. In case of 44 Boötis, I used another way. As described in the Introduction, it's known that component B is an eclipsing binary. From recent photometric and spectroscopic investigations made by Liu et al. (2001) and Pribulla (2001), the values for inclination and minimum mass for 44 Boötis B are available. Hence the derived mass (in unit of solar masses) for component B is:

The Rapid Convergence of 44 Boötis with Revised Orbit and Updated Ephemerides

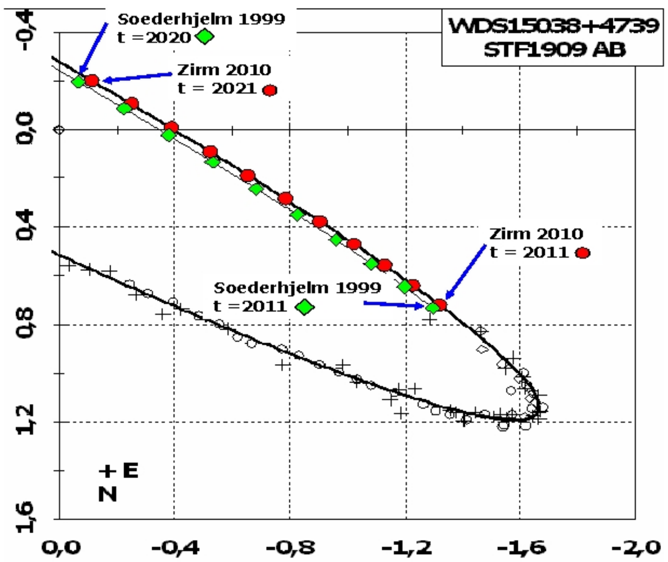


Figure 5: 44 Boötis, detail of apparent orbit and yearly ephemerides points from new orbit and those from Soederhjelm orbit.

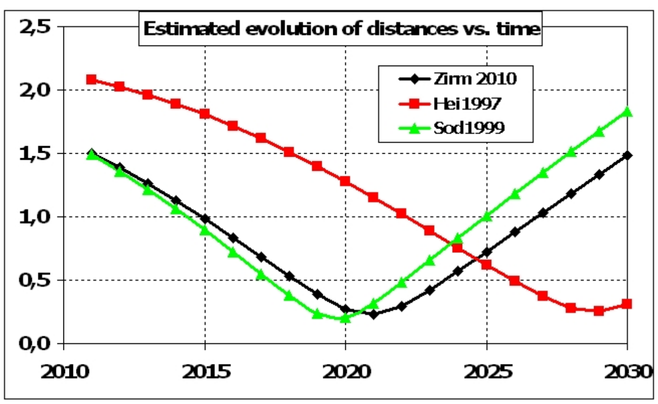


Figure 6: 44 Boötis, estimated evolution of distances (in arc seconds) vs. time

$$M / M_{\odot B} = 1.28 \pm 0.02$$

With a known parallax (π in arc seconds), the period (P in years) and the semi major axis (a in arc seconds), the sum of the masses can be calculated from Kepler's third law:

$$\Sigma M = M_A + M_B = a^3 / (\pi^3 P^2)$$

Furthermore, the mass uncertainty is

$$\sigma\Sigma M = \Sigma M \sqrt{9(\sigma a / a)^3 + 9(\sigma\pi / \pi)^3 + 4(\sigma P / P)^2}$$

Now the mass (and a simplified estimation for the mass error) are calculated for the A component.

$$M_A = \Sigma M - M_B; \quad \sigma M_A = \sigma\Sigma M - \sigma M_B$$

The recent parallax value comes from "Hipparcos, the New Reduction of the Raw Data" (van Leeuwen, 2007) and was:

$$\pi = 0.07838 \pm 0.00103 \text{ (arc seconds)}$$

or,

$$\text{distance} = 12.8 \pm 0.2 \text{ parsec.}$$

The resulting sum of masses and mass for component A from the discussed orbits are listed in Table 3.

Due the possible high mass sum described by Pribulla (2001), he assumed on basis of Soederhjelms orbit, 44 Boötis A is possibly itself a binary. With the new orbit the sum of masses was clearly reduced.

Adapted from Schmidt-Kaler (1982) tables for physical parameters of main sequence stars, with the derived absolute magnitude 4,6 mag and the spectral class of an early G-Star (G0 - G2 V), a theoretical mass of 1,0 - 1,1 Msol is adopted. The calculated mass 1.04 ± 0.10 M_{sol} supports my assumption that component A is a simple, normal main sequence star.

Acknowledgements

Andreas Alzner, played a crucial role in my interest in the calculation and publication of orbits. This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory, the NASA Astrophysics Data System Bibliographic Services and the SIMBAD database (operated at CDS, Strasbourg, France).

Table 3: 44 Boötis, sum of masses and mass for component A

	Zirm 2010	Heintz 1997	Soederhjelm 1999
ΣM	2.32	2.17	2.69
σΣM	±0.12	>±0.08	>±0.10
		no information about uncertainty in a and P available	
M_A	1.04	0.89	1.41
σM_A	±0.10	>±0.06	>±0.08

References

Anton, R., 2010, Journal of Double Star Observations, vol. 6, no. 3, p. 180-196.

Observing and measuring visual double stars, by Bob Argyle. Patrick Moore's practical astronomy series. Berlin: Springer, 2004, ISBN: 1852335580

Docobo, J. A.; Ling, J. F., 2003, Astronomy and Astrophysics, v.409, 989-992.

Hartkopf, W. I., & Mason B. D., Sixth Catalog of Orbits of Visual Binary Stars (Washington:USNO), http://ad.usno.navy.mil /wds/orb6/orb6frames.html

Hartkopf, W. I., Mason, B. D., Wycoff, G. L., & McAlister, H. A., Fourth Catalog of Interferometric Measurements of Binary Stars (Washington: USNO), http://ad.usno.navy.mil /wds/int4.html

Heintz, W. D., 1997, Astrophysical Journal Supplement v.111, p.335.

Heintz, W. D., 1978, Double Stars (revised edition), Dordrecht, D. Reidel Publishing Co. (Geophysics and Astrophysics Monographs. Volume 15).

Heintz, W.D, 1967, ActaAstr., 17, 311.

Lu, Wenxian; Rucinski, Slavek M.; Ogłoza, Waldemar, 2001, The Astronomical Journal, Volume 122, Issue 1, 402-412.

Mason, B. D., Wycoff, G. L., & Hartkopf, W. I., The Washington Double Star Catalog (Washington: USNO), http://ad.usno.navy.mil /wds/wds.html

Mason, B. D., Douglass, G.G., Hartkopf, W. I., 1999, AJ, 117, 1023.

Perryman, M. A. C., et al. 1997, The Hipparcos and Tycho Catalogues (ESA SP-1200; Noordwijk: ESA)

Pribulla, T.; Tremko, J.; Rovithis-Livaniou, H.; Rovithis, P., 2001, Odessa Astronomical Publications, 14, 74-77.

Schilt, J., 1926, Astrophys. J., 64, 215-224.

Schlimmer, J., 2010, Journal of Double Star Observations, vol. 6, no. 3, p. 197-205.

Schlimmer, J., 2008, Gamma Virginis (ADS 8630) - Interferometrische Beobachtungen

der Periastronpassage, http://www.epsilon-lyrae.de/Doppelsterne/GammaVirginis/GammaVirginis_Interferometrie.html

Schmidt-Kaler, T.H.: Physical parameters of the stars. In: 1982, Landolt-Bornstein New Series, Volume 2b, astronomy and astrophysics – stars and star cluster (eds. K.Schaifers, H.H. Voigt), (New York: Springer)

Söderhjelm, Staffan., 1999, Astronomy and Astrophysics, v.341, 121-140.

van Leeuwen, F. 2007, Hipparcos, the New Reduction of the Raw Data (New York: Springer) (data obtained from Simbad data base: I/311).

The Rapid Convergence of 44 Boötis with Revised Orbit and Updated Ephemerides

Appendix

A total of 799 measures up to mid 2009 are available, collected and transformed in weighted yearly normal points: 175 normal points for the class of visual measurements, 23 for photographic and CCD and 29 for speckle normal points. Due to large errors or insufficient measurements 11 single measurements were not used.

Table 4: 44 Boötis, normal points for each observation class and residuals, compared with the recent orbits

					Weights		Zirm 2010		Heintz 1997		Soederhjelm 1999	
Date	$\vartheta°_{2000}$	ρ"	Reference/Nights	Class	Wi ϑ"	Wi ρ"	O-C ϑ°	O-C ρ"	O-C ϑ°	O-C ρ"	O-C ϑ°	O-C ρ"
1781.620	60.1	1.500	H__1	Visual	0.06	0.02	9.8	-0.21	4.4	-0.70	14.2	0.07
1802.250	63.0		H__1	Visual	0.00	0.00	-0.7		-7.8		3.5	
1819.430	228.0	1.500	StF1	Visual	0.21	0.07	-0.1	0.13	-1.0	-0.05	1.1	0.41
1821.330	229.1	2.280	SHJ1	Visual	0.07	0.02	-0.9	0.63	-1.4	0.49	-0.5	0.87
1826.790	231.0	2.230	StF1	Visual	2.19	0.73	-2.0	-0.13	-2.2	-0.20	-2.3	-0.01
1829.200	233.6	2.560	StF2	Visual	2.76	0.92	-0.3	-0.08	-0.4	-0.13	-0.6	0.00
1830.497	234.6	2.974	HJ_3 Smy1	Visual	8.77	2.92	0.3	0.19	0.2	0.16	0.0	0.25
1831.507	234.1	3.004	HJ_4 Smy1 Da_8	Visual	8.74	2.91	-0.4	0.11	-0.5	0.09	-0.8	0.16
1832.565	234.4	2.964	StF12 HJ_1 Da_4	Visual	11.80	3.93	-0.4	-0.03	-0.5	-0.05	-0.8	0.00
1833.250	235.0	3.060	HJ_1	Visual	1.96	0.65	0.0	-0.01	0.0	-0.02	-0.4	0.02
1834.557	235.2	3.300	Smy1 Da_2	Visual	3.00	1.00	-0.1	0.11	-0.1	0.10	-0.5	0.12
1835.511	235.3	3.270	Mad2 StF6 Da_2	Visual	10.53	3.51	-0.1	-0.01	-0.2	-0.01	-0.6	0.00
1836.551	235.1	3.541	Mad4 Da_1 StF4 Smy1	Visual	12.22	4.07	-0.6	0.17	-0.6	0.17	-1.0	0.17
1837.750	236.0	3.390	StF4	Visual	4.34	1.45	0.1	-0.08	0.1	-0.07	-0.3	-0.10
1839.620	235.3	3.500	Smy1	Visual	2.49	0.83	-0.9	-0.12	-1.0	-0.11	-1.3	-0.15
1840.760	235.2	3.660	Stt5	Visual	6.26	2.09	-1.2	-0.05	-1.2	-0.03	-1.6	-0.09
1841.408	236.0	3.765	Da_11 Gsh1 Mad3 Kai6	Visual	16.34	5.45	-0.5	0.01	-0.5	0.03	-0.9	-0.03
1842.712	236.5	3.816	Smy1 Da_1 Mad2	Visual	9.54	3.18	-0.2	-0.04	-0.2	-0.01	-0.5	-0.08
1843.626	236.9	3.829	Mad6 Kai9	Visual	11.45	3.82	0.1	-0.08	0.0	-0.06	-0.3	-0.14
1845.513	237.1	4.100	Mad5	Visual	6.27	2.09	0.0	0.07	0.0	0.10	-0.3	0.01
1846.180	236.5	4.220	Jc_2	Visual	2.79	0.93	-0.6	0.15	-0.7	0.18	-1.0	0.08
1847.423	237.0	3.915	Hin2 Mad1 Smy1 Mtl1	Visual	11.59	3.86	-0.3	-0.23	-0.4	-0.20	-0.6	-0.30
1848.481	237.6	4.253	Stt3 Da_3 BdW2 BdG1	Visual	21.86	7.29	0.2	0.05	0.1	0.08	-0.2	-0.02
1849.480	237.3	4.360	Da_1	Visual	3.10	1.03	-0.2	0.10	-0.3	0.14	-0.6	0.03
1851.656	237.8	4.430	Flt4 Da_1 Mad9	Visual	14.84	4.95	0.0	0.07	0.0	0.10	-0.3	-0.01
1852.650	237.9	4.250	Mad15	Visual	10.12	3.37	0.0	-0.16	-0.1	-0.12	-0.3	-0.24
1853.345	238.0	4.309	Stt2 Jc_2 Flt1 MiJ5 Mad7 Pwl8	Visual	24.60	8.20	0.0	-0.13	0.0	-0.09	-0.3	-0.21
1854.570	239.0	4.481	Mrt2 D__11 Da_1	Visual	14.79	4.93	0.9	-0.01	0.8	0.03	0.6	-0.09
1855.245	238.4	4.405	D__2 Mad3 Pwl2	Visual	9.21	3.07	0.2	-0.11	0.2	-0.08	-0.1	-0.20
1856.576	238.0	4.575	Se_7 D__5 Stt4	Visual	19.35	6.45	-0.3	0.01	-0.4	0.05	-0.6	-0.08

Table continues on next page.

The Rapid Convergence of 44 Boötis with Revised Orbit and Updated Ephemerides

Table 4, continued: 44 Boötis, normal points for each observation class and residuals, compared with the recent orbits

					Weights		Zirm 2010		Heintz 1997		Soederhjelm 1999	
Date	$\vartheta°_{2000}$	ρ"	Reference/Nights	Class	Wi ϑ"	Wi ρ"	O-C ϑ°	O-C ρ"	O-C ϑ°	O-C ρ"	O-C ϑ°	O-C ρ"
1858.560	237.6	4.680	D__4 Mad2	Visual	9.45	3.15	-0.9	0.05	-1.0	0.08	-1.2	-0.04
1861.290	238.8	5.040	Pwl5	Visual	4.84	1.61	0.0	0.33	0.0	0.36	-0.2	0.24
1862.420	238.1	4.610	Mai1	Visual	3.92	1.31	-0.8	-0.13	-0.8	-0.10	-1.0	-0.22
1863.388	237.8	4.717	D__6 Stt7	Visual	15.05	5.02	-1.2	-0.05	-1.2	-0.01	-1.4	-0.13
1864.670	240.6	4.500	Eng1	Visual	3.83	1.28	1.5	-0.29	1.5	-0.26	1.3	-0.38
1865.375	239.5	4.711	Eng4 D__12 Flt1	Visual	16.91	5.64	0.4	-0.09	0.3	-0.06	0.1	-0.18
1866.586	240.3	4.776	Se_1 Sea1	Visual	10.94	3.65	1.0	-0.05	1.0	-0.02	0.8	-0.14
1867.379	237.7	4.720	Win2 Tal2	Visual	6.75	2.25	-1.6	-0.12	-1.7	-0.09	-1.9	-0.20
1869.372	239.2	4.762	Du_10 Mai2 D__5	Visual	19.10	6.37	-0.3	-0.10	-0.4	-0.07	-0.5	-0.19
1870.320	240.0	4.690	Gld1	Visual	4.31	1.44	0.4	-0.18	0.4	-0.16	0.2	-0.27
1871.463	240.0	4.808	Gld4 Du_14 Pei1 Tal1 WS_4 Brn1	Visual	36.06	12.02	0.3	-0.08	0.3	-0.05	0.1	-0.16
1872.191	238.8	4.887	Stt2 Brn1	Visual	11.68	3.89	-0.9	0.00	-1.0	0.02	-1.2	-0.09
1873.113	240.4	5.058	D__6 WS_3	Visual	11.79	3.93	0.6	0.16	0.5	0.19	0.3	0.08
1874.144	238.9	4.608	Tal2 Gld11	Visual	13.82	4.61	-1.0	-0.29	-1.1	-0.27	-1.2	-0.37
1875.442	240.2	4.778	Mai1 Stt1 Du_4	Visual	16.44	5.48	0.2	-0.13	0.1	-0.10	-0.1	-0.21
1876.322	240.2	4.944	Sp_6 Dob4 Hl_2	Visual	18.98	6.33	0.1	0.04	0.0	0.06	-0.1	-0.04
1877.281	240.0	5.011	Plm7 Dob5 Fla1 Je_8	Visual	19.64	6.55	-0.2	0.11	-0.2	0.13	-0.4	0.03
1878.482	240.7	4.981	WJM7 Smt2 Dob3	Visual	19.03	6.34	0.4	0.08	0.4	0.10	0.2	0.00
1879.488	240.5	4.898	Sp_6 Hod4 Sbk6 Prc2 Je_3	Visual	33.31	11.10	0.1	0.00	0.1	0.02	-0.1	-0.08
1880.379	240.7	4.930	Dob3 Je_3	Visual	11.29	3.76	0.2	0.04	0.2	0.05	0.0	-0.04
1881.365	241.4	4.837	Sp_5 Big1 Hl_2 Prt2 Prc2	Visual	33.52	11.17	0.9	-0.05	0.8	-0.03	0.7	-0.12
1882.489	240.8	4.904	Hl_4 Sbk6 Frs3 Sp_5 Stt1 Je_5	Visual	45.41	15.14	0.2	0.02	0.1	0.04	0.0	-0.05
1883.471	240.4	4.869	Eng6 Frs3 Sp_5 Hl_3 Per2 Ku_5	Visual	47.52	15.84	-0.3	0.00	-0.4	0.01	-0.5	-0.07
1884.453	241.4	4.889	Nst1 Hl_3 Sp_4	Visual	19.95	6.65	0.6	0.03	0.5	0.04	0.4	-0.04
1885.444	240.9	4.982	Hl_3 Per3 Smt1 Sp_4 Je_3	Visual	33.08	11.03	0.0	0.13	-0.1	0.15	-0.2	0.07
1886.473	241.7	4.843	Hl_3 Smt2	Visual	15.01	5.00	0.7	0.01	0.7	0.02	0.5	-0.06
1887.527	241.0	4.850	Tar2 Cel4 Sp_6	Visual	20.81	6.94	-0.1	0.03	-0.1	0.04	-0.3	-0.03
1888.581	240.6	4.825	Glp2 Hl_3 Cel2 Sp_5 Stt3	Visual	34.88	11.63	-0.6	0.02	-0.6	0.04	-0.8	-0.04
1889.518	241.9	4.767	SBc2 Hl_3 Maw2	Visual	18.97	6.32	0.6	-0.02	0.6	-0.01	0.5	-0.08
1890.481	241.5	4.812	Glp2 Hl_3 Nst1 Cel1	Visual	21.75	7.25	0.1	0.05	0.1	0.06	0.0	-0.01
1891.482	241.6	4.844	Hl_3 See4 Sp_4	Visual	34.05	11.35	0.2	0.10	0.1	0.11	0.0	0.04
1892.486	241.4	4.852	Lv_2 Sea3 Com2	Visual	18.78	6.26	-0.1	0.13	-0.2	0.14	-0.3	0.07
1893.398	241.5	4.794	Jns2 Cls2 Big7	Visual	18.60	6.20	-0.1	0.09	-0.2	0.10	-0.3	0.04
1894.560	242.7	4.790	Ebl1	Visual	4.69	1.56	1.0	0.11	0.9	0.12	0.8	0.06
1895.313	241.0	4.789	Ren8 Glp2 Cls2 Com3	Visual	33.00	11.00	-0.8	0.13	-0.9	0.14	-1.0	0.08
1896.486	242.2	4.738	Lv_2 Nst1 Hu_4 Eic3	Visual	21.46	7.15	0.3	0.11	0.2	0.12	0.1	0.06
1897.539	241.9	4.506	Vil3 Col3	Visual	10.36	3.45	-0.1	-0.09	-0.2	-0.09	-0.3	-0.14
1898.412	241.7	4.649	Hu_1 Col4 Coh1	Visual	16.04	5.35	-0.4	0.08	-0.5	0.08	-0.6	0.03
1899.582	243.0	4.646	See2 Maw2	Visual	10.08	3.36	0.8	0.11	0.7	0.11	0.6	0.06
1900.407	242.2	4.517	Doo3 Loh2 Bog3 Dob2	Visual	24.93	8.31	-0.1	0.01	-0.2	0.01	-0.3	-0.04
1901.463	243.6	4.466	Loh1 Es_4 Bow1	Visual	18.09	6.03	1.2	-0.01	1.1	-0.01	1.0	-0.05
1902.520	242.6	4.800	Pos1	Visual	5.66	1.89	0.1	0.36	0.0	0.36	-0.1	0.32
1903.322	241.6	4.444	VBs2 Dob2 L__1	Visual	21.42	7.14	-1.0	0.03	-1.1	0.03	-1.2	-0.01

Table continues on next page.

The Rapid Convergence of 44 Boötis with Revised Orbit and Updated Ephemerides

Table 4, continued: 44 Boötis, normal points for each observation class and residuals, compared with the recent orbits

					Weights		Zirm 2010		Heintz 1997		Soederhjelm 1999	
Date	ϑ°_{2000}	ρ"	Reference/Nights	Class	Wi ϑ"	Wi ρ"	O-C ϑ°	O-C ρ"	O-C ϑ°	O-C ρ"	O-C ϑ°	O-C ρ"
1904.518	244.7	4.279	Loh1 Frm1	Visual	8.43	2.81	1.9	-0.09	1.9	-0.09	1.8	-0.13
1905.333	243.5	4.275	Bu_4 L__1 Bow1 Lau2	Visual	34.71	11.57	0.7	-0.06	0.6	-0.06	0.5	-0.10
1906.451	243.2	4.416	A__2 L__2	Visual	20.80	6.93	0.2	0.12	0.2	0.12	0.1	0.08
1907.462	242.6	4.100	VBs3	Visual	6.19	2.06	-0.5	-0.16	-0.5	-0.16	-0.6	-0.19
1908.373	243.2	4.251	VBs2 Lau1 Jan1 Bu_4 Fox3 Dob3 Prz4 L__1 Has6	Visual	49.82	16.61	0.0	0.03	0.0	0.03	-0.1	-0.01
1909.429	243.3	4.179	VBs3 Phl2 J__3 Dob4 Doo3 Lau3	Visual	33.72	11.24	0.0	0.00	0.0	0.00	-0.1	-0.03
1910.576	244.5	4.184	Lau1 Dob3 VBs3 Gut2 Fur2	Visual	32.55	10.85	1.0	0.06	1.0	0.06	0.9	0.02
1911.448	243.4	4.067	VBs3 Dob3 Vou4 Es_3 Fox3 L__1 Jan1	Visual	34.69	11.56	-0.2	-0.02	-0.2	-0.02	-0.3	-0.06
1912.434	243.7	4.077	Neu3 Vou4 Dob2 Fes1	Visual	19.24	6.41	0.0	0.03	0.0	0.03	-0.1	0.00
1913.480	244.1	3.970	Vou6 Sla3 Lv_1 VBs3 WFD1	Visual	19.10	6.37	0.3	-0.03	0.2	-0.03	0.2	-0.06
1914.407	244.7	4.018	Vys3 Rab7 Phl3 Chp1	Visual	24.39	8.13	0.7	0.06	0.7	0.06	0.6	0.03
1915.356	244.7	3.914	Dob3 Rab12 Frk3 Com2	Visual	17.85	5.95	0.6	0.00	0.6	0.00	0.5	-0.03
1916.340	245.0	3.814	VBs3 Rab10 Com3	Visual	23.42	7.81	0.8	-0.05	0.8	-0.05	0.7	-0.08
1917.474	244.4	3.875	Com3 J__2	Visual	14.45	4.82	0.0	0.07	0.0	0.07	-0.1	0.04
1918.480	243.9	3.770	Com3	Visual	5.92	1.97	-0.7	0.01	-0.7	0.01	-0.7	-0.01
1919.492	243.9	3.739	Com3 Lv_3	Visual	10.28	3.43	-0.8	0.03	-0.8	0.04	-0.9	0.01
1920.463	244.5	3.717	Dob3 Pav2 Cha4 Kpz4	Visual	21.56	7.19	-0.4	0.06	-0.4	0.06	-0.4	0.04
1921.459	244.9	3.588	Lbz2 VBs3 Prz4 Btz1 B__3	Visual	31.25	10.42	-0.1	-0.01	-0.1	-0.01	-0.2	-0.04
1922.501	245.0	3.600	Nec1 B__4 Lv_1 Dic5 Lbz1 Prz3 StG3 Pek3	Visual	38.34	12.78	-0.2	0.06	-0.2	0.06	-0.3	0.03
1923.469	245.0	3.551	Fur3 B__4 VBs2 Dic2 Rou2 Lv_3 Lbz2 Prz5 StG2	Visual	54.01	18.00	-0.4	0.06	-0.4	0.06	-0.4	0.04
1924.478	245.2	3.389	StG1 B__4 Dob4 Jan2 Fat2 Lv_2 Wtl1 VBs3	Visual	42.36	14.12	-0.3	-0.04	-0.3	-0.04	-0.4	-0.07
1925.445	245.9	3.377	B__4 Dob4 VBs3 StG4 Baz4 Lv_4 Ber6	Visual	37.08	12.36	0.2	0.00	0.2	0.00	0.1	-0.02
1926.455	245.9	3.183	VBs3 Lv_6 Ber6	Visual	18.40	6.13	0.0	-0.14	0.0	-0.13	-0.1	-0.16
1927.516	245.4	3.339	Rab4 Kom5 StG4 Baz2	Visual	19.27	6.42	-0.7	0.08	-0.7	0.08	-0.8	0.06
1928.443	246.4	3.348	Kom3 Buc5 Bea4	Visual	13.53	4.51	0.1	0.15	0.1	0.15	0.0	0.12
1929.255	246.3	3.170	VBs3 All2 Kom3	Visual	16.07	5.36	-0.2	0.02	-0.2	0.02	-0.2	0.00
1930.502	246.6	3.070	Kui4 Dob3 All1 Kom4 StG3 Baz19	Visual	28.37	9.46	-0.2	-0.01	-0.2	0.00	-0.2	-0.03
1931.455	247.1	2.901	VBs3 StG4 Smw6 All1 Kom4 Bon4	Visual	30.92	10.31	0.1	-0.11	0.1	-0.11	0.1	-0.14
1932.433	247.0	2.890	VBs2 Smw4 Kom3 StG4 Smw19 Rab5	Visual	38.78	12.93	-0.2	-0.06	-0.2	-0.06	-0.3	-0.09
1933.572	248.0	2.801	Baz4 Rab5	Visual	6.89	2.30	0.5	-0.08	0.5	-0.08	0.5	-0.10
1934.377	247.7	2.934	Rab10 Kui1 Dob4 Pok2	Visual	15.08	5.03	0.0	0.11	0.0	0.11	0.0	0.08

Table continues on next page.

The Rapid Convergence of 44 Boötis with Revised Orbit and Updated Ephemerides

Table 4, continued: 44 Boötis, normal points for each observation class and residuals, compared with the recent orbits

					Weights		Zirm 2010		Heintz 1997		Soederhjelm 1999	
Date	$\vartheta°_{2000}$	ρ"	Reference/Nights	Class	Wi ϑ"	Wi ρ"	O-C ϑ°	O-C ρ"	O-C ϑ°	O-C ρ"	O-C ϑ°	O-C ρ"
1935.161	249.0	2.702	Baz4 Rab6	Visual	4.84	1.61	1.0	-0.08	1.1	-0.07	1.0	-0.10
1936.396	250.5	2.778	Dur3 Rab6	Visual	3.94	1.31	2.2	0.08	2.2	0.09	2.2	0.06
1937.305	248.9	2.599	Baz4 Mlr4 Str5 Phl3 Rab9 Dur4	Visual	17.31	5.77	0.3	-0.04	0.3	-0.03	0.3	-0.06
1938.417	248.4	2.573	Mlr1 Str4 Woy5 Dur9 Mlr6 Rab8 Phl3	Visual	20.69	6.90	-0.6	0.01	-0.5	0.02	-0.5	-0.01
1939.446	249.2	2.433	Baz6 Mlr5 Scd5 Sem4 Woy3 Rab9 Dur13 Sem2 VBs4	Visual	36.20	12.07	-0.1	-0.06	-0.1	-0.05	-0.1	-0.08
1940.421	249.9	2.420	Kor4 Dur1 Rab9	Visual	13.09	4.36	0.2	0.00	0.3	0.01	0.3	-0.02
1941.430	250.5	2.264	Baz5 VBs5 Rab10 Sem4 Dur5	Visual	21.62	7.21	0.4	-0.09	0.5	-0.08	0.5	-0.11
1942.466	251.0	2.298	Ahn5 Dur10 Rab11	Visual	11.72	3.91	0.5	0.02	0.6	0.03	0.6	0.00
1943.381	251.8	2.122	Baz5 VBs1 Dur16 Rab9	Visual	20.35	6.78	0.9	-0.09	1.0	-0.08	1.0	-0.11
1944.387	252.7	2.058	VBs6 Dur12 Rab5	Visual	21.18	7.06	1.3	-0.08	1.4	-0.07	1.5	-0.11
1945.347	253.2	2.011	Baz5 VBs4 Arm2 Dur5	Visual	20.13	6.71	1.4	-0.06	1.4	-0.05	1.5	-0.08
1946.508	252.3	1.982	Mlr5 Rab5	Visual	4.94	1.65	-0.2	0.00	-0.1	0.01	0.0	-0.03
1947.305	252.3	2.002	Baz5 Mlr5 Mun3	Visual	7.91	2.64	-0.6	0.08	-0.5	0.09	-0.4	0.05
1948.478	253.9	1.831	Mlr3 Fok4 Rab7 Baz2 VBs2	Visual	14.12	4.71	0.3	-0.01	0.3	0.00	0.4	-0.04
1949.349	255.3	1.677	VBs4 Rab7 Baz2	Visual	9.91	3.30	1.1	-0.10	1.2	-0.09	1.3	-0.13
1950.379	255.8	1.634	VBs4 Mlr3 Rab10 Guy4	Visual	9.92	3.31	0.8	-0.06	0.9	-0.05	1.1	-0.09
1951.465	255.3	1.614	Mlr4 Pre1 Rab11 WRH2 Baz4	Visual	12.12	4.04	-0.6	0.00	-0.5	0.01	-0.3	-0.03
1952.381	256.2	1.485	VBs4 Mlr2 Pre1 Rab12	Visual	13.38	4.46	-0.5	-0.06	-0.4	-0.05	-0.1	-0.09
1953.468	258.1	1.404	Mlr3 Dju3 Rab9 Ces3 Baz4 VBs6	Visual	16.58	5.53	0.4	-0.06	0.4	-0.05	0.7	-0.09
1954.362	257.9	1.366	Guy2 Mlr5 Wie2 Rab7 Baz4	Visual	7.20	2.40	-0.8	-0.03	-0.7	-0.02	-0.4	-0.06
1955.394	258.9	1.307	Wor4 Mlr7 Cou3 Br_4 Baz5 Rab7 Fle5	Visual	12.36	4.12	-1.0	-0.01	-1.0	0.00	-0.6	-0.04
1956.373	261.7	1.222	VBs4 Mlr6 Br_3 Wor3 Rab4 Baz4	Visual	14.73	4.91	0.4	-0.02	0.5	-0.01	1.0	-0.05
1957.473	262.5	1.194	Sgt4 Mlr6 Clu3 Br_3 VBs6 Cou4 Dju4 Dic1 Hnz4 Pau4 Rab6 B__3	Visual	30.76	10.25	-0.4	0.03	-0.4	0.05	0.2	0.00
1958.476	264.3	1.116	Cou3 B__6 Wor3 VBs4 Clu3	Visual	14.80	4.93	-0.4	0.03	-0.4	0.04	0.4	0.00
1959.423	266.0	1.093	Hg_2 Cdy4 Dic1 Hnz3 Pau5 Sgt6 Wor4 Woy13	Visual	12.94	4.31	-0.6	0.08	-0.6	0.09	0.3	0.04
1960.465	269.2	0.958	Cou3 Dic1 Pau5 Hnz4 You3 Hei5 VBs7	Visual	12.26	4.09	0.1	0.02	0.1	0.03	1.2	-0.01
1961.591	272.4	0.886	Wor4 Cdy3 Woy3 Cou2 B__4 VBs12	Visual	8.91	2.97	0.2	0.03	0.1	0.04	1.6	0.00
1962.425	274.8	0.854	B__4 Wor4 Cou3 Pau2 Hei4 Hnz1 Lan1 Baz4	Visual	13.17	4.39	-0.1	0.06	-0.2	0.07	1.5	0.02
1963.371	279.0	0.720	VBs5 Wor3 Dur9 Hei6 B__6 Cou3 Pau3 Hnz4	Visual	11.53	3.84	0.5	-0.01	0.3	0.00	2.4	-0.05

Table continues on next page.

The Rapid Convergence of 44 Boötis with Revised Orbit and Updated Ephemerides

Table 4, continued: 44 Boötis, normal points for each observation class and residuals, compared with the recent orbits

					Weights		Zirm 2010		Heintz 1997		Soederhjelm 1999	
Date	ϑ°2000	ρ"	Reference/Nights	Class	Wi ϑ"	Wi ρ"	O-C ϑ°	O-C ρ"	O-C ϑ°	O-C ρ"	O-C ϑ°	O-C ρ"
1964.445	283.1	0.677	Cdy5 Wor4 Cou2 Sym8 Dju2 Pop2 Baz4	Visual	7.07	2.36	-0.3	0.01	-0.6	0.03	2.1	-0.02
1965.305	287.7	0.642	VBs8 Dur13 Cdy5 Sle3 Wor4 Dju3 Hei4	Visual	7.00	2.33	-0.4	0.03	-0.9	0.04	2.5	0.00
1966.334	294.9	0.571	Dur5 VBs8 Wak4 Wor9 Sym3 Mlr4 Baz2	Visual	10.06	3.35	0.1	0.01	-0.6	0.03	3.7	-0.01
1967.388	302.0	0.534	Dur5 Wor6 Wak3 Sym5 Baz4 VBs2 Srb3	Visual	5.44	1.81	-1.0	0.02	-2.0	0.04	3.4	0.00
1968.404	312.1	0.506	VBs6 Wor8 Wak3 Dur5	Visual	7.88	2.63	-0.2	0.03	-1.6	0.04	5.0	0.01
1969.419	324.1	0.479	Wor4 Cou2 Baz4	Visual	2.67	0.89	1.3	0.02	-0.3	0.03	7.2	0.01
1970.455	334.8	0.508	Wor6 Ary3 Wak2 Dur4	Visual	1.47	0.49	0.8	0.06	-1.0	0.06	7.0	0.05
1971.492	346.2	0.515	Cou2 Wor2 Dur1	Visual	1.50	0.50	1.1	0.05	-0.7	0.05	7.3	0.06
1972.381	355.9	0.480	Wor4 Dur5	Visual	2.16	0.72	2.1	-0.01	0.4	-0.01	7.9	0.01
1973.455	3.4	0.561	Dur6 Wie1 Hei4 Wor4 Hln4	Visual	3.95	1.32	0.3	0.03	-1.2	0.03	5.5	0.06
1974.395	10.1	0.584	Dur3 Wor4 Cou2 Beh3	Visual	4.02	1.34	0.1	0.01	-1.2	0.00	4.7	0.04
1975.398	16.5	0.611	Ole1 Hei4 Wor4 Wie4 Wak2 Beh1	Visual	4.53	1.51	0.4	-0.02	-0.8	-0.03	4.3	0.01
1976.450	21.6	0.725	Wor3 Wie4 Wak2	Visual	2.10	0.70	0.2	0.03	-0.8	0.02	3.5	0.07
1977.343	25.6	0.839	Hei3 Wor3 Wie2	Visual	2.32	0.77	0.4	0.08	-0.4	0.08	3.3	0.13
1978.488	30.1	0.849	Wie4 Hln2 Wor4	Visual	4.60	1.53	0.8	0.02	0.2	0.01	3.3	0.06
1979.460	33.8	0.920	Wor3	Visual	1.98	0.66	1.7	0.02	1.1	0.01	3.8	0.07
1980.418	35.5	1.007	Cll3 Wor2 Hei3	Visual	4.88	1.63	0.9	0.04	0.4	0.03	2.8	0.09
1982.416	38.7	1.240	Wor4 Ary2 Wie3 Mss3	Visual	6.15	2.05	0.0	0.13	-0.3	0.11	1.6	0.18
1985.531	45.6	1.382	Wie2 Wor3	Visual	3.12	1.04	2.3	0.05	2.1	0.03	3.4	0.10
1986.437	44.9	1.462	Tob1 Stu3 Sca1 Wor5	Visual	5.67	1.89	0.5	0.07	0.4	0.05	1.6	0.12
1987.350	45.6	1.660	Doc2	Visual	2.34	0.78	0.2	0.20	0.1	0.18	1.2	0.25
1988.434	46.1	1.600	Stu5 Wie1 Gel5	Visual	4.53	1.51	-0.4	0.07	-0.4	0.05	0.6	0.12
1989.750	49.4	1.628	Stu4 Gir1 Wor4	Visual	5.00	1.67	1.8	0.02	1.8	-0.01	2.7	0.06
1990.356	48.0	1.589	Tob1 Kzn5 Ary4	Visual	2.91	0.97	-0.1	-0.06	-0.1	-0.09	0.7	-0.01
1991.620	49.7	1.780	Ary3	Visual	0.94	0.31	0.6	0.06	0.7	0.02	1.4	0.10
1992.459	49.9	1.799	Tob2 Stu4 Kzn5 Ary5	Visual	5.41	1.80	0.2	0.03	0.3	-0.01	1.0	0.07
1993.463	49.6	1.842	Stu3 Kzn4 Ary4	Visual	3.21	1.07	-0.8	0.02	-0.6	-0.03	0.0	0.06
1994.576	52.0	1.916	Tob2 Ary4 WFD4	Visual	4.22	1.41	0.8	0.05	1.1	-0.01	1.6	0.08
1995.471	51.2	1.853	Tob3 Doc3 Ary4	Visual	6.87	2.29	-0.5	-0.05	-0.2	-0.12	0.3	-0.02
1996.498	52.7	1.951	Ctt4 Hei3 Kzn3 Ary4	Visual	9.09	3.03	0.4	0.01	0.7	-0.07	1.1	0.03
1997.465	52.7	1.926	Alz4 Kzn3 Ary5	Visual	9.61	3.20	-0.2	-0.05	0.2	-0.14	0.6	-0.03
1998.519	53.4	1.962	Alz2 Tob1 Ary5	Visual	4.85	1.62	-0.1	-0.04	0.4	-0.15	0.7	-0.02
1999.456	54.4	2.021	Alz3 Tob1 Tob1 Ary5	Visual	6.33	2.11	0.4	0.01	1.0	-0.12	1.2	0.02
2000.452	54.5	2.046	Alz4 Ary5	Visual	4.32	1.44	0.0	0.02	0.6	-0.13	0.7	0.03
2001.459	55.1	2.027	Alz4 Ary5	Visual	5.53	1.84	0.1	0.00	0.7	-0.17	0.8	0.00
2002.499	55.3	2.034	Alz4 Ary5	Visual	5.55	1.85	-0.3	0.02	0.5	-0.18	0.4	0.01
2003.490	56.7	1.989	Alz2 Ary4	Visual	4.83	1.61	0.6	-0.01	1.4	-0.24	1.3	-0.02
2004.495	56.7	1.934	Alz2 Ary3	Visual	4.51	1.50	0.0	-0.04	1.0	-0.30	0.8	-0.05

Table continues on next page.

The Rapid Convergence of 44 Boötis with Revised Orbit and Updated Ephemerides

Table 4, continued: 44 Boötis, normal points for each observation class and residuals, compared with the recent orbits

					Weights		Zirm 2010		Heintz 1997		Soederhjelm 1999	
Date	$\vartheta°_{2000}$	ρ"	Reference/Nights	Class	Wi ϑ"	Wi ρ"	O-C ϑ°	O-C ρ"	O-C ϑ°	O-C ρ"	O-C ϑ°	O-C ρ"
2005.455	57.7	1.902	Alz3 Ary5	Visual	5.00	1.67	0.4	-0.03	1.6	-0.33	1.2	-0.05
2006.507	57.6	1.836	Alz3 Ary6	Visual	5.01	1.67	-0.3	-0.04	1.0	-0.39	0.5	-0.06
2007.494	59.2	1.835	Alz2 Ary6	Visual	4.83	1.61	0.7	0.02	2.2	-0.37	1.5	0.00
2008.548	60.4	1.680	Ary4	Visual	1.93	0.64	1.1	-0.06	2.9	-0.50	2.0	-0.07
1889.520	241.2	4.700	Kin1	Phot+CCD	4.70	4.70	-0.1	-0.084	-0.1	-0.074	-0.2	-0.144
1904.270	243.4	4.360	Thi1	Phot+CCD	4.36	4.36	0.7	-0.019	0.6	-0.016	0.5	-0.059
1915.322	243.9	3.909	Hzg7	Phot+CCD	7.82	7.82	-0.2	-0.004	-0.2	-0.003	-0.3	-0.033
1919.356	244.7	3.712	Hzg2	Phot+CCD	7.42	7.42	0.0	0.001	0.0	0.001	-0.1	-0.026
1922.437	245.0	3.540	Mch1	Phot+CCD	7.08	7.08	-0.2	-0.007	-0.2	-0.006	-0.2	-0.032
1926.464	246.1	3.301	Mch2 Lbz1	Phot+CCD	16.51	16.51	0.2	-0.017	0.2	-0.016	0.1	-0.041
1930.320	246.8	3.170	Reu2	Phot+CCD	6.34	6.34	0.1	0.084	0.1	0.086	0.0	0.061
1938.310	248.9	2.555	Jef2	Phot+CCD	10.22	10.22	0.0	-0.011	0.0	-0.006	0.0	-0.034
1941.490	250.0	2.306	Str1	Phot+CCD	4.61	4.61	-0.1	-0.040	0.0	-0.033	0.0	-0.063
1949.184	254.2	1.747	DeO2	Phot+CCD	6.99	6.99	0.1	-0.040	0.2	-0.029	0.3	-0.067
1951.483	255.6	1.567	Jef1	Phot+CCD	3.13	3.13	-0.3	-0.048	-0.2	-0.036	0.0	-0.076
1953.502	257.3	1.417	Jef1	Phot+CCD	2.83	2.83	-0.5	-0.045	-0.4	-0.032	-0.1	-0.075
1954.292	258.1	1.320	Jef1	Phot+CCD	2.64	2.64	-0.5	-0.082	-0.4	-0.069	-0.1	-0.112
1955.209	260.0	1.294	Jef1	Phot+CCD	2.59	2.59	0.3	-0.038	0.4	-0.025	0.8	-0.069
1957.190	261.9	1.089	Gzl1	Phot+CCD	1.09	1.09	-0.6	-0.093	-0.5	-0.079	0.0	-0.125
1997.660	53.9	2.000	ADP10	Phot+CCD	4.00	4.00	0.9	0.021	1.3	-0.076	1.7	0.042
2003.366	55.8	1.995	Izm8	Phot+CCD	7.98	7.98	-0.3	-0.008	0.6	-0.233	0.5	-0.015
2004.234	55.9	1.971	Izm7	Phot+CCD	7.88	7.88	-0.7	-0.009	0.3	-0.263	0.1	-0.020
2005.180	56.9	1.945	Izm4	Phot+CCD	7.78	7.78	-0.2	-0.001	0.9	-0.290	0.6	-0.014
2006.241	57.4	1.897	Izm5	Phot+CCD	7.59	7.59	-0.3	0.001	0.9	-0.331	0.5	-0.013
2007.401	57.9	1.816	Izm6 WSI2 Smr1	Phot+CCD	16.34	16.34	-0.6	-0.009	0.9	-0.394	0.2	-0.022
2008.333	58.3	1.723	Ant2 Smr1	Phot+CCD	5.17	5.17	-0.8	-0.033	0.9	-0.465	0.0	-0.043
2009.347	60.4	1.680	Ant1 Smr1	Phot+CCD	3.36	3.36	0.5	0.010	2.5	-0.475	1.4	0.006
1976.241	21.2	0.684	McA5	Speckle	11.63	11.63	0.7	0.001	-0.3	-0.006	4.2	0.039
1977.136	24.7	0.745	McA2	Speckle	3.73	3.73	0.3	0.004	-0.6	-0.004	3.3	0.045
1978.183	29.1	0.813	McA2	Speckle	4.07	4.07	0.8	0.001	0.1	-0.008	3.4	0.045
1979.464	32.5	0.906	McA2 Tok1	Speckle	4.53	4.53	0.4	0.005	-0.2	-0.006	2.5	0.051
1980.318	35.0	0.977	McA2	Speckle	7.82	7.82	0.7	0.015	0.2	0.003	2.6	0.063
1981.459	36.2	1.056	Tok2 McA3	Speckle	13.73	13.73	-0.6	0.012	-1.1	-0.001	1.0	0.061
1982.428	37.3	1.106	McA3 Tok1	Speckle	4.42	4.42	-1.4	-0.008	-1.7	-0.021	0.1	0.042
1983.471	40.8	1.190	McA4	Speckle	11.90	11.90	0.4	0.001	0.1	-0.014	1.7	0.052
1984.316	42.0	1.251	McA7	Speckle	25.02	25.02	0.3	0.002	0.1	-0.014	1.6	0.053
1985.333	43.2	1.323	McA5	Speckle	15.88	15.88	0.1	0.003	0.0	-0.015	1.3	0.053
1986.362	44.4	1.394	McA6	Speckle	19.52	19.52	0.1	0.003	0.0	-0.017	1.2	0.053
1987.261	45.3	1.459	McA6	Speckle	17.51	17.51	0.0	0.007	-0.1	-0.015	1.0	0.056
1988.175	46.0	1.508	McA7	Speckle	24.13	24.13	-0.2	-0.004	0.3	-0.029	0.8	0.044
1989.224	47.2	1.589	McA3 Iso3	Speckle	14.62	14.62	0.0	0.010	0.0	-0.019	0.9	0.056
1991.381	48.3	1.696	HIP1 Hrt1 WSI7 TYC1	Speckle	23.74	23.74	-0.7	-0.012	-0.6	-0.050	0.2	0.031
1992.428	48.6	1.745	WSI2	Speckle	3.49	3.49	-1.1	-0.020	-1.0	-0.065	-0.3	0.020

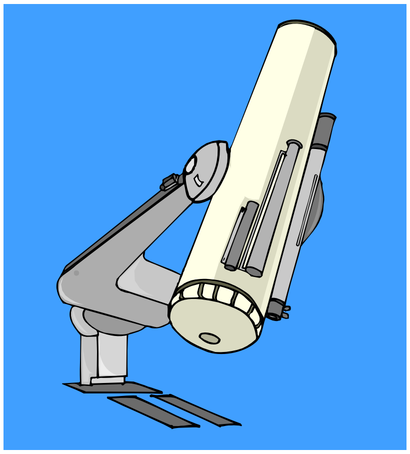
Table continues on next page.

The Rapid Convergence of 44 Boötis with Revised Orbit and Updated Ephemerides

Table 4, concluded: 44 Boötis, normal points for each observation class and residuals, compared with the recent orbits

					Weights		Zirm 2010		Heintz 1997		Soederhjelm 1999	
Date	$\vartheta°_{2000}$	ρ"	Reference/Nights	Class	Wi ϑ"	Wi ρ"	O-C ϑ°	O-C ρ"	O-C ϑ°	O-C ρ"	O-C ϑ°	O-C ρ"
1993.479	49.2	1.790	WSI2	Speckle	3.58	3.58	-1.2	-0.029	-1.0	-0.080	-0.4	0.008
1994.414	49.8	1.852	WSI5	Speckle	9.26	9.26	-1.2	-0.010	-1.0	-0.070	-0.5	0.024
1995.150	51.6	1.885	Hrt1	Speckle	3.77	3.77	0.1	-0.009	0.4	-0.075	0.9	0.022
1996.477	51.7	1.967	WSI3	Speckle	5.90	5.90	-0.6	0.024	-0.3	-0.057	0.1	0.050
1997.145	51.9	1.965	Hrt1 TtB1	Speckle	4.32	4.32	-0.8	0.001	-0.4	-0.089	0.0	0.023
1998.413	53.3	1.960	WSI5	Speckle	9.80	9.80	-0.1	-0.037	0.4	-0.145	0.6	-0.020
1999.379	53.1	2.025	WSI2	Speckle	4.05	4.05	-0.8	0.011	-0.3	-0.114	-0.1	0.023
2000.409	55.1	2.000	WSI3	Speckle	2.00	2.00	0.6	-0.025	1.2	-0.171	1.3	-0.018
2001.443	55.8	2.030	WSI1 Hor2	Speckle	6.09	6.09	0.8	0.003	1.4	-0.167	1.5	0.005
2002.385	55.6	1.900	WSI1	Speckle	0.38	0.38	0.1	-0.120	0.8	-0.315	0.8	-0.122
2004.274	56.6	1.975	Doc1 WSI3	Speckle	3.95	3.95	0.0	-0.004	1.0	-0.259	0.8	-0.015
2005.427	57.1	1.935	WSI4 Sca1	Speckle	5.81	5.81	-0.1	-0.001	1.0	-0.299	0.6	-0.014
2006.320	58.1	1.900	WSI2	Speckle	1.90	1.90	0.3	0.009	1.6	-0.327	1.1	-0.006

The author is a mechanical engineer involved in research and development for laser direct imaging technologies. In addition to double stars, he also enjoys hiking.



Neglected Double Stars: First Measurement of Double Star SEI 1007 and Updating Measures to SEI 1006AB, SLE 964AC, and SEI 1011

Giuseppe Micello

Bologna
Emilia Romagna, Italy

EMAIL: 7mg8@libero.it

Abstract: The purpose of this study is to obtain updated measurements of the double star SEI 1007, discovered by J. Scheiner in 1896. Moreover, I updated the astrometric measurements of the double stars SEI 1006AB, SLE 964AC and SEI 1011. The data were controlled on Washington Double Star Catalog (General Catalog and "Neglected Doubles" section).

Introduction

I used the Washington Double Star Catalog to identify an interesting double star and to perform some astrometric measurements: SEI 1007 (WDS 20127+3642SEI1007). This double star was seen for the first time by J. Scheiner in 1896.

Moreover, I checked the archives of "Journal of Double Star Observations" to see if this double star had recently been measured.

In the same field of the CCD camera, near SEI 1007, there are other double stars including two observed by Scheiner in 1896: SEI 1006AB and SEI 1011.

From the Washington Double Star Catalog, I saw that SEI 1006AB is a triple star. The third companion belongs to the system SLE 964AC with the component C (visual magnitude 13) discovered and measured in 1985.

The main interest of this study is to obtain precise astrometric measurements of SEI 1007 and to compare new measurements of Theta and Rho with the measures of 1896.

Methods

With the collaboration of Lorenzo Preti on September 13, 2010 I obtained images of SEI 1007 and with processing, I have seen other double and multiple systems near SEI 1007.

I made some checks on Washington Double Star Catalog and on The Aladin Sky Atlas (NED, Simbad and DSS2.F.POSSII), and I identified the following systems: SEI 1006AB, SLE 964AC and SEI 1011.

In Figure 1, we see the reference field (The Aladin Sky Atlas) with the double stars identified, in the constellation Cygnus.

While in Figure 2, we see the field in the CCD camera with an exposure of about 10 seconds.

The telescope used was a Newton SkyWatcher 200/1000 on German equatorial mount EQ6 SkyScan and the optical train is composed of CCD camera MAGZERO MZ-5m and Barlow 2x Celestron Ultima.

In Figure 3, the secondary component of the system SLE 964AC has been carefully marked. The visual magnitude of this star is 13 and it position is more obvious with the image processing.

Neglected Double Stars: First Measurement of Double Star SEI 1007 and Updating Measures ...

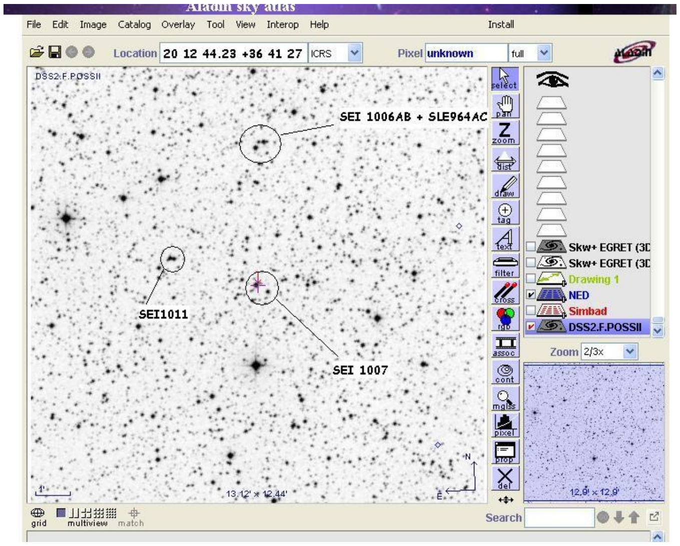


Figure 1: Reference field from the Aladin Sky Atlas.

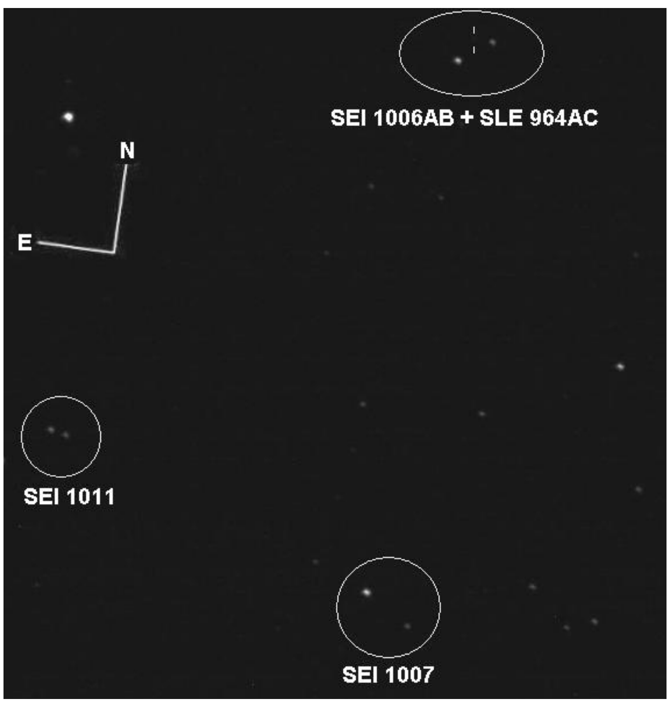


Figure 2: Field of the CCD camera.

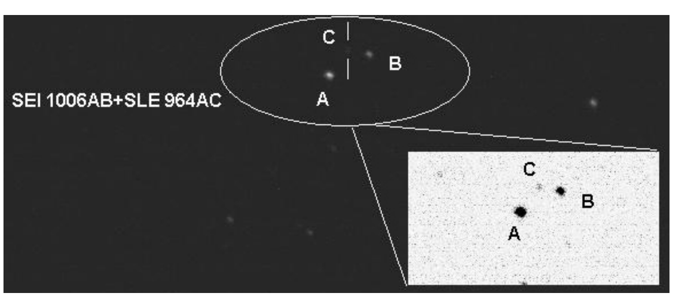


Figure 3: Detail of SEI 1006AB and SLE 964AC.

When I analyzed the data, I saw a difference in visual magnitude of the systems SEI 1006AB and SLE 964AC.

The latest measurements are in the WDS are dated 1999 and the Washington Double Star Catalog provides the following magnitudes:

SEI 1006AB: Mv1 = 12; Mv2 = 12.8
SLE 964AC: Mv1 = 12; Mv2 = 14.7

I compared the data with the The Aladin Sky Atlas (NED, Simbad and DSS2.F.POSSII) which list the magnitudes as:

SEI 1006AB: Mv1 = 9.8; Mv2 = 10.5
SLE 964AC: Mv1 = 9.8; Mv2 = 13.

All these data are shown in Table 1.

Measurements and Comparisons

The astrometric measurements were performed using the software "Reduc" (V3.88e), courtesy of Florent Losse (http://www.astrosurf.com/hfosaf/).

For calibration of the stars I used an image of Albireo, obtained during the September 13 observing session. The measure of Theta and Rho, useful for calibration, was taken from the Washington Double Star Catalog.

As shown in Table 2, the measures Theta and Rho of the systems studied have not changed significantly over time. SEI 1007, topic of this study, has a slight change in the values of separation and position angle in 114 years.

Conclusions

From the astrometric measurements performed on SEI1007, the difference of Theta and Rho between 1896 and 2010 are 0.56° and 0.496", respectively. The position angle and separation, based on a mean of 15 measurements, are:

Teta: 239.56°;
Rho: 23.004";
DeltaM = 1,29.

No significant changes were noted (Theta and Rho) of systems SEI 1006AB , SLE 964AC and SEI1011.

Acknowledgements

I sincerely thank Florent Losse for the excellent software "Reduc".

Neglected Double Stars: First Measurement of Double Star SEI 1007 and Updating Measures ...

Table 1: Table with astrometric measurements (WDS). (*) = Exact values reported in The Aladin Sky Atlas.

Name	Coordinate (WDS)	Theta - Rho	Mv1 - Mv2
SEI 1006AB (WDS 20127+3645SEI1006AB)	20 12 43.53 +36 45 20.1	306 – 17.0	9.8* - 10.5*
SLE 964AC (WDS 20127+3645SEI964AC)	20 12 43.53 +36 45 20.1	331 – 11.5	9.8* - 13*
SEI 1007 (WDS 20127+3642SEI1007)	20 12 44.23 +36 41 27.6	239 – 23.5	9.5 – 11.0
SEI 1011 (WDS 20129+3642SEI1011)	20 12 56.25 +36 42 17.9	258 – 7.0	10.5 – 11.0

Table 2: Periodic astrometric measurements with data updated to September, 2010 (*).

Nane	Theta - Rho (1)	Theta - Rho (2)	Theta - Rho (3)
SEI 1006AB	307 - 17.1 (1896)	306 – 17.0 (1999)	307.12* – 17.124* (2010.701)
SLE 964AC	328 - 11.5 (1985)	331 – 11.5 (1999)	331.44* – 11.571* (2010.701)
SEI 1007	239 – 23,5 (1896)	239.56* – 23.004* (2010.701)	
SEI 1011	260 – 6.4 (1896)	258 – 7.0 (2006)	258.87* – 6.841* (2010.701)

This work was done thanks to The Aladin Sky Atlas, the Washington Double Star Catalog and consulting the archives of Journal of Double Star Observations.

Thanks to Lorenzo Preti for giving me the images and Adriano for advice.

References

Brian D. Mason, Gary L. Wycoff, and William I. Hartkopf. Washington Double Star Catalog http://ad.usno.navy.mil/wds/

The Aladin Sky Atlas. http://aladin.u-strasbg.fr/aladin.gml

Miscellaneous New Common Proper Motion Stars

Carlos E. López

Observatorio Astronómico Félix Aguilar
San Juan, Argentina

celopez@speedy.com.ar

Abstract: We report the identification of fifteen new common proper motion stars detected during the course of an extensive data mining search in astrometric and non-astrometric databases. In order to compile our final list, several catalogs were searched and compared; this approach allows us to avoid overlooking potential pairs due to large differences in the proper motions quoted in different databases for the same pair of stars.

Introduction

Our data mining search was started about eight years ago, mainly as a first project for undergraduate astronomy students interested in learning the different options included in the - at that time - new tool called Virtual Observatory. In order to define a focus for the project, it was decided to aim the search at double stars in general, exploring them with a two-fold purpose: to detect unreported common proper motion stars (CPMS) and to improve the astrometric parameters (coordinates, proper motions, separations and position angles) of already known systems listed in the Washington Double Star Catalog (WDS). With the purpose of providing participants with comprehensive training, the idea was to work with a telescope and observe those pairs showing large variations and differences with the values quoted in the WDS.

After a short time of searching, a wealth of data was collected and some students had the opportunity to use the Yale Southern Observatory Double Astrograph, located on the eastern side of the Andes (San Juan, Argentina) where they were introduced to the use of CCD detectors. Reports about our data mining program in general have been published by López (2004, 2006) and López, Mallamaci and Veramendi (2004). For different reasons, the program was in some way discontinued and a large amount of information was left on stand by for roughly five years.

In 2009 it was decided to resume the search starting by a general revision of all the material. In doing so, new CPMS were identified and other types of objects were included in our search (see López, 2008 and López and Varela Mugas, 2008 for details). We are now able to communicate some results, while about 500 new additional CPMS are still being processed and will be communicated as soon as possible.

Search and Results

Our search was first conducted by analyzing southern areas of the SuperCOSMOS Sky Survey Catalogue (SSS) (Hambly *et al.* 2001) around LDS doubles. This approach was used to improve the astrometric data for the LDS themselves as well as to detect potential new members for those systems. At the same time, the search was oriented to the detection of new, unreported CPMS. To this end, different limits and constraints were applied to the detections. In all cases, Halbwachs' (1986) criteria were used to

Miscellaneous New Common Proper Motion Stars

keep or reject the pairs.

After a list of pre-selected objects was compiled, we made a comparison of the astrometric data quoted in SSS, NOMAD (VizieR I/297), UCAC3 (VizieR I/315), and 2MASS Point Sources (VizieR II/246). This step allowed us to detect large differences (mainly in proper motions) among the catalogs we used (see the comment below for the system 12AB).

Our identifications are listed in Table 1. We refer to them as unreported since they were not found in the online version of the WDS we checked on September 19, 2010. For each star, we list an object identification, Right Ascension and Declination (from 2MASS), magnitude, proper motion (in mas/yr), epoch and PA (in degrees) and Sep (in seconds of arc). This data was primarily taken from the SSS, although some information was extracted from NOMAD and UCAC3.

Since the data we present in Table 1 has been taken from a variety of astrometric sources, we decided to use the coordinates given in 2MASS to compute the PA and Sep in order to have a more uniform type of data. The epochs listed in this Table correspond to the 2MASS epoch for each Right Ascension and Declination.

Acknowledgements

This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory and the Aladin facilities.

This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

References

Halbwachs, J. L. (1986) “Common proper motion stars in the AGK 3” Astronomy and Astrophysics Supplement Series **66**, 131.

Hambly, N. C.; MacGillivray, H. T.; Read, M. A. et al. (2001) “The SuperCOSMOS Sky Survey - I. Introduction and description” Monthly Notices of the Royal Astronomical Society **326**, 1279.

López, C. E. (2004) “Astrometry with Virtual Observatories” Astrophysics and Space Science **290**, 439.

López, C. E. (2006) “Improved Astrometric Parameters for Equatorial LDS Systems” *RevMexAA (Serie de Conferencias)* **25**, 16.

López, C. E. (2008) “New Common Proper Motion Stars in the LSPM-North Catalogue” *Revista Mexicana de Astronomía y Astrofísica (Serie de Conferencias)* **34**, 123.

López, C. E., Mallamaci, C., and Veramendi, M. E. (2004) “Astrometric Data for Southern Double Stars”, ADeLA Publications Series, No. 1, 213.

López, C.E., and Varela Mugas, M. L. (2008) “A Revision of the Trapezium Systems Catalogue” *Revista Mexicana de Astronomía y Astrofísica (Serie de Conferencias)* **34**, 125.

Table 1 begins on the next page.

Miscellaneous New Common Proper Motion Stars

Table 1: Data on the individual star of each pair.

Object	RA (2000.0) Dec	Mag	pmRA	pmDec	Epoch	PA	Sep	Notes
1 A	00 00 03.819 -01 22 24.42	12.3	123.9	34.6	1998.8	347	6.2	1
B	00 00 03.725 -01 22 18.38				1998.8			
2 A	00 06 29.729 -07 37 07.73	14.6	-48.3	-49.6	1998.8	299	48.6	2
B	00 06 26.873 -07 36 44.13	17.2	-46	-42	1998.8			
3 A	00 17 38.109 -32 50 00.19	16.3	121.9	-100	1998.9	181	13.5	
B	00 17 38.084 -32 50 13.65	17.8	120.1	-93.7	1998.9			
4 A	00 44 36.893 -39 17 13.13	12.6	175.4	29	1999.6	152	92.4	
B	00 44 40.569 -39 18 35.07	19.7	181.5	32.1	1999.6			
5 A	01 20 46.347 -09 33 36.52	15.3	48	84	1998.8	90	8.9	3
B	01 20 46.946 -09 33 36.53	19.8	58	76	1998.8			
6 A	01 23 07.832 -32 40 23.42	17.3	100.9	-137.4	1998.9	286	44.7	
B	01 23 04.427 -32 40 11.06	18.6	102.6	-134.4	1998.9			
7 A	01 25 08.736 -15 47 02.88	18.1	55.7	-13	1998.6	335	25.8	
B	01 25 07.987 -15 46 39.44	19.2	57.2	-13.8	1998.6			
8 A	01 26 36.747 +00 37 30.94	18.1	-10	-62	2000.7	96	12.5	4
B	01 26 37.574 +00 37 29.56	18.9	-10	-60	2000.7			
9 A	01 32 45.961 -13 36 36.06	14.8	110.5	13.1	2000.9	347	14.3	
B	01 32 45.739 -13 36 22.17	18	104.4	9.1	2000.9			
10 A	02 42 43.914 -15 13 05.67	16.7	-20	-68	1998.6	224	28	5
B	02 42 42.580 -15 13 25.98	17.7	-20	-74	1998.6			
11 A	02 48 47.151 -03 01 08.05	10.8	171.9	100.3	1998.7	333	49.3	6
B	02 48 45.665 -03 00 24.11	19.8	160	106	1998.7			
12 A	02 57 06.336 -12 43 59.40	15	-37.0	-132	1998.6	18	8.9	7
B	02 57 06.520 -12 43 50.87	15.7	-42.0	-103	1998.6			
13 A	03 26 59.834 -20 47 22.29	13.8	150.5	-46.3	1998.9	28	61.9	
B	03 27 01.934 -20 46 27.79	14	143.6	-48.0	1998.9			
14 A	03 33 18.327 -43 25 10.02	14.5	239.1	146.9	1999.6	21	16.3	8
B	03 33 18.870 -43 24 54.81	19.8	220.6	144.7	1999.6			
15 A	09 25 58.176 -15 35 14.66	14.7	-44.0	-20.0	1998.2	19	37.2	9
B	09 25 59.017 -15 34 39.53	17.9	-52	-28.0	1998.2			

Miscellaneous New Common Proper Motion Stars

Table Notes

1. Proper motion and V magnitude for the A component taken from NOMAD. The B component is not included in the SSS and the NOMAD proper motion is zero in both coordinates. The A component is also included in UCAC3. Due to the small separation between these two stars we have been not able to determine a reliable proper motion for both components, however the blinking of POSS1 and POSS2 images clearly shows these two stars share a very similar proper motion. A composite image of the pair is shown in Fig. 1.

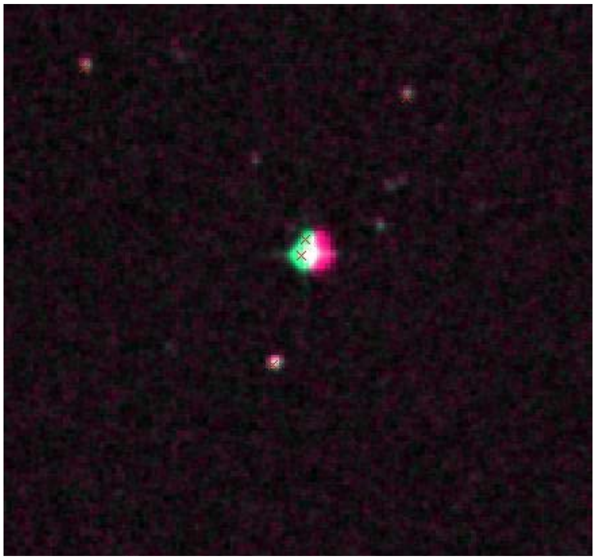


Figure 1: Aladin composite (POSS1, red and POSS2, green) image showing the motion of this pair. The crosses mark 2MASS positions. For all the figures, North is up and East is to the left.

2. Proper motions and B magnitudes taken from NOMAD.
3. Proper motions and B magnitudes taken from NOMAD.
4. Proper motions and B magnitudes taken from NOMAD.
5. Proper motions and B magnitudes taken from NOMAD. This pair should not be confused with the nearby LDS 5391. See Fig. 2 for a proper identification.
6. Proper motion and B magnitudes taken from NOMAD.
7. The available proper motion determinations of this system are very discordant. The two stars are included in UCAC3, but with no proper motion determination for the A component and zero for the B one. They are also included in NOMAD with zero proper motion for A and a motion for the B component that does not match what is seen in the blinking of POSS1 and POSS2 images. This system is also included in the SSS with a proper motion that depends on the passband. The proper motion quoted on Table 1 is a preliminary value determined by us through the rereduction of DSS plate areas around this pair. The B magnitudes are from NOMAD. These two stars should not be confused with the nearby LDS 5406. A composite image of the pair is shown in Fig. 3.

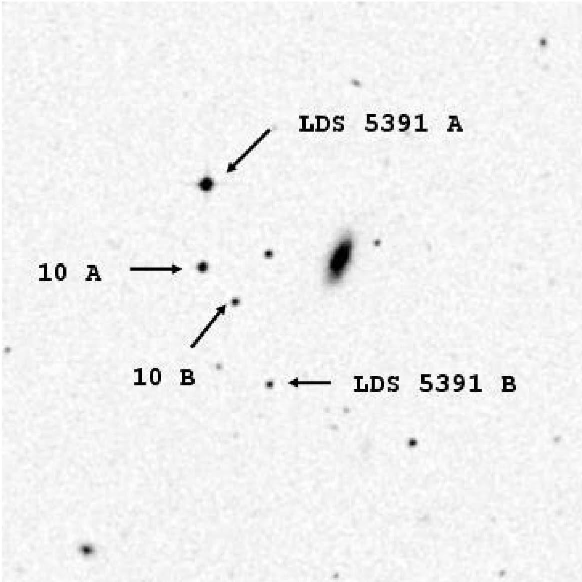


Figure 2: Location of pair 10 with respect to LDS 5391.

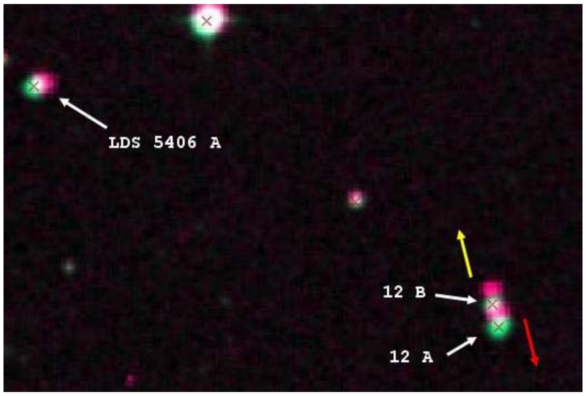


Figure 3: Aladin composite image showing the motion of pair 12. The yellow arrow shows the direction of motion according to the proper motion quoted by NOMAD for the B component. The red arrow represents the direction of motion suggested by the blinking of POSS1 (red, epoch 1955) and POSS2 (green, epoch 1995) images. The crosses mark 2MASS positions.

Miscellaneous New Common Proper Motion Stars

8. The A component is UCAC3 star, but with no proper motion determination.
9. Proper motions and B magnitudes taken from NOMAD. This pair is around 4.5 arc minutes to the south of the A component of LDS 3891. See Fig. 4 for a proper identification.

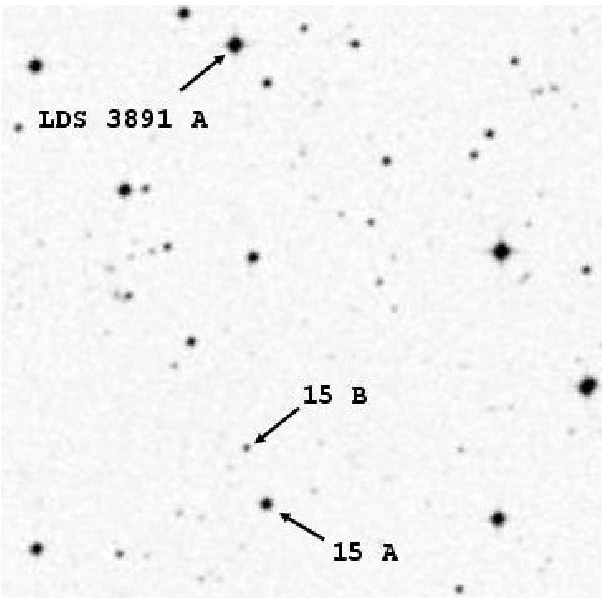


Figure 4: Location of pair 15 with respect to the A component of LDS 3891.

Carlos E. López teaches an introductory course in astronomy for undergraduate students at the National University of San Juan, Argentina.

Visual Measurements of the Binary Star S 654

Thomas G. Frey[1], Irina Achildiyev[2], Chandra Alduenda[2],
Reid Bridgeman[2], Rebecca Chamberlain[2], and Alex Hendrix[2]

1. California Polytechnic State University, San Luis Obispo
2. Evergreen State College, Olympia, Washington

Abstract: A member of the faculty and students from The Evergreen State College, Olympia, Washington, participated in the 2010 summer astronomy workshop at Pine Mountain Observatory. They learned the proper techniques and skills required for measuring the separation and position angle of binary star S 654. They learned how to calibrate an astrometric eyepiece, make appropriate measurements, do a statistical analysis, and analyze the data. The separation and position angle values obtained were 69.9 arc seconds and 237 degrees, respectively. The percent difference for each value was less than 0.5% from the literature value.

Introduction

An interdisciplinary group of undergraduate liberal arts and science students from The Evergreen State College (TESC) in Olympia, Washington, and students from other institutions, joined an invitational summer research workshop at Pine Mountain Observatory (PMO) near Bend, Oregon. The workshop ran from August 5-8, 2010. The observatory, run by the University of Oregon, hosted the workshop conducted by both professional and amateur astronomers. The projects included double star observations and measurements, photometry, and spectroscopy. The students from TESC participated in the double star research as part of a course entitled, *Astronomy and Cosmology: Stars and Stories*, taught by team member, Rebecca Chamberlain. None of the students had ever done any type of astronomy research, so a bright double star with moderate separation was selected for their project.

Figure 1: The Evergreen State College team, left to right: Thomas G. Frey, Professor Emeritus, California Polytechnic State University, Rebecca Chamberlain, Faculty, The Evergreen State College, followed by Chandra Alduenda, Irina Achildiyev, Reid Bridgeman, and Alex Hendrix, all students at Evergreen State College. The team is standing by Frey's 18-inch Obsession alt-az telescope used in this investigation.

Visual Measurements of the Binary Star S 654

Background

Double star observation began in 1650 when the Italian Giovanni Roccioli recorded Mizar, in the constellation Ursa Major, as a double star. But Sir William Herschel in the late 18th century is credited with the initiation of double star investigations. He utilized his 20 and 40-foot alt-azimuth reflectors without clock-drives to observe double stars. He therefore had to continuously move the telescope in both coordinates to keep the stars in the field of view. He published catalogs in 1782, 1784, and 1821 citing a total of 848 double stars. (Aitken 1935)

In 1802, Herschel presented a paper to the Royal Society entitled *Catalogue of 500 new Nebulae, nebulous Stars, planetary Nebulae, and Clusters of Stars; with Remarks on the Construction of the Heavens,* where it cites the distinction between optical and binary stars. Namely, "a real double star-the union of two stars that are formed together in one system, by the laws of attraction." (Aitken 1935)

Following in Herschel's footsteps, the German-Russian astronomer Friedrich G.W. von Struve, performed unparalleled observations using the Dorpat refractor, constructed by Joseph Fraunhofer. This telescope was undoubtedly the largest and finest refractor of its time. It was 13 feet long with a 9.5-inch objective lens and utilized a clock-drive on an equatorial mount. Struve stated that the telescope was so easy to manipulate and the optical properties were so excellent that he was able to examine 400 stars per hour. He surveyed 120,000 stars from 1823-1827. (Aitken 1935)

Other astronomers followed these historic beginnings into the modern period of astronomy research. S. W. Burnham of Chicago, who worked at the Dearborn, the Lick, and the Yerkes observatories, discovered over 1340 new double stars and made thousands of very accurate measurements. His 1906 *A General Catalogue of Double Stars within 121° of the North Pole* contained 13,665 double stars with measurements, notes, and complete references to all published papers regarding each pair. (Aitken 1935)

Presently, the Washington Double Star Catalog, under the direction of Brian Mason at the US Naval Observatory, has accumulated over 107,000 double star measurements (Mason 2009).

Historically, most double star measurements have been made using telescopes on equatorial mounts (Argyle 2004, and Teague 2000). In recent years, telescopes on altitude-azimuth mounts have been shown to be effective in these studies (Frey 2008). The double star research at Pine Mountain Observatory was conducted with Frey's 18 inch, f/4.5 Obsession telescope, equipped with a ServoCAT GOTO system and an Argo Navis computer. Double star measurements were made with an illuminated Celestron 12.5 mm Micro Guide astrometric eyepiece. Calibration of the eyepiece was done with a stopwatch having 0.01-second resolution.

Pine Mountain is located at +43.79 degrees north latitude and 120.94 degrees west longitude. During the observing period the transparency was very good with the exception of some smoky haze produced by a nearby forest fire, which had minimal effect on the observations. The seeing was excellent with minimum scintillation. The temperature during observing hours of 9:00 PM to 2:00 AM was 40-45 degrees Fahrenheit. Breezy conditions existed each night with occasional strong gusts which did hamper some results.

Calibration of the Celestron Micro Guide Astronomic Eyepiece

Double star measurements can only be carried out after the astrometric eyepiece-telescope system has been calibrated. The linear scale on the eyepiece is divided into 60 equal divisions. It is necessary to determine the number of arc seconds per division for each eyepiece-telescope setup. This calibration procedure has been described at length (Frey 2008). The reference star used for the calibration was Dubhe (Alpha Ursae Majoris), which fulfilled the requirement of a declination between 60-75 degrees. The students worked together as a team to learn the calibration procedure. The results of the calibration and determination of the scale constant is summarized in Table 1. Twelve observations were made with one outlier deleted. The statistical standard deviation and mean error are given to show the precision of the observations. The scale constant for the Celestron-Obsession setup is given in arc seconds per division.

Star	Bess. epoch	Declin.	#Obs	AvDrift time(sec)	Std dev	Mean error	Scale constant
Dubhe	B2010.594	61°75′	11*	86.30	0.94	0.29	10.23

Table 1. Scale Constant Determination. * One outlier

Double Star S 654

After determining the scale constant, the Obsession was two-star aligned and the tracking motors engaged. The double star selected for observation was S 654 in the constellation Canes Venatici. The primary star is a K0III giant star with a magnitude of 5.6. The secondary star is a F8V main sequence star with a magnitude of 8.9. These stars are sufficiently bright to be easily measured with the 18-inch aperture Obsession. This binary pair was first studied in 1825 when a separation of 71.3 arc seconds and position angle of 238 degrees was reported. The pair has been observed 24 times since then. The latest published observation in the Washington Double Star catalog was in 2004 with a separation of 70.1 arc seconds and position angle of 236 degrees.

There appears to have been little change in the orientation over 179 years. The primary star has a proper motion of RA: -134.18, Dec: -21.64 milli-arc seconds per year (SIMBAD, RA: 13 46 59.7, Dec: 38 32 33.7) and the secondary star has a proper motion of -135.20, -15.80 milli-arc seconds per year (TheSky6, RA:13 47 27, Dec: 38 29 30), indicating similar motions through space and the possibility of it being a visual binary star.

Separation Measurements of S 654

The telescope was two-star aligned and the servomotors engaged. The Celestron Micro Guide eyepiece was rotated until the central linear scale was parallel with the axis joining the two stars. The distances between the centers of the two stars was estimated to the nearest 0.1 divisions and recorded. Then, using the slow motion controls, the stars were shifted to a new location along the linear scale, a new measurement was made, and the process repeated many times. This method of moving the stars to new locations each time is to negate any systematic error that might exist if the stars were continually kept and measured at the same division marks. The method seemed to work very well since our standard deviation was only 0.37 divisions and the standard error of the mean was 0.11 divisions. The results of the separation measurements for S 654 are shown in Table 2. Thirteen observations were recorded with one outlier deleted due to a wind gust. The SD/ME are the standard deviation and standard error of the mean. The observed and literature separations are given in arc seconds. The percent difference is based on the difference between our observations and the most recently reported literature values.

Position Angle Measurements of S 654

The determination of the position angle using the drift method with an alt-az telescope has been described at length in a previous paper (Frey 2008). Briefly, it involves disengaging the servo-motors so the telescope becomes a “push Dob”. The double star is aligned with the linear scale and adjusted manually so when it is released the primary star drifts through the central division (the 30th division) and continues to drift to the outer protractor scales. It usually takes several attempts to get the star to drift precisely through the center. To compensate for field rotation, the eyepiece was continually adjusted so that the two stars remained aligned with the linear scale. The results of the position angle measurements for S 654 are shown in Table 3. Position angles (PA) are given in degrees. The SD/ME are the standard deviation and standard error of the mean. The percent difference for the positional angle is based on the difference between our observations and the most recently reported literature value.

Table 2. Separation Measurements for S 654 * One outlier

Double star	Identifier	Bess. epoch	Lit. epoch	# Obs.	SD/ME	Obs. sep	Lit. sep	% difference
S 654	134659+3832	B2010.594	2004	12*	0.37/0.11	69.9	70.1	-0.29%

Table 3: Position Angle Measurements for S 654

Double star	Identifier	Bess. epoch	Lit. epoch	# Obs.	SD/ME	Obs. PA	Lit. PA	% difference
S 654	134659+3832	B2010.594	2004	12	2.04/0.59	237	236	0.42%

Visual Measurements of the Binary Star S 654

Discussion

The separation measurements from 1825 and 2004 were 71.3 and 70.1 arc seconds, respectively. Our experimental separation taken in 2010 is 69.9 arc seconds, indicating a further statistically significant decrease in separation. If the orbit is elliptical, this could indicate that the secondary star is approaching the periastron since the change in separation from 1825 to 2004 was 1.2 arc seconds and the change from 2004 to 2010 was a proportionally larger 0.2 arc seconds. If the change had continued at the same rate from 2004 to 2010 as it did from 1825 to 2004, we would have expected a change of only 0.07 arc seconds instead of the observed 0.20 arc seconds. Yet, our precision was very good with a percent difference based on the literature value of -0.29%.

The position angle measurements were similarly close in agreement with the literature values. Yet the standard deviation of 2.04 indicated a much broader distribution of observed position angles. This is probably due to the fact that students taking position angle measurements for the first time have some problems aligning the double stars on the linear scale before allowing the drift to the protractor scale. There is also a slight parallax that occurs when looking at the values on the protractor scales. First-time investigators find it frustrating to read the angles on the protractor scale, seeing the numbers move slightly, resulting in erroneous values. This is one reason 12 observations were made to reduce these random errors. Even though the standard deviation was fairly high, by making many observations the percent difference of 0.42%, indicated a very close agreement between our observations and the most recent literature value.

Conclusions

The purpose of Rebecca Chamberlain's interdisciplinary course, *Astronomy and Cosmology: Stars and Stories*, is the introduction of "… cosmological concepts from mythology, literature, philosophy, and history, to an introduction to astronomy, archeo-astronomy, and theories about the origins of the universe" (Chamberlain 2010). She wanted the students "... to deepen their understanding of the principles of astronomy and refine their understanding of the role that cosmology plays in our lives ..." By attending the summer research workshop at Pine Mountain the students enhanced their observing skills and learned how to make fairly rigorous physical measurements of a double star, winding up with precise and accurate results.

The workshop experience consisted of a combination of rapidly learning the operation of a sophisticated telescope in a professional research context, the pleasure of the impressive viewing conditions at Pine Mountain Observatory, the satisfaction of successful class teamwork, and additional understanding of binary stars and telescope operation. Some students were surprised and perplexed by the ability of the telescope to focus the image of such distance objects. Some had experience using telescopes before the workshop but were never involved in scientific investigations. Through developing skills in making accurate readings, students discovered latent talents and achieved remarkably accurate results for new researchers, thus enhancing their motivation, focus, and discipline. Each member of this diverse team developed and offered different skills as they rotated through a variety of tasks, from recording observations, to assessing the data through analysis, to writing narratives that described their experience. Throughout the process, they supported each other's learning. Mentorship from the professional and amateur astronomers, along with the cutting edge scientific research being conducted and presented by various teams at PMO throughout the week, provided students with a guided, hands-on, professional experience in scientific methods of investigation and inquiry. This team of students, new to astronomical research, left trained and enthusiastic about continuing binary star research at their own institutions.

Acknowledgements

The team wants to thank Russ Genet, Jo Johnson, and Tom Smith for reviewing this paper and for their suggestions and corrections. We also want to thank Gregory Bothun, Director of Pine Mountain Observatory, Mark Dunaway, Kent Fairfield, Allan Chambers, and Rick Kang, for opening the facility and being on hand to answer questions and assist our needs. A special thanks goes to Danyal Medley at Celestron for the donation of a 12.5 mm Micro Guide astrometric eyepiece to Evergreen State College, and to Theresa Aragon (Dean of TESC Summer School), and Peter Robinson (Director of Lab I and Lab II, and Science Technician at TESC), for purchasing an additional 12.5 mm Micro Guide astrometric eyepiece. Thanks to Sarah Pederson, Tina Pearson, Lori Moore, Sharon Wendt, Frank Barber, Katie Frank, and the other members of the TESC community for their support. The workshop would never have been as successful with out the organization, dedication, and tireless effort of Richard Berry as Workshop Director. Our team also wants to recognize the other double star team leaders, Jo Johnson and Chris Estrada, for their cooperation and assistance with the project. Finally, if it weren't for Russ Genet's initial efforts, none of the double star projects would have taken place.

References

Aitken, Robert G., *The Binary Stars*, Dover Publications, Inc., New York, 1935.

Argyle, Robert, *Observing and Measuring Visual Double Stars,* Springer, London, 2004.

Chamberlain, Rebecca, course syllabus for *Astronomy and Cosmology: Stars and Stories*, 2010.

Frey, Thomas G., Spring 2008, *Journal of Double Star Observations,* **3(2),** p. 59-65.

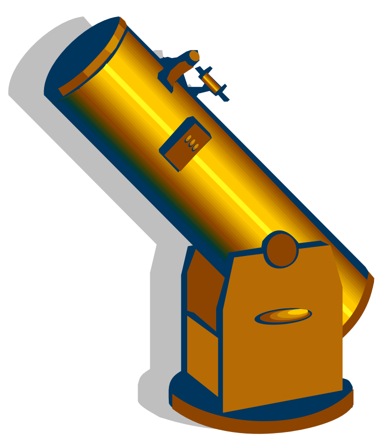
Mason, Brian, The Washington Double Star Catalog. July 2009. Astrometry Department, U.S. Naval Observatory. http://ad.usno.navy.mil/wds/wds.html.

SIMBAD database: http://simbad.u-strasbg.fr/simbad/.

Teague, Thomas, 2000, *Sky and Telescope,* July, 112-117.

TheSky6 software: http://www.bisque.com/sc/pages/thesky6family.aspx.

Thomas Frey is a Professor Emeritus of Chemistry at California Polytechnic State University. He was a Team Leader at the PMO Workshop 2009, and the Principle Investigator of the double star group at the PMO Workshop in 2010. Rebecca Chamberlain, is a Member of the Faculty at The Evergreen State College and teaches interdisciplinary programs that link sciences, humanities, and the arts. She has taught Earth and Sky Sciences for Antioch University's Teacher Education Program, and has worked as the lead Science Interpreter in the Starlab Planetarium at the Pacific Science Center. Irina Achildiyev, Chandra Alduenda, Reid Bridgeman, and Alex Hendrix are all students at Evergreen State College.



Visual Measurements of the Multiple Star STT 269 AB-C and ARN 8 AB-D

Thomas G. Frey[1], Irina Achildiyev[2], Chandra Alduenda[2], Reid Bridgeman[2], Rebecca Chamberlain[2], and Alex Hendrix[2]

1. California Polytechnic State University, San Luis Obispo
2. Evergreen State College, Olympia, Washington

Abstract: This astrometry project was performed by a member of the faculty and students from The Evergreen State College at the 2010 Pine Mountain Observatory Summer Science Research Workshop. This study involved measuring and analyzing the separation and position angles of the multiple star system STT 269 AB-C and ARN 8 AB-D. The astrometric binary AB was treated as a single star. Separation and position angles of the C and D components relative to AB were made. Percent differences between observed and literature values were all less than 1 percent.

Introduction

A multiple star astrometry investigation was performed by an interdisciplinary team (Figure 1) from The Evergreen State College (TESC) at the Pine Mountain Observatory (PMO) Summer Science Research Workshop near Bend, Oregon. The workshop was conducted August 5-8, 2010. This investigation involved the separation and position angle measurements of the multiple star system, STT 269 AB-C and ARN 8 AB-D, shown in a modified ALADIN image in Figure 2 (ALADIN previewer, RA: 13 32 50.99, Dec: +34 54 25.69).

Figure 1. Clockwise from top right: Thomas Frey, Alex Hendrix, Rebecca Chamberlain, Irina Achildiyev, Reid Brickman, and Chandra Alduenda. The team is gathered around Frey's 18" alt-az Obsession telescope used in this study.

Equipment

The instrumentation used in this investigation was the same as has been previously reported [Frey 2008], namely, an 18-inch Newtonian telescope by Obsession on an alt-az mount. The tracking unit was StellarCAT's ServoCAT GOTO system guided by an Argo Navis computer. A Celestron 12.5 mm Micro Guide astrometric eyepiece was used to measure the separation and position angles. Calibration of the Celestron eyepiece was unnecessary because the telescope was in the same configuration as in a previous study [Frey, et. al. 2010]. The scale constant for the linear scale, as previously determined, was 10.24 arc seconds per division. The standard deviation for the 11 observations was 0.94 arc seconds/division; the standard error of the mean was 0.29 arc seconds/division.

Locale and Observing Conditions

Pine Mountain is located east of Bend, Oregon at +43.79 degrees north latitude and 120.94 degrees

Visual Measurements of the Multiple Star STT 269 AB-C and ARN 8 AB-D

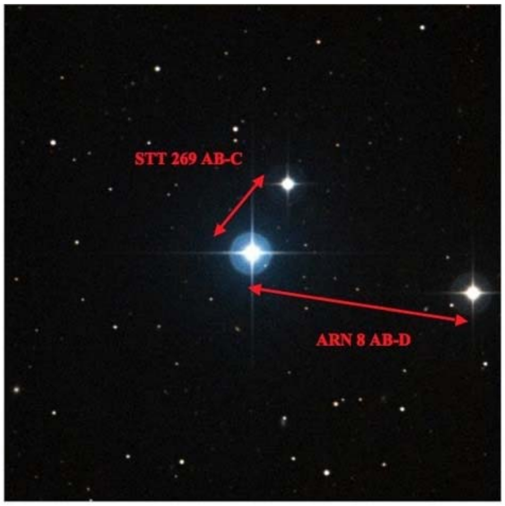


Figure 2: The multiple star system STT 269 AB-C and ARN 8 AB-D

west longitude. The sky was clear and the seeing was excellent with a minimum of scintillation. The temperature during observing hours was 40-45 degrees Fahrenheit. Breezy conditions existed each night with occasional strong gusts that did lead to a few outliers that were recorded, but were deleted from the analysis.

Background

In past workshops and undergraduate research seminars. double star investigations often follow the pattern of (1) calibration of the eyepiece, (2) collecting separation and position angle measurements on a "known " double star (a system that has been extensively studied), and (3) repeating this operation on a "neglected" double star. Neglected double stars are systems that have been rarely studied or have not been restudied for quite a while. For investigators new to double star research, the neglected double stars are chosen to be fairly bright and have separations of 25 arc seconds or greater because only an astronomic eyepiece is being used without a Barlow lens and cannot effectively measure dim stars or ones with small separations. The choice of neglected double stars in the northern hemisphere has diminished in recent years thanks to the Herculean efforts of such visual observers as David Arnold in Flagstaff, Arizona. The ones remaining on the neglected double star list are either too dim or too close together to be easily evaluated by beginners.

So the Pine Mountain Observatory team decided to measure a visual triple star system instead of attempting one of the neglected double stars. Triple stars are common, such as Σ279 in Andromeda (Haas 2006). The three stars are indicated by the letters A, B, and C listed in this order and, usually, in diminishing brightness. In essence, this study is like measuring two double stars in the same field of view, with the same primary star. Since triple star measurements are less often reported, the students decided to take on the challenge.

The multiple star chosen was STT 269 AB-C and ARN 8 AB-D. Frey had originally requested a list of triple stars from Brian Mason, Director of the Washington Double Star Catalog (WDS) at the US Naval Observatory [Mason, 2010]. His request included stars with no RA limits, declinations limited from -15 to +90 degrees, separations greater than 15 arc seconds and magnitudes for each star no greater than 11. Mason graciously sent a list of 26 possible candidates. As an added bonus the 26 were actually quaternary systems. The four-star system selected for observation by the TESC team visually appears as a triple star since the A and B components have a very small separation. The stars are in the constellation Canes Venatici.

Historical Information on STT 269 AB

The investigation of STT 269 AB began in 1843 when it was discovered by Otto Struve, the son of the Russian astronomer Friedrich G. W. von Struve. In 1839 the Russian government called upon Friedrich to build and direct the new Imperial Observatory at Pulkowa. The principle instrument was an equatorial refractor with a 15-inch objective lens. This was the largest refractor in the world at the time just as the 9.5-inch Fraunhofer refractor at Dorpat Observatory had been in 1824. It was thought that this 15-inch instrument might reveal double stars that had escaped detection by the Dorpat refractor due to smaller angular separations or faint components [Aitken 1935]. Otto Struve's observations of STT 269 AB revealed a binary system having magnitudes 7.3 and 8.1 with a position angle of 210 degrees and a separation of 0.3 arc seconds (Mason 2009). This separation was just within the Dawes limit for this instrument.

In 1879 the third star of the system was identified as the "C" component of STT 269 AB-C with a position angle of 333 degrees relative to the AB components, a separation of 116.5 arc seconds, and magnitude of the "C" star of 9.2. Its spectral type is F5.

The Dawes Limit

If two stars of approximately the same magnitude are close enough that their Airy disks overlap, they will be seen as an elongated single star. If these disks generate a figure-8 shape and the light intensity between the two touching disks drops by 30%, the two stars can still be viewed as separate stars. William Dawes (1799-1868), an English astronomer, discovered that the smallest separation between two stars manifesting this 30% drop in intensity can be determined by the empirically developed formula

Dawes Limit = 4.56 arc seconds/A

where A is the aperture of the objective lens in inches. The larger the aperture, the smaller the Dawes limit. For a 15-inch refractor, the Dawes limit is 0.304 arc seconds. Dave Arnold (Arnold 2010), a well known double star observer, pointed out that Struve's 15-inch refractor had the theoretical capability to resolve this pair, especially since the difference in magnitudes were minimal (7.3 and 8.1). The combined magnitude of the two stars in STT 269 AB listed in the WDS is 6.8.

Current Separation and Position Angle of STT 269 AB

In 2007, according to the WDS, the position angle of STT 269 AB had changed to 220 degrees while the separation had remained constant at 0.3 arc seconds. This system, also known as ADS 8939, has been used as an astrometric standard to calibrate deformable secondary mirror adaptive optic systems [Close 2003]. Its separation of 0.3 arc seconds in our telescope, using just the Celestron astrometric eyepiece, cannot be detected and thus it appears as a single star.

Separation and Position Angle Measurements of STT 269 AB-C

After performing two star alignment and engaging the servo motors, 21 separation trials were taken and 4 outliers were deleted due to strong wind gusts leaving a total of 17 observations. The separation of the AB-C system in the current study was determined to be 123.4 arc seconds. The most recent WDS separation, determined in 2002, was 122.5 arc seconds. The standard deviation of our observations was 0.53 arc seconds, while the standard error of the mean was 0.13 arc seconds. The percent difference from the most recent literature value was 0.74%. These values are summarized in Table 1. The Besselian epoch for all measurements recorded in this study was B2010.597.

The position angle was then evaluated. Some 15 trials with no outliers were observed. Our observationally determined position angle was 331 degrees, compared to the WDS value of 332 degrees. The standard deviation was 0.66 degrees and the standard error of the mean was 0.18 degrees. The percent difference from the most recent literature value was -0.30%. These values are summarized in Table 2.

Separation and Position Angle Measurements of ARN 8 AB-D

The separation measurements of both STT 269 AB-C and ARN 8 AB-D were taken consecutively while the servo motors were still engaged. After the separation measurements had been completed, the servo motors were disengaged and the position angles evaluated by the drift method. Both operations were easily manipulated because all stars in the system were in the same field of view.

In 1919, the fourth "D" star was incorporated into the system. It was originally observed with position angle of 259 degrees from STT 269 AB, a separation of 357.1 arc seconds, and the magnitude of the "D" component was 8.4. Dave Arnold is the official discoverer of ARN 8 AB-D, dated in 2002. The 1919 data were obtained from other catalogs available to the Naval Observatory (Mason 2010). Arnold's discovery of the AB-D system occurred in 2002 with an 8"

Table 1: Separation Measurements for STT 269 AB-C. *plus 4 Outliers

Star System	Identifiers	Lit. Epoch	# Obs.	SD/ME	Obs. Sep.	Lit. Sep.	% Diff.
STT 269AB-C	13 32 52.1 +34 54 25.8	2002	17*	0.53/0.13	123.4	122.5	0.74

Table 2: Position Angle Measurements for STT 269 AB-C

Star System	Identifiers	Lit Epoch	# Obs.	SD/ME	Obs. PA	Lit. PA	% Diff.
STT 269AB-C	13 32 52.1 +34 54 25.8	2002	15	0.66/0.18	331	332	-0.30

Visual Measurements of the Multiple Star STT 269 AB-C and ARN 8 AB-D

Table 3: Separation Measurements for ARN 8 AB-D. *plus 1 Outlier

Star System	Identifiers	Lit. Epoch	# Obs.	SD/ME	Obs. Sep.	Lit. Sep.	% Diff.
ARN 8AB-D	13 32 52.1 +34 54 25.8	2002	19*	0.42/0.10	349.7	352.5	-0.79

Table 4:. Position Angle Measurements for ARN 8 AB-D

Star System	Identifiers	Lit Epoch	# Obs.	SD/ME	Obs. PA	Lit. PA	% Diff.
ARN 8AB-D	13 32 52.1 +34 54 25.8	2002	12	1.08/0.31	258	260	-0.77

Schmidt Cassegrain telescope. The results were published in 2003 [Arnold 2003].

In 2002, position angle and separation measurements were taken yielding 260 degrees and 352.5 arc seconds, respectively. In the current study, 20 trials with 1 outlier deleted resulted in a separation of 349.7 arc seconds, with a standard deviation of 0.42 arc seconds and a standard error of the mean of 0.10 arc seconds. The percent difference from the most recent literature value was -0.79%. This information is summarized in Table 3.

The position angle was then observed with 12 trials (no outliers). The experimentally determined position angle was 258 degrees, compared to the most recent WDS value of 260 degrees. The standard deviation was 1.08 degrees and the standard error of the mean was 0.31 degrees. The percent difference from the most recent literature value was -0.77%. These values are summarized in Table 4.

Analysis

Triple star systems, analogous to double stars, can either be bound by gravity or just optically aligned by coincidence. For instance, the Alpha Centauri system is composed of two sun-like stars, Centauri AB, orbiting one another every 80 years, and Proximi Centauri located at a distance of about 15,000 AU, orbiting the AB components about every 100,000 to 150,000 years. All three components are bound by gravity. Beta Cephei, however, is composed of a true binary star and an optical component. In some other triple systems none of the components are bound by gravity due to the great distances between them, i.e. their alignment is just coincidental.

In order to specify the binary or optical nature of the star system it is necessary to examine the proper motion vectors and relative distances between the components. Some of the physical parameters for the star system STT 269 AB-C and ARN 8 AB-D are summarized in Table 5. Proper motion vectors and parallax values are given in milli-arc seconds per year (mas/yr).

Experienced double star observer, Dave Arnold, [Arnold 2010] explains that in order to be considered a true binary star, the proper motion vectors of a pair should have about 90% agreement. Examination of the AB-C and AB-D proper motion vectors in Table 5 shows that these vectors lay outside these restrictions and should be considered optical components. However, the STT 269 AB system has been studied at length [Close 2003] and with a separation of 0.3 arc seconds is considered an astrometric binary.

Examination of the standard deviation and standard error of the mean for separation and position angle for this system shows our measurements to be precise and in good agreement with the Washington Double Star data of 2002.

Figure 3 shows a modified ALADIN applet photo

Table 5: Parameters for SST 269 AB-C and ARN 8 AB-D

Star System	Proper Motion[1] (mas/yr)	Parallax (mas/yr)	Distance (parsecs)	Sep.[1] (arcsec)	Spectral Type	WDS Epoch
STT 269AB	(A)-046-015	5.73[2]	174.5	0.3	(A) A6III[1]	2007
STT 269AB-C	(AB)-046-015 (C) -082+037	4.36[3]	229.5[3]	122.5	(C) F5[3]	2002
STT 269AB-D	(AB)-046-015 (D) +013-027	2.31[3]	432.9[3]	352.9	(D) G0[3]	2002

1-Washington Double Star Catalog, 2-SIMBAD, 3-The Sky6

Visual Measurements of the Multiple Star STT 269 AB-C and ARN 8 AB-D

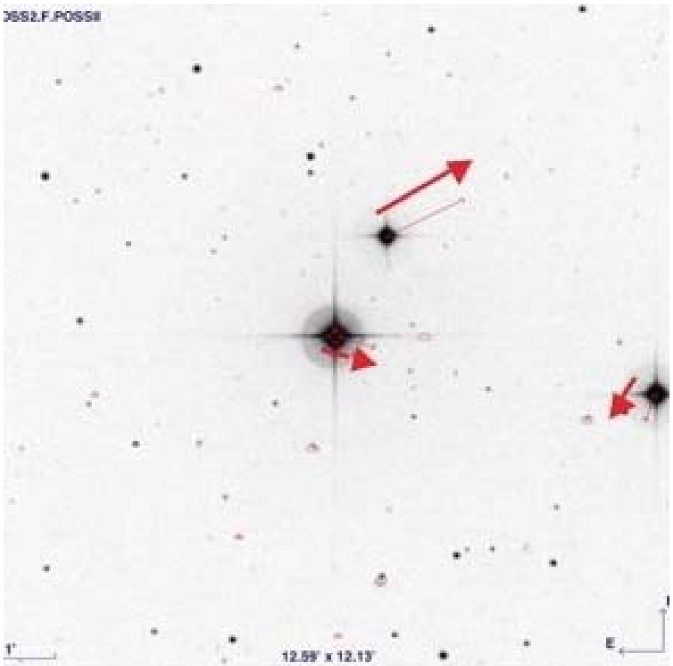


Figure 3: Proper motion vectors for STT 269 AB-C, ARN 8 AB-D.

with enhanced proper motion vectors. Arrows are shown to approximate scale and direction. The vectors show pictorially the divergent proper motion vectors indicating the optical nature of the AB, C, and D stars.

Conclusions

The separation measurements for both components were precise with standard deviation and mean error values all below 1.0 arc seconds. The experimental difference in separation for STT 269 AB-C was less than 1 arc second from the current WDS literature value. However, the experimental value for the separation of ARN 8 AB-D differed from the literature value by 2.8 arc seconds. One possibility for this difference could be due to a persistent breeze that was causing the two stars to jitter around on the linear scale making precise measurements more difficult. The larger separation was an additional factor. With a separation of about 350 arc seconds, and a scale constant of about 10 arc seconds per division, it required the observer to scan about 35 divisions on the linear scale, simultaneously, to get the appropriate separation. Actually, the observer would often cite one value on the scale and the second value several seconds later. During this hiatus, the breeze could easily have moved the telescope so the second value would be inaccurate.

Future studies of multiple stars will concentrate on systems with smaller angular separations when true binary star systems may be investigated.

The position angle measurement for ARN 8 AB-D also suffered from the wide separation. For STT 269 AB-C, the experimental separation of 123.4 arc seconds was small enough to allow easy alignment on the linear scale. The position angle was then precisely measured to within a degree of the literature value and standard deviation and mean error values less than 1.0. But the observed separation of ARN 8 AB-D was over 2.8 times larger than that of STT 269 AB-C. Team members found it more challenging to align the two stars on the linear scale before performing the drift method of position angle determination. The resulting values for the position angle had a wider spread (standard deviation of 1.08 degrees) and an experimental value 2 degrees from the literature value.

Through these experiences, the students gained confidence and the ability to apply these newly crafted skills toward further work on the "push-Dobs" available at The Evergreen State College.

Acknowledgements

The team wants to thank Dave Arnold, Russ Genet, and Tom Smith for reviewing this paper and for their suggestions and corrections. A special thanks is extended to Brian Mason at the U.S. Naval Observatory for additional information on the multiple star system studied. We also want to thank Gregory Bothun, Director of Pine Mountain Observatory, Mark Dunaway, Kent Fairfield, Allan Chambers, and Rick Kang, for opening the facility and being on hand to answer questions and assist our needs. A special thanks goes to Danyal Medley at Celestron for the donation of a 12.5 mm Micro Guide astrometric eyepiece to Evergreen State College, and to Theresa Aragon (Dean of TESC Summer School), and Peter Robinson (Director of Lab I and Lab II, and Science Technician at TESC), for purchasing an additional 12.5 mm Micro Guide astrometric eyepiece. Thanks to Sarah Pederson, Tina Pearson, Lori Moore, Sharon Wendt, Frank Barber, Katie Frank, and the other members of the TESC community for their support. The workshop would never have been as successful without the organization, dedication, and tireless effort of Richard Berry as Workshop Director. Our team also wants to recognize the other double star team leaders, Jo Johnson and Chris Estrada, for their cooperation and assistance with the project. Finally, if it

weren't for Russ Genet's initial efforts, none of the double star projects would have taken place.

References

Aitken, Robert G., *The Binary Stars*, Dover Publications, Inc., New York, 1935.

ALADIN database (applet): http://aladin.u-strasbg.fr/java/alapre.pl.

ALADIN database (previewer): http://aladin.u-strasbg.fr/alapre.pl.

Arnold, D., *The Double Star Observer*, **9**(1), 2003.

Arnold, D., *Small Telescopes and Astronomical Research*, Collins Foundation Press, Santa Margarita, CA, 2010.

Arnold, D., personal communication, 2010.

Close, Laird M., et.al., *The Astrophysical Journal,* **599**, 537-547, 2003.

Frey, Thomas G., Spring 2008, *Journal of Double Star Observations,* **3(2),** p. 59-65.

Frey, Thomas G., et. al., submitted *JDSO* Sept. 2010.

Haas, Sissy, *Double Stars for Small Telescopes,* Sky Publishing, Cambridge, MA, 2006, p.15.

Mason, Brian, The Washington Double Star Catalog. July 2009. Astrometry Department, U.S. Naval Observatory.

Mason, Brian, personal communication, 2010.

SIMBAD database:http://simbad.u-strasbg.fr/simbad/.

The U.S. Naval Observatory Double Star Program: Frequently Asked Questions

Brian D. Mason and William I. Hartkopf

U.S. Naval Observatory
3450 Massachusetts Avenue, NW
Washington, DC, 20392-5420

bdm@usno.navy.mil
wih@usno.navy.mil

Abstract: We present from the U.S. Naval Observatory's web site Frequently Asked Questions on double star observations, the Washington Double Star Catalog, and other products and services provided by the U.S. Naval Observatory Astrometry Department.

Introduction

Over the past dozen years, questions about double stars and the work of the USNO Double Star group have been asked by a variety of astronomers and other interested parties. The highlights of these, which have been posted to our website (http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/faq/), are listed below. We hope that these questions will generate others, which the authors will be happy to entertain for possible inclusion on our faq page.

Glossary of Terms and Acronyms

- - **ADS**: The "New General Catalogue of Double Stars within 121 degrees of the North Pole" (a.k.a., "Aitken Double Star Catalog"; Aitken, 1932). When Burnham retired, he gave all his double star catalog information to W. Hussey of Lick Observatory, with the intent that he publish an updated version of the BDS. Hussey died before this could be accomplished, however, and the task was assumed by Robert Grant Aitken, also of Lick. Lick later obtained the files of the SDS and merged all these data to create the IDS.
- **BDS**: The "General Catalogue of Double Stars within 121 degrees of the North Pole" (a.k.a., "Burnham Double Star Catalog"; Burnham 1906). Based on S.W. Burnham's observing notes collected over three decades, this was the first attempt to collect all published double star measurements.
- **DM3**: The "USNO Third Photometric Magnitude Difference Catalog". Currently maintained by the USNO. Earlier published versions were DM2 (2006.5) and DM (2001.0, Worley et al.).
- **DSL**: The "Double Star Library". This is the official webpage of IAU Commission 26 (Double and Multiple Stars).
- **IAU**: The International Astronomical Union. This is a professional organization for astronomers around the world. Most of our work is centered around IAU Commission 26: Binary and Multiple Stars.
- **IDS**: Lick Observatory's "Index Catalogue of Visual Double Stars, 1961.0" (Jeffers & van den Bos, 1963). This catalog by Hamilton Jeffers and Willem van den Bos combined data from the ADS and SDS into the first all-sky compilation of double star data. Due to its size, individual measures were maintained on computer punch cards and only the first and last observations were published. These boxes of punch cards were brought to the USNO by Charles Worley soon afterward to form the basis of the WDS.
- **INT4**: The "Fourth Catalog of Interferometric Measurements of Binary Stars". Currently maintained by the USNO. An earlier version

published at the USNO was INT3 (2001.0, Hartkopf et al.). INT2 and INT1 were published by Georgia State University's Center for High Angular Resolution Astronomy (CHARA) in 1988 and 1984, respectively. Initially created to keep track of observations made at CHARA and elsewhere using the technique of speckle interferometry, the catalog was later expanded to include other high-resolution techniques (Hipparcos, adaptive optics, etc.) as well as infrared methods.

- **LIN1**: The "Catalog of Rectilinear Elements". Currently maintained by the USNO.
- **ORB6**: The "Sixth Catalog of Orbits of Visual Binary Stars". ORB5 was published in 2001 (Hartkopf et al.). Earlier versions, ORB4 (Worley & Heintz 1983), ORB3 (Finsen & Worley 1970), ORB2 (Finsen 1938) and ORB1 (Finsen 1934) were printed publications.
- **SDS**: The "Southern Double Star Catalogue, -19 to -90 degrees" (Innes, 1927). This catalog by R.T.E. Innes was the southern equivalent to the BDS and ADS and was later incorporated into the IDS.
- **WDS**: The "Washington Double Star Catalog". Currently maintained by the USNO. Major releases were made in 1984 (Worley & Douglass), 1996 (Worley & Douglass), 2001 (Mason et al.) and 2006.5, with additional incremental releases over the years.
- **WMC**: The "Washington Multiplicity Catalog". Currently in preparation, it will be maintained by the USNO.

Frequently Asked Questions

1. *The Double Star Library notes that some of the USNO catalogs are "updated nightly". What does that mean?*

At present there are two astronomers at the USNO who make changes to the WDS and associated catalogs. At approximately 2am local time the WDS is re-compiled from the existing data files and put online for users to access. Web versions of other catalogs are usually updated whenever new data are added.

Changes are made in a sporadic fashion. Some days, like over the weekend, there may be no changes. Other days the changes may be significant. Some new papers may take only minutes to add, while others may yield many days' work.

2. *I am interested in making some double star observations but don't know what doubles are appropriate for my telescope or need observing. Can you help me?*

Yes. The Observing List Request form http://ad.usno.navy.mil/wds/obslist_request.html is designed for people to make requests for observing lists. While typical questions to make the list are provided, the field is free form and you can specify exactly what you want or ask the sorts of questions that can guide us in helping you generate an observing list.

3. *Are there actually doubles that still need to be observed?*

Quite a few. Naturally, the ones that most need observation are those which are hardest to observe and those that are easiest to observe do not typically need more. The number of pairs needing observation that are accessible to you depends on your capabilities.

4. *What sort of parameters are needed for a double star observation?*

Typically date, position angle and separation. If the magnitude difference is estimated, providing that is helpful, too. For publication the aperture of the telescope, method of data collection, etc., would be needed.

5. *What about calibration?*

Ah, yes. An uncalibrated measure is worthless. Independent methods for determining your calibration parameters, such as looking at a single star with a slit-mask and performing Young's experiment, are preferred. However, should you be unable to do this we provide a set of calibration quality orbits (http://ad.usno.navy.mil/wds/orb6/orb6c.html). The presumeably differential proper motion linear solution targets (http://ad.usno.navy.mil/wds/lin1.html) should also be good for this.

6. *I have made some double star observations. How do I get them into the WDS?*

The easiest way to get data in the WDS is to have them published in a refereed journal. Those will then be added as time permits. A faster way to get them into the WDS is to also send us a flat ascii file which includes the tabular information from the publication.

The fastest way is to get in touch with us (wds@usno.navy.mil) and let us provide you with the "ready to fold into the catalog" format.

The U.S. Naval Observatory Double Star Program: Frequently Asked Questions

7. *Who maintains all the USNO double star catalogs?*

The oldest catalog, the WDS, was created when Charles Worley brought the IDS from Lick Observatory in the early 1960s. It then is the "great grandcatalog" of the first comprehensive double star catalog, the BDS (BDS ---> ADS, ADS+SDS ---> IDS, IDS ---> WDS). For over thirty years it was maintained by him with help mainly from Geoff Douglass. Over this time, Charles painstakingly went through the enormous resources of the USNO library adding measures by hand. While intermediate versions were periodically released, Charles made two major releases in 1984 and 1996. As he compiled the WDS he also collected accurate magnitude difference measures in his own internal "Delta-M Catalog."

Shortly thereafter, Charles began collaborating with W.S. Finsen in producing the "Third Catalog of Binary Orbits." He later made the 4th Catalog with W.D. Heintz. The Interferometric Catalog was first compiled at Georgia State University. When two of those authors came to the USNO the Catalog came with them.

In 2001 new versions of all four catalogs were released on the first USNO double star CD. In 2006.5 the second double star CD was released with these four plus the new linear elements catalog for likely optical pairs. This catalog also included a html history of USNO double star work.

Currently the USNO catalogs are maintained by two astronomers in the Cataloging Division of the Astrometry Department at the US Naval Observatory. In addition to cataloging double stars we have observing and other responsibilities as assigned --- in actual work spent cataloging, probably from one to two FTE (i.e., "full-time equivalents") depending on circumstances.

8. *Is it possible to get a copy of the most recent double star CD?*

Yes. Fill out the form at http://ad.usno.navy.mil/wds/cd_request.html and one will be mailed to you.

9. *Why is there also an interferometric catalog? Aren't all these data in the WDS?*

No, not all of it. The interferometric catalog contains a subset of WDS data, but may contain additional photometric information. It also contains one-dimensional results (e.g., data from lunar occultations) not found in the WDS, as well as single-star information from large surveys for duplicity.

10. *Why are there separate catalogs of interferometric measurements and magnitude differences? Aren't all those data in the WDS?*

Much of the data in the Magnitude Difference Catalog is also found in the Interferometric Catalog. However, a large number of measures that were made by techniques not classified as "High Angular Resolution" are in the Magnitude Difference Catalog, such as measures from 2MASS.

11. *What is the difference between the WMC (Washington Multiplicity Catalog) and the WDS (Washington Double Star Catalog)?*

The WMC is an IAU-mandated catalog to hierarchically assign designations to pairs discovered by all double star techniques. While the vast majority of these will be resolved pairs from the WDS, the final WMC will also include spectroscopic, photometric and other unresolved companions. Also, these companions are not necessarily stellar, so it will include Brown Dwarfs and exoplanets.

12. *Why do astronomers care about double stars?*

The majority of stars in the sky are part of double or multiple star systems. The only way to determine stellar mass, the most fundamental property of a star, is through analysis of binary star systems. While stars similar to the Sun are known well, the most common stars, Red Dwarfs and those that have the greatest impact on Galactic Evolution, the Massive OB stars, are not well determined.

While double or multiple stars are broadly characterized as more abundant than single stars, how different subsets, either based on stellar type or environment, may be enhanced or not can have significant implications for the evolution of the Galaxy.

The coeval nature of binary stars makes them an insolated set which can be studied together. While the individual stars may be different, they are of at least approximately the same age and have the same chemical composition.

Binary stars are not only the predominent stellar evolutionary track, but they are a boon to astronomers for the plethora of data that can be determined from them.

13. *I am interested in a particular binary star, but the WDS only lists the first and last observations. How do I obtain all the data?*

The Data Request form ({http://ad.usno.navy.mil/wds/data_request.html) will return to you all data,

The U.S. Naval Observatory Double Star Program: Frequently Asked Questions

notes and references we have for double stars. If it has an orbit we will also provide elements, ephemerides and an orbit plot. These typically are returned within 24 hours.

14. *What are "discoverer designations"?*

Historically, each discoverer of a pair would provide a list of his "new" discoveries in his publications. When a pair was resolved and published for the first time it was added to the catalog with that designation. In more recent years pairs discovered, but not resolved, for the first time (by, for example, spectroscopy) were credited to someone sometimes many years later.

Generally speaking, the discovery designation can tell you something about the difficulty of seeing the pair. For example, STF pairs (first seen by F.G.W. Struve) are easier to split than BU pairs (first seen by S.W. Burham). Also, the discovery designation helps personalize the star and can make it a little more interesting.

The current plan of the more comprehensive WMC is to not use the discovery designation if alternate designators of greater usage are available. Coordinates and components will be the primary identifiers, instead.

15. *Some double-star names include components such as AB or AC, while others have Aa,Ab or Ba,Bb and still others have no components listed at all. Why?*

When a component designation is given the relative position is of the secondary relative to the primary. For example, for an AB pair at 90 deg and 3", in a polar coordinate system the A component is at the origin and the B component is at a position angle of 90 deg (i.e., due east of the A component) at a separation of 3".

By default a simple binary has no components explicitly listed; the primary is understood to be A and the secondary to be B.

Another common arrangement, such as AB-C or AB,C indicates that C is measured relative to the center of light (or photocenter) of the AB system. This is often measured when the AB pair is beyond the capability of one observer, but they can measure C.

More complex hierarchical arrangements follow a strict set of rules. More details are available at http://ad.usno.navy.mil/wds/wmc.html.

16. *Which is the primary?*

It depends on how much information we have. If we have a full characterization of the system, it is the most massive component. If not, it is the brightest component (considering bolometric magntiude).

If we don't know the magnitudes in many bands it is the brightest component as assigned by observers (most commonly in the visual band).

If the magnitude difference is zero or unknown the primary is arbitrarily assigned such that the angle of position is less than 180 deg.

In some cases other techniques, such as spectroscopy, can assist in assigning the primary.

17. *Do you have any information on spectroscopic binaries?*

While the WMC will contain information about spectroscopic binaries when fully populated, none of the all-sky USNO double star catalogs contains a comprehensive list of spectroscopic binaries. The notes file to the WDS contains some information and the orbit catalog has some other information as well, but these are not comprehensive. The best source for spectroscopic binaries is the 9th Catalogue of Spectroscopic Binary Orbits: http://sb9.astro.ulb.ac.be/.

18. *I published a paper of double star measurements and orbits, but it is not in your catalogs or even in your list of references. How can I get it included?*

We may have just missed it (we have a small staff and there are many papers out there!) See question 6 above. At the very least, drop an email to wds@usno.navy.mil and provide the reference or fill out the comment form http://ad.usno.navy.mil/wds/wds_comment.html. Speed of addition is based on how much information is provided.

19. *I found an error in the WDS. How can I get it corrected?*

Just tell us! The online comment form

http://ad.usno.navy.mil/wds/wds_comment.html

is designed for people to tell us of errors or ask us questions. Like the observing list form, it is free form so prattle on to your heart's content.

20. *Most of the doubles in the WDS have good right ascensions and declinations, but a few are only listed with very imprecise coordinates. Why?*

Historically, double star coordinates were published only to the nearest minute of arc and early double star catalogs did not include proper motion. The result of this is that if it was not followed on a regular basis the pair could become "lost". The pair could also be a chance alignment that is no longer there, or the erroneous identification of a "plate flaw" as a real star. There also may have been a printing error in the original paper or a transcription error in entering the object into the WDS or one of its predecessor catalogs. In any event, we have thus far been unable to match it to nearby pairs we have online in the Cataloging Division.

Sometimes it takes only a look through the telescope to see where it is and "find" the pair again. For example, using the 26" in Washington we have confirmed an extensive number of John Herschel's pairs, last seen in 1820 but long lost due to poor coordinates.

When a pair is judged to be false or lost for one or more of the above reasons we add an "X" code for the pair to it in the WDS. Removing the pair entirely might prompt someone to add it back in one day and adding the "X" code is like giving it the "Black Spot of Binaries."

21. *If there are bad doubles are there also bad measures?*

Yes, there are. When we have thoroughly analyzed a measure and found it to be insufficient we similarly mark it as such. It remains in the WDS but is henceforth not considered when, for example, counting measures of systems or calculating an orbit. It is a marker that lets someone else know that the measure has been added, evaluated and found wanting. If a published measure has an obvious error we will correct it and add a flag indicating a correction has been made.

22. *What is the orbit "grade" which is assigned in the orbit catalog?*

Both the Third and Fourth orbit catalogs assigned a quality grade to an orbit. This subjective grading was based on many factors as judged by probably the most experienced double star astronomers and catalogers at the time. Since their expertise and experience could not be replicated, in the Fifth Catalog a painstaking method was developed to replicate their grading based on many key parameters: thus objectifying the previous subjective grade. See http://ad.usno.navy.mil/wds/orb6/orb6text.html for details.

23. *How is this grade assigned?*

When an orbit is added, all data are plotted with this new orbit and then evaluated. If the grade is better it becomes the new default orbit. Just adding one measure and re-computing an orbit is rarely justification for your orbit being the new "best" orbit, however.

In adding an orbit the weight of each measure in that orbit is considered, which takes into account the method, size of the telescope, separation, magnitude, magnitude difference, N (number of nights in a mean position) and person who made the measure.

24. *What are the weights of individual measurers used for orbit grading?*

Not all observers are the same. Some get a low weight because they were always working at the limits of their telescope. Some get a low weight because the observations were not as good (due to poor calibration, for example).

Evaluating an observer is a sociologically complex consideration. We do not release these parameters. But, for the record, ours are not the best.

25. *Who has observed the most double stars?*

It depends on how you count them. Counted by the number of measures, the three top are W.H. van den Bos, W.D. Heintz and C.E. Worley. A full listing of the top twenty-five groups and individuals counted many different ways is on the WDS website.

26. *Why aren't all the measures used to compile the WDS published online?*

Size is one consideration.

Integrity of the product is another, as it is not completely corrected.

There is also a historical reason. The full database was once taken, repackaged and then presented as a new catalog with no attribution. Given the enormous number of man years spent by USNO personnel over the past decades to maintain this database, that will not be allowed to happen again.

All measures of specific systems are always available via the Data Request form

http://ad.usno.navy.mil/wds/data_request.html.

Bottom line: You can have some of the data on all of the systems or all of the data on some of the systems, but you cannot have all of the data on all of the systems!

References

Aitken, R.G. 1932, New General Catalogue of Double Stars within 121 degrees of the North Pole, Carnegie Institution of Washington

The U.S. Naval Observatory Double Star Program: Frequently Asked Questions

Burnham, S.W. 1906, General Catalogue of Double Stars within 121 degrees of the North Pole, Carnegie Institution of Washington

Finsen, W.S. 1934, Union Obs. Circ. 4, 23

Finsen, W.S. 1938, Union Obs. Circ. 4, 66

Finsen, W.S. & Worley, C.E. 1970, Republic Obs. Circ. 7, 203

Hartkopf, W.I., Mason, B.D., & Worley, C.E. 2001, AJ 122, 3472

Hartkopf, W.I., McAlister, H.A., & Mason, B.D. 2001, AJ 122, 3480

Innes, R.T.A. 1927, Southern Double Star Catalogue, -19 to -90 degrees,

Union Observatory, Johannesburg, South Africa

Jeffers, H.M. & van den Bos, W.H. 1963, Index Catalogue of Visual Double Stars, 1961.0, Pub. of the Lick Observatory, 21

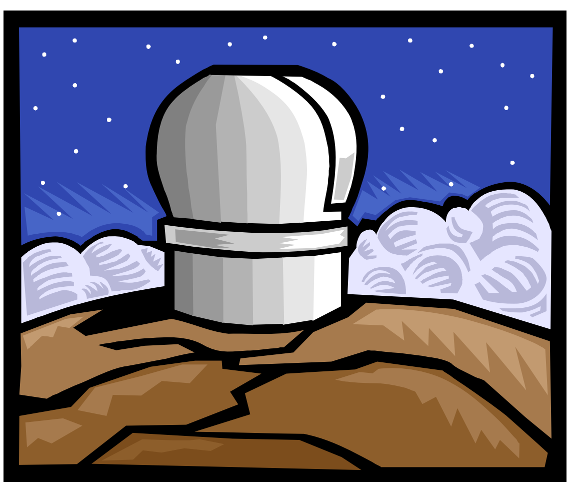
Mason, B.D., Wycoff, G.L., Hartkopf, W.I., Douglass, G.G., & Worley, C.E. 2001, AJ 122, 3466

Worley, C.E., & Douglass, G.G. 1984, Washington Visual Double Star Catalog, 1984.0, U.S. Naval Observatory, Washington

Worley, C.E., & Douglass, G.G. 1997, A&AS, 125, 523 (Washington Visual Double Star Catalog, 1996.0)

Worley, C.E. & Heintz, W.D. 1983, Pub. U.S. Naval Obs. 24, pt. 7

Worley, C.E., Mason, B.D., & Wycoff, G.L. 2001, AJ, 122, 3482



Journal of Double Star Observations

January 1, 2011
Volume 7, Number 1

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

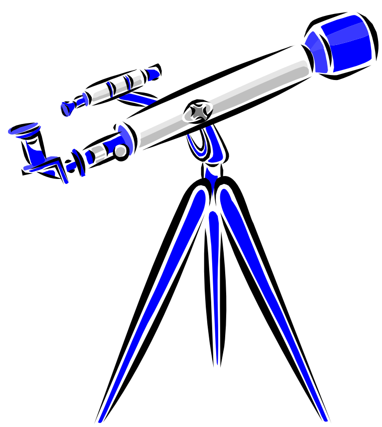
Questions, comments, or submissions may be directed to rclark@jaguar1.usouthal.edu or to rmollise@bellsouth.net

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

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

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

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



We're on the web!

http://www.jdso.org