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Double Star Measurements at the Northern Sky with a 10 inch Newtonian in 2014 and 2015

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Abstract: A 10 inch Newtonian was used for recordings of double stars with a CCD webcam, and measurements of 120 pairs were done with the technique of "lucky imaging". A rather accurate value of the image scale was obtained with reference systems from the recently published *Gaia* catalogue of very precise position data. For several pairs, deviations from currently assumed orbits were found. Some images of noteworthy systems are also presented.

Introduction

As in earlier work, recordings of double star images were evaluated with "lucky imaging". By using short exposure times, seeing effects can strongly be reduced, and the accuracy of position measurements is increased. More details of the technique are described, for example, in reference [1]. In this paper, measurements made in late 2014 and in 2015 at my home in northern Germany are reported. While in earlier work, the image scale was determined by extrapolation of trustworthy literature data for reference systems, the recent first release of data from the *Gaia* mission delivered star positions with unprecedented accuracy, which were used for obtaining a significant improvement of the precision of the image scale.

Instrumental

As in earlier work, I have used a 10 inch Newtonian at my home for recording double stars at the northern sky [2]. The primary focal length of 1.5 m was extended by a 2x Barlow lens. Series of 1000 to 2000 images were taken with a b/w-CCD camera of type "Chameleon" (PointGrey) with exposure times ranging from less than a millisecond to several tens of msec, depending on the star brightness, on the filter being used, and on the seeing. Recordings were usually made with a red or near infrared filter, in order to reduce effects from chromatic aberrations of the Barlow lens, as well as from the seeing. The best frames, typically several tens and up to more than 100, were selected, registered, and stacked with programs "VirtualDub" and "Registax", respectively. The pixel size of 3.75 µm square results in a nominal resolution of 0.258 arcsec/pixel, but the accuracy of position measurements is typically better by more than one order of magnitude. It was found helpful to re-sample the images before stacking, as registering can be done with sub-pixel accuracy, which results in smoothing of the intensity profiles, and better definition of the peak centroids. From these, star separations were calculated by simple pixel geometry. Position angles were obtained by recording star trails with the telescope drive switched off, from which the east-west direction was determined.

Calibration

The image scale was adjusted by using data from the *Gaia* catalog, which became freely available in September 2016, just as of writing this article [3]. For 40 systems out of the total of 120 investigated here, values for right ascension and declination were found, with error margins typically smaller than one milliarcsecond, from which separations and position angles were calculated. The reference systems are marked in table 1 below with shaded lines. The first release of *Gaia* data contains measurements performed in late 2014 and in 2015, but the positions refer to the epoch 2015.0. In some cases, where positions of double stars are known to rapidly change, those calculated from Gaia data were extrapolated corresponding to the epoch of my own

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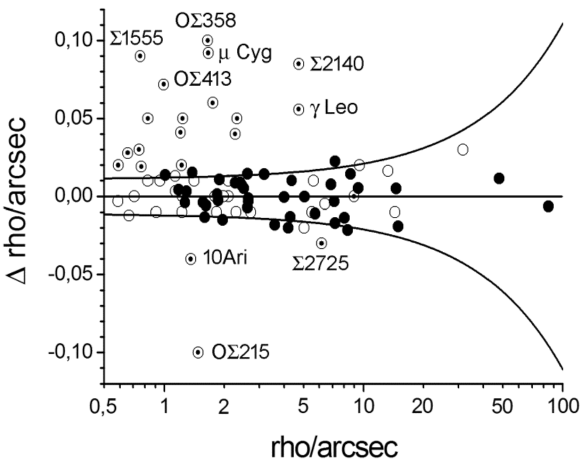

Figure 1. Plot of the residuals rho versus rho. Semi-logarithmic scale. Full circles denote reference systems, open circles all others. Symbols with dots indicate binaries, which exhibit deviations from currently assumed orbits. The curves represent the statistical error limits.

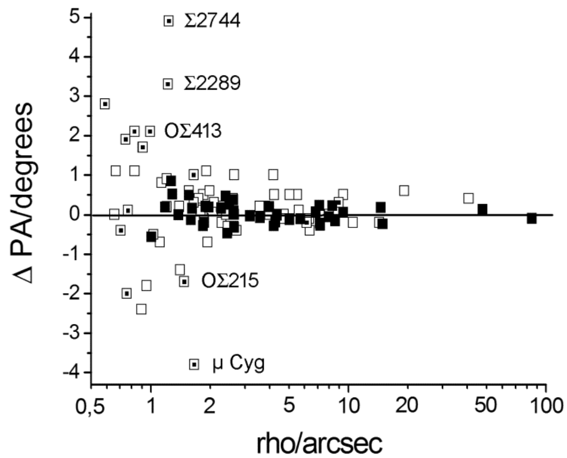

Figure 2. Plot of the residuals of the position angle PA versus rho. Semi-logarithmic scale. Pairs used for calibration of the image scale are marked with solid squares, all others with open squares. Dots within symbols mark binaries with exhibiting deviations from the ephemeris data.

recordings, in particular for those done in late 2015. Maximum changes were about 0.1 degrees and 0.01 arcsec, respectively. An example is shown below. The image scale was adjusted by statistical evaluation of the residuals of 40 reference systems, such that the mean values, as well the standard deviation (s. d.) were minimized. As a result, the range of remaining residuals extended from- 0.021 to +0.022 arcsec (this can be seen in fig. 1 below), the mean was less than 0.001 arcsec, the s. d. was +/- 0.011 arcsec, and the scale factor was calculated as 0.2631 arcsec/pixel, with an estimated error of +/- 0.1 per cent. A major improvement of accuracy is due to systems with large separations. Earlier literature data are mostly scarce, and exhibit large scatter with unknown error margins. In contrast, data from *Gaia* are extremely precise, regardless of the separation. The resulting effective resolution differs from the nominal value given above by almost +2 percent, which is probably caused by the Barlow lens. Needless to say that the Barlow-camera unit is fixed, and has never been changed during this work.

Results

All measurements are listed in Table 1. Names, nominal positions, and magnitudes are adopted from the *WDS* [4]. Residuals of the reference systems (shaded lines) refer to *Gaia* data, as was explained above, and for all other systems to trends of literature data, in particular from the Fourth Catalog of Interferometric Measurements of Binary Stars ("Speckle Catalog") [5], or to ephemeris data from the Sixth Catalog of Orbits of Visual Binary Stars [6]. In several cases, no reasonable residuals could be given, because of too few literature data and/or too large a scatter. The table is followed by individual notes, which are numbered with R.A. values.

In Figure 1, all residuals of the separations rho are plotted versus rho. In most "normal" cases, values do not exceed about ±0.02", independent on separation, in particular for reference systems with separations up to about 100 arcsec. The statistical error limits are represented by curved lines (due to the logarithmic scaling), which are calculated as the sum of the standard deviation of the calibration pairs (±0.011"), plus the contribution from the error margin of the calibration constant (±0.1 per cent), which increases with separation. Interestingly, some ("not normal") systems exhibit significantly larger deviations, some of which are indicated in Figure 1 by their names. These could be traced back to deviations from the currently assumed ephemeris. Typical reasons are "premature" orbit calculations, difficult edge-on orbits, or general scatter of data. Some noteworthy examples are illustrated in more detail below.

In Figure 2, the residuals of measurements of the position angles are plotted versus the separation rho. It is apparent that the range depends on the separation, and is generally smaller for the reference systems. The reason is the constant resolution of the image, which causes the error of angular measurements to increase towards small separations, and can reach several degrees for systems close to the resolution limit. Also,

(Continued on page 296)

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Table 1. List of measurements. Position angles (PA) are in degrees, separations (rho) in arc seconds. N is the number of recordings. Shaded lines indicate systems, which are used for calibration of the image scale by reference to Gaia data. Residuals (d PA, d rho) are given, when reasonable. Notes are numbered with RA values, and are listed below.

Pair	RA + Dec	mags	PA meas	rho meas	Date	N	d PA	d rho	Notes
AC 1	00 20.9 +32 59	7.27 8.26	288.7	1.862	2015.747	1	-0.2	<0.01	00209
STF 60AB	00 49.1 +57 49	3.52 7.36	324.5	13.30	2015.864	1	-0.1	0.02	00491
STF 61	00 49.9 +27 43	6.33 6.34	115.3	4.270	2015.777	2	-0.2	-0.01	00499
STF 65	00 52.7 +68 52	8.00 8.02	219.8	3.186	2015.864	1	<0.1	0.01	00527
STF 73	00 55.0 +23 38	6.12 6.54	330.1	1.12	2015.864	3	-0.2	<0.01	00550
STF 79	01 00.1 +44 43	6.04 6.77	193.2	7.853	2015.864	1	--	--	01001
STT 21	01 03.0 +47 23	6.76 8.07	175.5	1.290	2015.864	2	0.5	<0.01	01030
BU 303	01 09.7 +23 48	7.32 7.56	294.6	0.59	2015.777	1	--	<0.01	01097
STF 180AB	01 53.5 +19 18	4.52 4.58	0.3	7.39	2015.905	1	--	--	01535
STF 202AB	02 02.0 +02 46	4.10 5.17	263.6	1.83	2014.933	1	0.1	-0.01	02020
STF 208	02 03.7 +25 56	5.82 7.87	344.2	1.32	2015.905	1	<0.1	-0.04	02037
STF 205	02 03.9 +42 20	2.31 5.02	63.3	9.57	2015.864	1	<0.3	<0.02	02039
STF 228	02 14.0 +47 29	6.56 7.21	303.9	0.67	2015.777	1	2.1	-0.01	02140
STF 262AB	02 29.1 +67 24	4.63 6.92	231.0	2.81	2015.864	1	--	--	02291
AC		4.63 9.05	116.3	7.07		1	--	--	
BC		6.92 9.05	99.1	8.53		1	--	--	
HJL1021	03 09.3 +20 46	6.54 8.77	238.8	122.3	2015.905	1	--	--	03093
STF 376	03 20.3 +19 44	8.33 8.44	251.5	7.144	2015.905	1	0.2	<0.01	03203
STF1110AB	07 34.6 +31 53	1.93 2.97	54.4	5.03	2015.215	1	-0.1	-0.02	07346
AC		1.93 9.83	163.4	70.12		1	--	--	
STF1196AB	08 12.2 +17 39	5.30 6.25	22.4	1.14	2015.246	1	0.8	0.02	08122
AC		5.30 5.85	62.0	6.40		1	<0.5	-0.01	
BC		6.25 5.85	69.5	5.56			<0.5	--	
STF1291AB	08 54.2 +30 35	6.09 6.37	309.9	1.54	2015.264	1	<0.5	<0.02	08542
STF1356	09 28.5 +09 03	5.69 7.28	110.6	0.85	2015.215	1	1.1	0.01	09285
STT 215	10 16.3 +17 44	7.25 7.46	176.6	1.48	2015.215	1	-1.7	-0.1	10163
STF1424AB	10 20.0 +19 50	2.37 3.64	126.0	4.73	2015.215	1	<0.1	0.06	10200
STF1426AB	10 20.5 +06 26	7.99 8.30	314.3	0.91	2015.215	1	1.7	-0.01	10205
AB-C		7.30 9.43	11.6	7.59		1	--	--	
STT 216	10 22.7 +15 21	7.38 10.28	231.3	2.27	2015.215	1	0.2	0.04	10227
STT 217	10 26.9 +17 13	7.85 8.58	147.1	0.80	2015.215	1	<0.5	--	10269
STF1450AB	10 35.0 +08 39	5.80 7.90	157.2	2.05	2015.215	1	<1.0	0.01	10350
STF1517AB	11 13.7 +20 08	7.54 8.02	315.7	0.71	2015.215	1	-0.4	<0.01	11137
STF1523AB	11 18.2 +31 32	4.33 4.80	175.2	1.79	2015.308	1	0.1	<0.01	11182
STF1536AB	11 23.9 +10 32	4.06 6.71	96.0	2.10	2015.215	1	0.3	<0.01	11239
STF1552AB	11 34.7 +16 48	6.26 7.31	207.6	3.49	2015.215	1	<1.0	<0.03	11347
AC		6.26 9.77	234.9	63.01		1	--	--	
STF1555AB	11 36.3 +27 47	6.41 6.78	148.0	0.76	2015.215	1	-2.0	0.09	11363
STF1639AB	12 24.4 +25 35	6.74 7.83	323.4	1.842	2015.308	1	-0.3	<0.01	12244
STF1670AB	12 41.7 -01 27	3.48 3.53	5.1	2.29	2015.292	1	-0.2	-0.01	12471

Table 1 continues on next page.

Double Star Measurements at the Northern Sky with a 10 inch Newtonian in 2014 and 2015

Table 1 (continued) List of measurements. Position angles (PA) are in degrees, separations (rho) in arc seconds. N is the number of recordings. Shaded lines indicate systems, which are used for calibration of the image scale by reference to Gaia data. Residuals (d PA, d rho) are given, when reasonable. Notes are numbered with RA values, and are listed below.

Pair	RA + Dec	mags	PA meas	rho meas	Date	N	d PA	d rho	Notes
STF1687AB	12 53.3 +21 15	5.15 7.08	197.6	1.20	2015.308	1	0.9	0.04	12533
AC		5.15 9.76	127.0	28.47		1	--	--	
STF1692AB	12 56.0 +38 19	2.85 5.52	229.0	19.25	2015.264	1	--	--	12560
STF1695AB	12 56.3 +54 06	6.04 7.75	280.7	3.80	2015.308	1	--	--	12563
STT 261	13 12.0 +32 05	7.40 7.64	339.0	2.611	2015.292	1	0.4	-0.01	13120
STF1744AB	13 23.9 +54 56	2.23 3.88	152.8	14.36	2015.308	1	-0.2	-0.01	13239
STF1755	13 32.4 +36 49	7.34 8.10	130.0	4.169	2015.292	1	-0.3	-0.02	13324
STF1768AB	13 37.5 +36 18	4.98 6.95	95.4	1.75	2015.292	1	0.4	0.06	13375
STF1864AB	14 40.7 +16 25	4.88 5.79	111.7	5.52	2015.336	1	<0.5	<0.03	14407
STF1890	14 49.7 +48 43	6.31 6.67	45.2	2.631	2015.336	1	-0.5	0.01	14497
STF1888AB	14 51.4 +19 06	4.76 6.95	302.5	5.66	2015.336	1	0.1	0.01	14514
STT 288	14 53.4 +15 42	6.89 7.55	158.0	1.022	2015.336	1	-0.6	0.01	14534
STF1909	15 03.8 +47 39	5.20 6.10	66.1	0.95	2015.336	1	-1.8	0.01	15038
STF1932AB	15 18.3 +26 50	7.32 7.41	265.6	1.612	2015.371	1	0.2	-0.01	15183
STF1937AB	15 23.2 +30 17	5.64 5.95	208.2	0.66	2015.371	1	<0.1	0.03	15232
STF 28AB	15 24.5 +37 23	4.33 7.09	170.7	107.7	2015.336	1	--	--	15245
STF1938Ba-Bb		7.09 7.63	4.2	2.282		1	0.1	0.01	
STT 298AB	15 36.0 +39 48	7.16 8.44	184.3	1.184	2015.336	1	0.2	<0.01	15360
HU 1167AB	15 38.2 +36 15	8.07 9.87	75.1	1.24	2015.371	1	--	--	15382
STF1964AC		8.07 8.06	85.6	14.93		1	-0.2	-0.02	
STF1964CD		8.06 9.02	20.9	1.559		1	0.5	<0.01	
STF1965	15 39.4 +36 38	4.96 5.91	305.6	6.35	2015.371	1	--	<0.05	15394
STF2032AB	16 14.7 +33 52	5.62 6.49	238.1	7.238	2015.371	1	-0.3	0.02	16147
STF2084	16 41.3 +31 36	2.95 5.40	137.8	1.23	2015.426	1	3.5	<0.01	16413
STF2140AB	17 14.6 +14 23	3.48 5.40	102.9	4.73	2015.426	1	-0.1	0.09	17146
STF2161AB	17 23.7 +37 09	4.50 5.40	320.5	4.088	2014.716	1	<1.0	<0.05	17237
STF2220A,BC	17 46.5 +27 43	3.49 9.78	249.0	35.50	2014.716	1	--	--	17465
AC 7BC		10.2 10.7	281.9	0.75		1	1.9	0.03	
STT 338	17 52.0 +15 20	7.21 7.38	162.6	0.78	2014.716	1	<1.0	<0.03	17520
STF2245BA	17 56.4 +18 20	7.43 7.55	111.6	2.638	2015.426	1	-0.3	<0.01	17564
STF2264	18 01.5 +21 36	4.85 5.20	256.6	6.40	2015.426	1	--	--	18015
STF2289	18 10.1 +16 29	6.65 7.21	219.0	1.23	2015.493	1	3.3	-0.01	18101
STF2333	18 31.1 +32 15	7.82 8.57	333.2	6.43	2015.692	1	--	--	18311
STT 359	18 35.5 +23 36	6.35 6.62	3.7	0.77	2015.426	1	0.1	0.02	18355
STT 358AB	18 35.9 +16 59	6.94 7.08	148.6	1.61	2015.426	1	1.0	0.10	18359
STF2351	18 36.2 +41 17	7.60 7.64	160.2	5.049	2015.692	2	-0.1	<0.01	18362
STF2362	18 38.4 +36 03	7.53 8.72	186.9	4.371	2015.692	1	-0.1	0.01	18384
STF2372AB	18 42.1 +34 45	6.45 7.73	82.1	25.08	2015.692	1	--	--	18421
STF2390	18 45.8 +34 31	7.37 8.56	155.8	4.22	2015.692	1	--	--	18458
STFA 39AB	18 50.1 +33 22	3.63 6.69	148.2	45.62	2015.692	1	--	--	18501
BU 648	18 57.0 +32 54	5.34 7.96	243.1	1.265	2014.695	2	0.8	<0.01	18570
STF2446AB	19 05.8 +06 33	6.97 8.88	152.9	9.421	2015.615	1	0.1	<0.01	19058

Table 1 concludes on next page.

Double Star Measurements at the Northern Sky with a 10 inch Newtonian in 2014 and 2015

Table 1 (conclusion) List of measurements. Position angles (PA) are in degrees, separations (rho) in arc seconds. N is the number of recordings. Shaded lines indicate systems, which are used for calibration of the image scale by reference to Gaia data. Residuals (d PA, d rho) are given, when reasonable. Notes are numbered with RA values, and are listed below.

Pair	RA + Dec	mags	PA meas	rho meas	Date	N	d PA	d rho	Notes
STF2449	19 06.4 +07 09	7.20 7.72	289.7	8.004	2015.615	1	-0.1	-0.01	19064
STF2486AB	19 12.1 +49 51	6.54 6.67	204.1	7.174	2015.660	1	-0.2	-0.02	19121
STT 371AB	19 15.9 +27 27	7.03 7.55	159.2	0.85	2015.590	1	--	--	19159
STF2579	19 45.0 +45 08	2.89 6.27	216.3	2.72	2014.695	1	-0.4	-0.01	19450
STF 258AB	19 48.7 +11 49	6.34 6.75	106.0	1.42	2015.686	1	--	--	19487
STF2609	19 58.6 +38 06	6.69 7.64	21.3	1.942	2014.695	1	-0.7	0	19586
STF2613AB	20 01.4 +10 45	7.48 8.02	354.9	3.567	2015.615	1	-0.1	-0.02	20014
STF2624	20 03.5 +36 01	7.09 7.73	174.1	1.950	2014.695	1	0.2	-0.02	20035
STF2644	20 12.6 +00 52	6.92 7.06	205.9	2.633	2015.615	1	0.1	<0.01	20126
STT 410AB	20 39.6 +40 35	6.73 6.83	3.0	0.87	2015.686	1	--	--	20396
STF2725	20 46.2 +15 54	7.54 8.20	11.7	6.16	2015.582	1	0.1	-0.03	20462
STF2727AB	20 46.7 +16 07	4.36 5.03	265.3	8.97	2015.582	1	0.3	<0.01	20467
STT 413AB	20 47.4 +36 29	4.73 6.26	2.2	0.99	2015.686	3	2.1	0.07	20474
STF2729	20 51.4 -05 38	6.40 7.43	32.4	0.82	2015.777	1	2.1	0.02	20514
STF2741AB	20 58.5 +50 28	5.94 6.79	25.1	1.98	2015.694	1	0.6	<0.01	20585
STF2737AB-C	20 59.1 +04 18	5.30 7.05	66.5	10.58	2015.747	2	--	--	20591
STF2742	21 02.2 +07 11	7.41 7.64	214.4	2.90	2015.747	1	--	--	21022
STF2744AB	21 03.1 +01 32	6.76 7.33	108.6	1.24	2015.777	1	4.9	0.05	21031
STF2758	21 06.9 +38 45	5.20 6.05	153	31.62	2015.582	1	0.4	0.03	21069
S 786	21 19.7 +53 03	6.94 9.16	299.5	47.77	2015.694	1	0.1	0.01	21197
STF2789AB	21 20.0 +52 59	7.71 7.87	114.3	6.861	2015.694	1	0.1	0.01	21200
STT 437AB	21 20.8 +32 27	7.15 7.42	18.9	2.452	2015.686	2	-0.5	0.01	21208
STF2799	21 28.9 +11 05	7.37 7.44	259.9	1.902	2015.777	2	0.1	0.01	21289
STF2822AB	21 44.1 +28 45	4.75 6.18	317.8	1.66	2015.582	1	-3.8	0.92	21441
STF2863AB	22 03.8 +64 38	4.45 6.40	274.4	8.00	2015.615	1	<0.5	--	22038
STF2854	22 04.4 +13 39	7.77 7.89	83.5	1.584	2015.777	1	-0.1	-0.01	22044
STF2862	22 07.1 +00 34	8.04 8.41	96.1	2.510	2015.777	1	0.3	0.01	22071
BU 173	22 26.9 +57 12	6.74 10.5	234.3	2.86	2014.673	1	--	--	22269
KR 60AB	22 28.0 +57 42	9.93 11.41	287.7	1.43	2015.615	2	-1.4	0.01	22280
STF2909AB	22 28.8 -00 01	4.34 4.49	164.5	2.32	2015.777	3	0.2	0.05	22288
STFA 58AC	22 29.2 +58 25	4.21 6.11	191.4	40.75	2015.590	1	--	--	22292
STT 473	22 30.3 +57 14	6.74 10.5	358.7	14.63	2014.673	1	0.2	<0.01	22303
STF2934	22 41.9 +21 26	8.64 9.55	56.8	1.396	2015.747	2	<0.1	0.02	22419
STF2958	22 56.9 +11 51	6.63 9.09	14.9	3.987	2015.747	1	0.2	<0.01	22569
STTA241	22 58.6 +12 03	8.28 8.37	160.6	84.67	2015.747	1	-0.1	-0.02	22586
STF2978	23 07.5 +32 50	6.35 7.46	144.8	8.308	2015.615	1	0.2	-0.02	23075
BU 720	23 34.0 +31 20	5.67 6.11	107.1	0.59	2015.692	2	2.8	0.02	23340
STF3042	23 51.9 +37 53	7.62 7.75	86.2	5.717	2014.744	1	-0.1	-0.01	23519
STF3048AB	23 58.1 +24 20	7.94 10.17	312.8	8.611	2015.692	1	-0.2	0.01	23581
AC	23 58.1 +24 20	7.94 11.33	265.7	36.91	2015.692		--	--	23581
STF3050AB	23 59.5 +33 43	6.46 6.72	339.7	2.408	2015.660	2	0.1	0.01	23595

Double Star Measurements at the Northern Sky with a 10 inch Newtonian in 2014 and 2015

Table Notes: Terms “cpm” (common proper motion), and “relfix“ (relatively fixed) refer to Burnham [7].

00209: in Andromeda, binary, P = 525 y (?), orbit highly inclined, PA data show some scatter.

00491: η Cassiopeiae, binary, P = 480 y (?), orbit rather well documented, almost circular, but eccentric.

00499: 65 Piscium, rho slowly decreasing.

00527: in Cassiopeia, large scatter of literature data.

00550: 36 Andromedae, binary, P = 168 y, many speckle data.

01001: in Andromeda, cpm, relfix, too few data, residuals ambiguous.

01030: in Andromeda, binary, P = 450 y (?), orbit edge-on, trend of recent speckle measures of rho, as well as own data, and the value from Gaia, all deviate from currently assumed ephemeris.

01097: in Pisces, rho slowly decreasing?, large scatter of speckle measures of PA.

01535: γ Arietis, cpm, orbital motion suspected few data, residuals ambiguous.

02020: α Piscium, binary, P = 3267 y (?), only small portion of orbit documented.

02037: 10 Arietis, binary, P = 325 y, own measures, as well as recent speckle data are slightly off from currently assumed ephemeris.

02039: γ Andromedae, few data with some scatter.

02140: in Andromeda, binary, P = 145.4 y, many speckle data.

02291: ι Cassiopeiae, famous triple, AB binary, P = 620 y, separation of AB deviates from orbit with period of 47 y, due to a close and dim companion to A. Rho values of AB and BC are currently decreasing. Residuals somewhat ambiguous.

03093: in Aries, few data.

03203: in Aries, few data.

07346: α Gemini, “Castor”, AB binary, P = 459.8 y, many speckle data with small scatter. Component C belongs to the system with P > 10000 y, few data.

08122: ζ Cancri, famous multiple system, AB binary with P = 59.6 y, while C revolves about AB in estimated 1115 y, with wobble of period 19 y, due to an unseen companion to C. Many speckle data of AB. Rho (AC) currently decreasing. Large scatter of rho data for BC.

08542: 57 Cancri, cpm, PA slowly decreasing, many speckle data, but with some scatter. Only upper limits for the residuals given.

09285: ω(2) Leonis, binary, P = 118 y, many speckle data.

10163: in Leo, binary, P = 670 y (?), own measures significantly deviate from ephemeris, in accordance with recent speckle data.

10200: γ Leonis, binary, P = 554 y, residuals refer to ephemeris, significant deviation of rho, in accordance with recent literature data.

10205: in Leo, AB binary, P = 2209 y (?), only small portion of orbit documented. Few data for AC.

10227: in Leo, binary, P = 314.9 y.

10269: in Leo, binary, P = 139.8 y, many speckle data.

10350: 49 Leonis, recent speckle data for PA exhibit some scatter. Rho decreasing.

11137: in Leo, binary, P = 924 y (?), orbit almost edge-on, many speckle data. While the ephemeris is only preliminary, extrapolation of speckle data is virtually unambiguous.

11182: ξ Ursae Majoris, binary, P = 59.9 y, well documented orbit, many speckle data.

11239: ι Leonis, binary, P = 186 y.

11347: 90 Leonis, some scatter of data for AB, residuals ambiguous, few data for AC.

11363: in Leo, binary, P = 916 y (?), orbit almost edge-on, many speckle data, rho data deviate from ephemeris. Residuals refer to ephemeris.

12244: in Coma, binary, P = 575.4 y, many speckle data. Gaia position slightly off ephemeris.

12471: γ Virginis, “Porrima”, famous binary, P = 169.1 y, orbit well documented.

12533: 35 Comae, AB binary, P = 539.4 y. Recent speckle data for rho, as well as own measurement may indicate a slight deviation from ephemeris. C probably physical, few data.

12560: α Canum Venaticorum, “Cor Caroli”, cpm, relfix, few data, residuals ambiguous.

12563: in Ursa Majoris, few data with some scatter, residuals ambiguous.

13120: in Canes Venatici, PA decreasing, rho increasing.

13239: ζ Ursae Majoris, "Mizar", PA of AB slowly increasing, few data, A is a famous double-lined spectroscopic double.

13324: in Canes Venatici, relfix, few data.

13375: 25 Canum Venaticorum, binary, P = 228 y, many speckle data, rho data exhibit some scatter, and tend to deviate from ephemeris.

14407: π Bootis, PA slowly increasing, few data, residual refers to speckle measurements in 2013.

14497: 39 Bootis, rho decreasing.

14514: ξ Bootis, binary, P = 151.6 y, orbit well documented.

14534: in Bootes, binary, P = 313 y, many speckle data with small scatter.

15038: 44 Bootis, binary, P = 209.8 y, orbit highly inclined, rho rapidly closing in.

15183: in Corona Borealis, binary, P = 203.1 y, many speckle data.

15232: η Coronae Borealis, fast binary, P = 41.7 y, many speckle data, orbit well documented. Recent speckle data, as well as own measure of rho may indicate a slight deviation from ephemeris.

15245: μ Bootis, AB ($\mu^{1,2}$, STF 28) cpm, B (μ^2, STF1938) binary, P = 265 y, many speckle data.

15360: in Booties, fast binary, P = 55.6 y, many speckle data, orbit well documented.

15382: in Corona Borealis, quadruple system, HU1167AB binary, P = 834 y (?), STF1964 CD binary, P = 1230 y, for both only short arcs on highly inclined orbits documented, few data, all with some scatter.

15394: ζ Coronae Borealis, relfix, few data with large scatter.

16147: σ Coronae Borealis, binary, P = 726 y. Gaia position, as well as own measurement, differ from ephemeris.

16413: ζ Herculis, fast binary, P = 34.5 y, speckle data with small scatter, residual of own measurement of PA somewhat ambiguous, as weak companion is lying on the diffraction ring of the main star.

17146: α Herculis, "Rasalgethi", binary, P = 3600 y (?), only small portion of orbit documented, while speckle data for rho exhibit some scatter, there is a significant deviation from ephemeris.

17237: ρ Herculis, PA increasing, few data with some scatter.

17465: μ Herculis, cpm, few data, PA and rho incrreasing. BC: red dwarf binary, P = 43.1 y, residuals refer to ephemeris. Recent speckle data, as wellas own measure of rho may indicate a slight deviation.

17520: in Hercules, PA decreasing. Literature data exhibit some scatter.

17564: in Hercules, cpm, relfix, some scatter of recent speckle data, PA slowly decreasing?

18015: 95 Herculis, cpm, relfix, some scatter of literature data.

18101: in Hercules, binary, P = 3040 y (?), only small portion of (preliminary) orbit documented, own measurements, in accordance with literature data, deviate from ephemeris. Reiduals refer to ephemeris.

18311: in Lyra, relfix, few data, PA decreasing.

18355: in Hercules, binary, P = 219.3 y, many speckle data, occasional large scatter, own measure of rho deviates by +0.02" from the ephemeris, but is 0.02" lower than a speckle measure of about the same epoch.

18359: in Hercules, binary, P = 380 y, many speckle data. These, as well as own measure significantly deviate from currently assumed orbit. Residuals refer to ephemeris.

18384: in Lyra, few data, PA and rho increasing.

18421: in Lyra, few data, PA decreasing.

18458: in Lyra, PA and rho decreasing, too much scatter of literature data, residuals ambiguous.

18501: beta Lyrae, rho decreasing, few data.

18570: in Lyra, binary, P = 61.4 y, difficult, as dim companion overlaps with the diffraction ring of the main star.

19058: in Aquila, relfix, few data.

19064: in Aquila, few data, rho decreasing.

19121: in Cygnus, binary, P = 3100 y (?), only small portion of the preliminary orbit is documented, PA and rho decreasing. GAIA position extrapolated to 2015.66.

19159: in Lyra, many speckle data, but with some scatter, PA increasing, residuals ambiguous.

19450: δ Cygni, binary, P = 918 y, residuals refer to ephemeris.

19487: π Aquilae, many speckle data, some scatter of rho data, residuals ambiguous, PA slowly decreasing.

19586: in Cygnus, PA slowly decreasing?

20014: in Aquila, binary. P = 2356 y (?), premature orbit, highly inclined, many speckle data, significant deviations of both speckle data as well as own data from ephemeris, in accordance with data from Gaia. Rho is decreasing.

20035: in Cygnus, PA and rho slowly increasing?

20126: in Aquila, many speckle data, rho decreasing.

20396: in Cygnus, many speckle data, but with some scatter, residuals ambiguous, PA decreasing, rho slowly increasing?

20462: in Delphinus, binary, P = 2945 y (?), premature orbit, PA increasing, rho is slightly increasing, and deviates from ephemeris. Residuals refer to ephemeris.

20467: γ Delphinum, binary, P = 3249 y (?), premature orbit, only small portion of orbit documented, PA and rho decreasing, recent speckle data as well as own measure seem to deviate from ephemeris.

20474: λ Cygni, close binary, P = 391.3 y, many speckle data, both PA and rho exhibit systematic variations, which are apparently due to a companion of A with period of 11.6 y, which has been detected by spectroscopy and by infrared speckle interferometry. Residuals refer to ephemeris.

20514: 4 Aquarii, close binary, P = 199.8 y, many speckle data. Residuals refer to ephemeris.

20585: in Cygnus, cpm, PA decreasing.

20591: ε Equulei, all cpm, AB close binary, not resolved here, few data for C.

21022: λ Equulei, PA decreasing, recent speckle data exhibit some scatter, residuals ambiguous.

21031: in Aquarius, binary, P = 1532 y, premature orbit, only small portion documented, PA and rho decreasing. Residuals refer to ephemeris, significant deviation.

21069: 61 Cygni, binary, P = 678 y, 61 Cygni is more famous for its large proper motion of about 5"/year.

21197: also known as STTA 217, wide pair in Cygnus, few data.

21200: in Cygnus, few data.

21208: in Cygnus, many speckle data, PA decreasing, rho increasing, Gaia position extrapolated.

21289: in Cygnus, binary, P = 978 y (?), many speckle data, only small portion of orbit documented. Currently assumed ephemeris deviates from GAIA position.

21441: μ Cygni, binary, P = 789 y (?), many speckle data until 2012, significant deviation from ephemeris. Residuals refer to ephemeris.

22038: ξ Cephei, cpm, PA decreasing. Few data, residuals somewhat ambiguous.

22044: in Cepheus, many speckle data, rho decreasing, Gaia position extrapolated to epoch of own recording.

22071: in Cepheus, recent speckle data exhibit some scatter, residuals ambiguous.

22269: in Cepheus, few data.

22280: in Cepheus, famous red dwarf binary, P = 44.7 y.

22288: ζ Aquarii, binary, P = 486.7 y, orbit exhibits wobble with period 25.7 y, due to an unseen companion to B, which has been detected in the infrared. Residuals refer to the currently assumed ephemeris for B.

22292: δ Cephei, wide pair, few data.

22303: in Cepheus, relfix.

22419: in Pegasus, binary, P = 3350 y (?), only small portion of orbit documented. An unseen companion with period 82 y is attributed to A.

22569: in Pegasus, cpm, few data, PA increasing.

22586: in Pegasus, wide pair, few data.

23075: in Pegasus, cpm, relfix, few data.

23340: 72 Pegasi, close binary, P = 492.3 y, orbit almost circular, but eccentric, many speckle data, occasional large scatter.

23519: in Andromeda, PA decreasing, rho increasing.

23581: in Pegasus, few data, rho (AB) decreasing.

23595: in Andromeda, binary, P = 717 y, many speckle data.

Double Star Measurements at the Northern Sky with a 10 inch Newtonian in 2014 and 2015

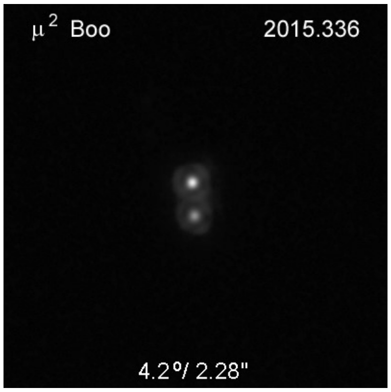

Figure 3. The binary μ^2 Bootis. The date of recording is indicated at upper right, the measures of position angle and separation at the bottom. Stack of 76 frames with exposure time 38.5 msec. North is down, east is right.

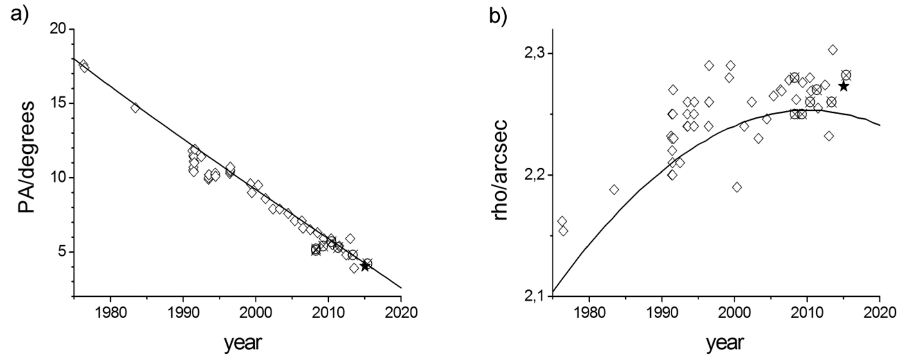

Figure 4 a): Plot of the position angle of mu2 Bootis vs. time. Open squares indicate speckle data, crossed circles own measurements. Full stars represent the results from Gaia. b): Plot of the separation rho vs. time.

(Continued from page 289)

errors increase, when a dim companion is lying at or near the diffraction ring of the main star, which makes selection of "lucky" images difficult. For large separations, in particular for the reference systems, the error is of the order of ±0.1 to 0.2 degrees, which mainly reflects the error of determining the east-west direction from star trails. As in Figure 1, some binaries with positions deviating from ephemeris data are marked with their names. In several cases of binaries, data from Gaia reveal and confirm deviations from currently assumed orbits. An example is the well-known binary μ^2 Bootis (STF 1938 Ba,Bb), which is illustrated in Figures 3 and 4. While the position angle fits the ephemeris reasonably well, the separation is off by about 0.023", clearly exceeding the error margins. In contrast, recent speckle measurements, as well as my own data exhibit considerable scatter, so that any conclusion regarding deviations from the ephemeris would have been rather ambiguous.

Another example is the binary STF 2486 Cygni, an image of which is shown in Figure 5. An ephemeris has been calculated by A. Hale in 1994, resulting in a period of 3100 years, and the companion has only passed a short arc on the orbit. Again, measurements in the past exhibit significant scatter, as can be seen in Figure 6, but the results from Gaia clearly deviate in both position angle and separation. Nevertheless, the ephemeris can be used to estimate the variation with time, so as to extrapolate the Gaia data at epoch 2015.0 to the epoch of my own recording with date 2015.66. As a result, the PA was reduced by 0.1 degrees, and the separation by

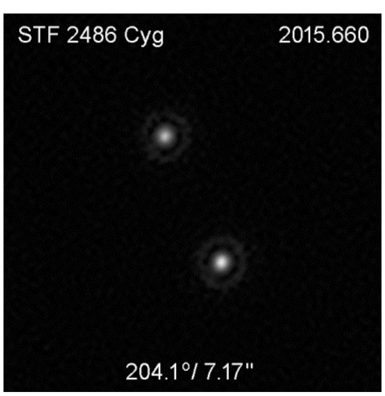

Figure 5. The binary STF 2486 in Cygnus. Stack of 108 frames with exposure 40 msec.

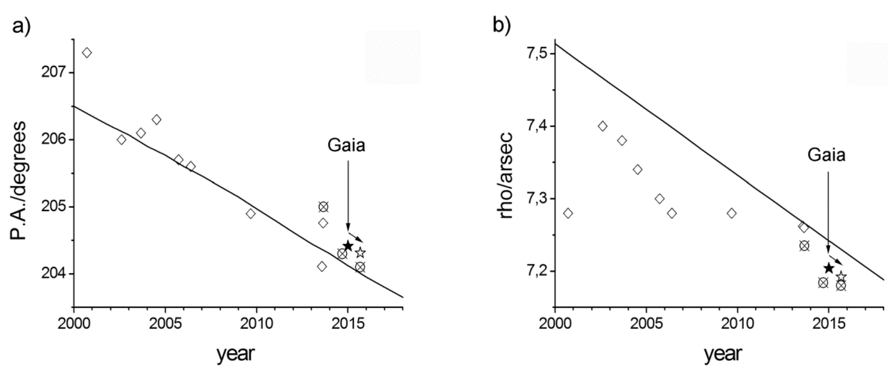

Figure 6a). The position angle of STF2486 Cygni vs. time. b). The separation rho vs. time. The meaning of the symbols is as in fig.4. Short arrows in parallel to the ephemeris lines, and the open stars indicate the extrapolation of the Gaia data to the epoch of the own recording.

Double Star Measurements at the Northern Sky with a 10 inch Newtonian in 2014 and 2015

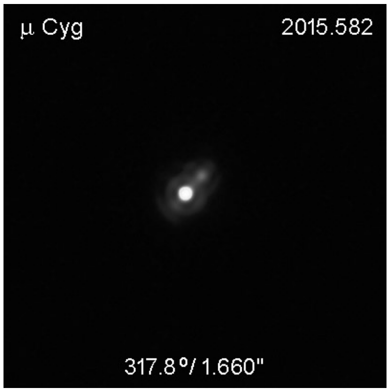

Figure 7. The binary mu Cygni. Stack of 154 frames with exposure 51 msec.

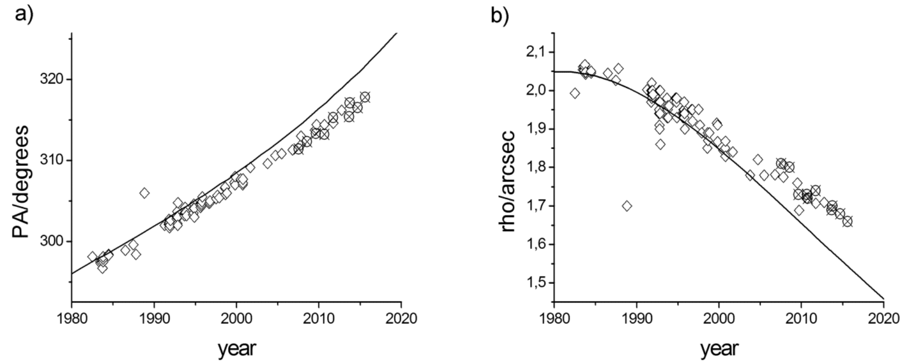

Figure 8a). The position angle of mu Cygni vs. time. b). The separation rho vs. time. The meaning of the symbols is as in fig.4. Both speckle measurements and own data deviate from the ephemeris. Solid lines represent ephemeris data from W. Heintz 1995 [8].

0.012". While these values are of the order of the statistical error margins, a correction to the separation helps in improving the accuracy of the scaling factor, as was discussed above.

Another example of strongly deviating positions from ephemeris data is the pair μ Cygni. An image is shown in Figure 7. The variations with time of the position angle and separation are plotted in Figures 8 a) and b), respectively. An orbit has been calculated by W. Heintz [8] in 1995, with a period of 789 years. In the last 20 years the companion has passed a strongly bent arc of the highly inclined orbit, and is drifting away since about 10 years ago.

An especially interesting case is the system ζ Aquarii (STF2909 AB, see Figure 9). Component B is known to be periodically pulled off its regular orbit (calculated by *M. Scardia* [9] in 2010) by an invisible companion, which has only been detected in the infrared. These deviations have been seen in recent years much more clearly than before, due to an improved accuracy of measurements. This is illustrated in Figure 10. An astrometric orbit has been obtained for the companion by *A. Tokovinin* [10] in 2014, with a period of 25.7 years. Dates 1994.1 and 2006.9 indicate epochs of apastron and periastron of the companion, respectively.

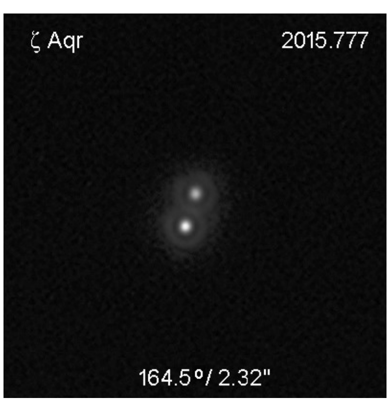

Figure 9 The binary ζ Aquarii. Stack of 41 frames with exposure 10 msec.

Concluding remarks

A major improvement of the accuracy of double star measurements was possible by calibrating the image scale with reference stars, for which the recently published first Gaia catalog provides extremely precise position data. An error margin of the scale factor of ±0.1 per cent was obtained. This is 1/5 of previous values, which were based on double star data from catalogs, which exhibited more or less pronounced scatter. The remaining statistical scatter of separation measure-

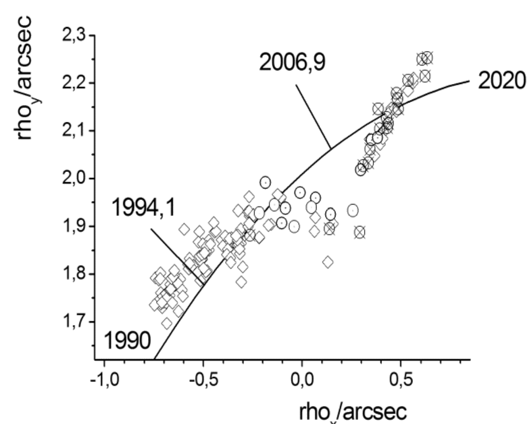

Figure 10. The movement of ζ Aquarii B (STF 2909 AB) in Cartesian coordinates. The origin is at the main star A. Open squares indicate speckle measurements, open circles visual, crossed circles own. The curve represents the ephemeris. Dates 1994.1 and 2006.9 indicate the epochs of apastron and periastron of the unseen companion to B. Curved line represents ephemeris data from Scardia 2010 [9].

ments of ±0.011 arcsec is mainly caused by seeing effects, and by the limited resolution of the telescope. Nevertheless, the precision of position measurements is about 1/50 of the Rayleigh limit, which, however, merely characterizes the splitting power of close doubles.

Many of the double stars investigated here fall within the error limits discussed above. However, for some binaries, star positions from Gaia revealed or confirmed deviations from currently assumed ephemeris data, mostly in accordance with my measurements and/or recent speckle measurements (within the error limits of these methods). The following list includes such systems with deviations of separations greater than 0.02”:

Name	Note
STT21	01030
STF1938 Ba,Bb (see Fig. 4)	15245
STF1964 CD	15382
STF2032	16147
STF2486 AB (see Fig. 6)	19121
STF2613 AB	20014
STF3050	23595

The list is continued with binaries, which are so far not supported by Gaia, but my measurements as well as recent speckle data nevertheless reveal deviations from orbit calculations. These are indicated in Figs. 1 and 2 by dots within open symbols. Many of these pairs contain stars, which are too bright for Gaia.

STF208	02037
STT215	10163
STT216	10227
STF1555 AB	11363
STF1687 AB	12533
STF1768 AB	13375
STF1937 AB (η CrB)	15232
STF2140 AB (α Herculis)	17146
AC7 BC (μ^2 Her)	17465
STF2289	18101
STT359	18355
STT358 AB	18359
STF2725	20462
STT413 AB (λ Cyg)	20474
STF2744 AB	21031
BU690 (μ Cygni, Fig.8)	21441
BU720	23340

Finally, there are many pairs, for which only few data could be found in the literature. In general, the present measurements may help to improve the statistics of double star data, and to improve the knowledge about their status. It has been shown that data from Gaia are helpful for improving the accuracy of my own measurements. Also, it seems that even in the times of Gaia, earth-bound work may not be obsolete, at least regarding double stars with components being too bright for Gaia.

Acknowledgements

This work has made use of data from the double star catalogs provided by the United States Naval Observatory, as well as data from the Gaia satellite mission, which were recently published by the ESA consortium.

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STT Doubles with Large ΔM – Objects Nearby

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Abstract: Following our series of reports on STT doubles with large delta_M, we are submitting measurements of WDS objects which were by chance found nearby in the images taken of the STT doubles. In these cases we did not suspect any issues with the current WDS catalog data, but wanted to make use of existing image material as any double star visited is worth a current measurement.

As a follow up to our STT reports we decided to finish our project with the many double stars found near the STT objects which we investigated. All values are based on WDS data as of August 2016 and are shown in Table 1.

1. Photometry and Astrometry Results

From the available several hundred images taken with iTelescope remote telescopes, we selected the best suited for measurements of nearby objects. The selected images were then plate solved with Astrometrica with URAT1 reference stars with Vmags in the range 10.5 to 14.5mag. The RA/Dec coordinates resulting from plate solving with URAT1 reference stars in the 10.5 to 14.5mag range were used to calculate Sep and PA using the formula provided by R. Buchheim (2008). *Err_PA* is the error estimation for PA in degrees calculated as arctan (Err_Sep/Sep) assuming the worst case that *Err_Sep* points perpendicular to the separation vector. *Mag* is the photometry result based on URAT1 reference stars with Vmags between 10.5 and 14.5mag. *Err_Mag* is calculated as

$$Err\_Mag = \sqrt{dVmag^2 + \left[2.5\log_{10}\left(1 + 1/SNR\right)\right]}$$

with *dVmag* as the average Vmag error over all used reference stars and *SNR* is the signal to noise ratio for the given star. The results are shown in Table 2.

In the next step we took a closer look at a few objects listed with the WDS V-code indicating physical relationship, comparing the WDS data with the data in the star catalogs available in Aladin/VizieR for positions allowing calculation of proper motion data (Table 3.). Additionally we have one case with a possible third component of BRT 1204 found in an Aladin image, but not listed in the WDS. We were unable to resolve this component in our own images, so we've used the available star catalog data in Aladin/Vizier. Also included is CPM analysis of a possible third component of ES 1585 which is not listed in the WDS, but which we've labeled as C (see Figure 7.).

2. Historical Research, Catalog Comparison and Summary

After researching each object in this report for historical information as well as other interesting material, we decided to include information on the group of stars shown in Figure 1.

(Text continues on page 308)

STT Doubles with Large ΔM – Objects Nearby

Table 1. WDS Catalog Data per August 2016 for the Objects Found Nearby STT Doubles with Large ΔM

WDS ID	Name		RA	Dec	Sep	M1	M2	PA	Con
00049+4554	VYS 1	AB	00:04:55.300	+45:54:52.6	2.9	10.50	10.50	208	And
00049+4540	BU 997	AB	00:04:57.530	+45:40:25.6	3.9	7.64	9.39	337	And
05098+4856	DAM1026	AB	05:09:46.589	+48:56:16.7	6.3	12.30	13.40	346	Aur
05175+3312	CTT 4	AB	05:17:31.709	+33:12:05.9	108.8	7.74	11.73	105	Aur
05175+3312	CTT 4	AC	05:17:31.709	+33:12:05.9	111.6	7.74	10.96	283	Aur
05175+3312	CTT 4	AD	05:17:31.709	+33:12:05.9	94.3	7.74	11.35	271	Aur
05175+3312	CTT 4	AE	05:17:31.709	+33:12:05.9	114.3	7.74	12.27	269	Aur
05187+3331	ES 59	AB	05:18:41.811	+33:31:27.2	13.9	8.46	9.59	10	Aur
05187+3331	ES 2611	AE	05:18:41.811	+33:31:27.2	74.8	8.46	12.13	170	Aur
05410+1620	BPM 151	AB	05:41:00.881	+16:20:07.4	107.3	14.19	14.95	50	Tau
05460+2606	J 1906	AB	05:45:59.000	+26:06:35.9	7.6	12.00	12.00	335	Tau
05461+2605	J 1907	AB	05:46:07.090	+26:05:29.4	9.0	11.00	11.50	234	Tau
05463+2542	BRT 138	AB	05:46:16.410	+25:42:06.0	6.0	8.38	11.20	119	Tau
06312+1656	FOX 147	AC	06:31:09.990	+16:56:19.0	47.3	6.20	11.41	346	Gem
06314+1646	BPM 282	AB	06:31:22.229	+16:45:44.9	73.9	12.79	15.27	324	Gem
06315+1535	BRT1204	AB	06:31:33.911	+15:34:44.9	5.3	10.50	11.50	79	Gem
06420+2528	TDS4042	AB	06:42:00.580	+25:28:10.9	1.7	10.09	11.65	80	Gem
07070+2444	POU2442	AB	07:07:00.510	+24:43:36.9	3.6	12.40	12.60	351	Gem
07285+3437	CBL 24	AB	07:28:30.990	+34:37:04.4	34.1	12.19	14.30	86	Gem
07445+2415	POU2883	AB	07:44:28.929	+24:14:25.7	10.5	12.70	12.90	82	Gem
07455+3431	GRV 740	AB	07:45:35.900	+34:31:04.9	76.0	10.93	11.73	204	Gem
09207+5116	ARN 71	AD	09:20:43.759	+51:15:57.8	231.1	6.19	7.89	52	UMa
12227+0325	CBL 380	AB	12:22:44.440	+03:24:40.1	39.7	14.40	18.00	338	Vir
17525+1530	L 17	AB	17:52:30.762	+15:31:31.0	2.2	10.50	11.20	288	Her
17525+1530	WLY 20	AC	17:52:30.762	+15:31:31.0	38.2	11.90	12.47	122	Her
18477+1029	BRT1310	AB	18:47:43.552	+10:28:01.0	3.9	12.47	12.86	21	Aql
18485+1045	STF2396	AB	18:48:29.152	+10:44:47.4	76.5	8.08	11.25	336	Aql
18485+1045	STF2396	AD	18:48:29.152	+10:44:47.4	199.4	8.08	10.83	36	Aql
18485+1045	STF2396	AC	18:48:29.152	+10:44:47.4	198.5	8.08	10.14	6	Aql
19162+1612	BPM1005	AB	19:16:10.999	+16:12:10.6	73.2	14.02	15.55	267	Aql
19164+1612	BPM1006	AC	19:16:22.748	+16:12:18.6	94.0	14.90	14.80	312	Aql
19164+1612	BPM1006	AB	19:16:22.748	+16:12:18.6	4.2	14.90	16.00	337	Aql
19304+5015	TDT1508	AB	19:30:21.272	+50:14:36.6	2.1	11.45	11.77	207	Cyg
19548+0636	J 3032	AB	19:54:55.892	+06:36:53.6	4.0	11.00	13.80	21	Aql
21181+3500	SLE 383	AB	21:18:08.642	+35:00:04.5	15.1	10.49	11.92	58	Cyg
21183+3456	BU 289	AC	21:18:18.200	+34:55:36.2	12.7	9.13	13.00	252	Cyg
21183+3456	SLE 384	AD	21:18:18.200	+34:55:36.2	43.0	9.13	11.98	190	Cyg
21183+3456	FYM 142	AE	21:18:18.200	+34:55:36.2	36.7	9.13	13.50	95	Cyg
21183+3456	FYM 142	AF	21:18:18.200	+34:55:36.2	45.7	9.13	14.90	200	Cyg
21183+3456	FYM 142	AG	21:18:18.200	+34:55:36.2	68.2	9.13	13.70	272	Cyg
21183+3456	FYM 142	DF	21:18:17.678	+34:54:53.7	4.9	11.98	14.90	277	Cyg
21183+3456	FYM 142	EI	21:18:21.221	+34:55:33.8	7.1	13.50	15.70	279	Cyg
21183+3456	FYM 142	GH	21:18:12.659	+34:55:38.5	4.7	13.70	14.60	81	Cyg
21214+4301	ES 1585	AB	21:21:29.143	+43:00:51.0	18.7	10.17	13.60	230	Cyg

STT Doubles with Large ΔM – Objects Nearby

Table 2: Photometry and astrometry results for the double star objects nearby the imaged STT objects. Date is the Bessel epoch and N is the number of images used for the reported values. iT in the Notes column indicates the telescope used with aperture. number of images and exposure time given. Observation method is "C"

Name		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
VYS 1	A	00 04 55.386	45 54 53.82	0.03	0.03	2.842	0.042	207.555	0.855	11.844	0.043	74.95	0.04	2015.774	5	iT24 0.61m stack 5x3s
	B	00 04 55.260	45 54 51.30							11.792	0.043	74.92				
BU 997	A	00 04 57.550	45 40 24.58	0.03	0.03	3.773	0.042	337.284	0.644	7.561	0.040	258.45	0.04	2015.774	5	iT24 0.61m stack 5x3s
	B	00 04 57.411	45 40 28.06							9.512	0.044	62.14				
DAM 1026	A	05 09 46.575	48 56 16.42	0.10	0.10	6.817	0.141	348.494	1.188	12.058	0.119	23.61	0.11	2016.108	5	iT24 0.61m stack 5x3s. SNR B <20
	B	05 09 46.437	48 56 23.10							13.639	0.138	12.54				
CTT 4	A	05 17 31.715	33 12 05.30	0.12	0.10	108.863	0.156	105.024	0.082	7.713	0.103	40.42	0.10	2016.108	5	iT24 0.61m stack 5x1s
	B	05 17 40.092	33 11 37.08							11.517	0.108	26.96				
CTT 4	A	05 17 31.715	33 12 05.30	0.12	0.10	111.908	0.156	283.045	0.080	7.713	0.103	40.42	0.10	2016.108	5	iT24 0.61m stack 5x1s
	C	05 17 23.029	33 12 30.56							10.896	0.107	27.92				
CTT 4	A	05 17 31.715	33 12 05.30	0.12	0.10	94.517	0.156	271.152	0.095	7.713	0.103	40.42	0.10	2016.108	5	iT24 0.61m stack 5x1s
	D	05 17 24.186	33 12 07.20							11.352	0.108	25.83				
CTT 4	A	05 17 31.715	33 12 05.30	0.12	0.10	113.113	0.156	269.108	0.079	7.713	0.103	40.42	0.10	2016.108	5	iT24 0.61m stack 5x1s. SNR E <20
	E	05 17 22.704	33 12 03.54							12.454	0.125	14.04				
CTT 4	A	05 17 31.715	33 12 05.30	0.12	0.10	41.905	0.156	167.177	0.214	7.713	0.103	40.42	0.10	2016.108	5	iT24 0.61m stack 5x1s. Additional component F with SNR <20
	F	05 17 32.456	33 11 24.44							12.744	0.125	13.97				
ES 59	A	05 18 41.804	33 31 26.97	0.12	0.10	13.876	0.156	9.388	0.645	8.415	0.105	35.00	0.10	2016.108	5	iT24 0.61m stack 5x1s
	B	05 18 41.985	33 31 40.66							9.461	0.106	30.00				
ES 2611	A	05 18 41.804	33 31 26.97	0.12	0.10	78.072	0.156	169.283	0.115	8.415	0.105	35.00	0.10	2016.108	5	iT24 0.61m stack 5x1s. SNR E<20
	B									12.738	0.131	12.26				

Table 2 continues on next page.

STT Doubles with Large ΔM – Objects Nearby

Table 2 (continued). Photometry and astrometry results for the double star objects nearby the imaged STT objects. Date is the Bessel epoch and N is the number of images used for the reported values. iT in the Notes column indicates the telescope used with aperture. number of images and exposure time given. Observation method is "C"

Name		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
BPM 151	A	05 41 00.897	16 20 07.51	0.12	0.11	107.338	0.163	49.948	0.087	14.163	0.126	28.29	0.12	2016.026	5	iT27 0.7m stack 5x3s. SNR B>20. This object is listed in the WDS catalog with code V - the reason for this may not be common proper motion, see text.
	B	05 41 06.605	16 21 16.58							15.218	0.139	15.16				
J 1906	A	05 45 59.003	26 06 35.98	0.06	0.06	7.509	0.085	335.634	0.647	13.510	0.105	13.49	0.07	2016.085	5	iT18 0.32m stack 5x3s. SNR for both components <20
	B	05 45 58.773	26 06 42.82							13.487	0.100	14.74				
J 1907	A	05 46 07.103	26 05 29.45	0.06	0.06	9.058	0.085	233.718	0.537	12.607	0.083	24.31	0.07	2016.085	5	iT18 0.32m stack 5x3s. SNR for B <20
	B	05 46 06.561	26 05 24.09							13.506	0.107	12.88				
BRT 138	A	05 46 16.420	25 42 05.93	0.06	0.06	6.052	0.085	118.095	0.803	8.237	0.070	184.35	0.07	2016.085	5	iT18 0.32m stack 5x3s. A too bright for reliable photometry
	B	05 46 16.815	25 42 03.08							11.578	0.078	31.93				
FOX 147	A	06 31 09.970	16 56 18.31	0.10	0.09	47.282	0.135	345.716	0.163	6.151	0.070	249.27	0.07	2015.281	5	iT24 0.61m stack 5x1s. A too bright for reliable photometry
	C	06 31 09.157	16 57 04.13							11.424	0.074	44.64				
BPM 282	A	06 31 22.247	16 45 44.72	0.10	0.09	69.013	0.135	333.739	0.112	12.663	0.085	21.65	0.07	2015.281	5	iT24 0.61m stack 5x1s. SNR for B <20. Why this object is listed with WDS code V is unclear - most likely is not common proper motion. See text.
	B	06 31 20.121	16 46 46.61							13.401	0.106	13.09				
BRT 1204	A	06 31 33.911	15 34 44.88	0.10	0.09	5.430	0.135	77.558	1.419	11.920	0.077	33.31	0.07	2015.281	5	iT24 0.61m stack 5x1s. SNR for B <20
	B	06 31 34.278	15 34 46.05							13.215	0.099	15.15				
TDS 4042	A	06 42 00.600	25 28 09.72	0.08	0.08	-	0.113	-	-	10.023	0.071	88.98	0.07	2015.281	5	iT24 0.61m stack 5x1s. No trace of a companion. Bogus?
	B										-					
POU 2442	A													2015.281	5	iT24 0.61m stack 5x1s. No resolution of both components. Faintest stars in the used image ~13.5mag -> both components have to be fainter than that
	B															
CBL 24	A	07 28 30.634	34 37 06.30	0.13	0.11	-	0.170	-	-	12.231	0.098	26.78	0.09	2015.281	5	iT24 0.61m stack 5x1s. No resolution of B. Faintest stars in the image ~13.5mag
	B										-					

Table 2 continues on next page.

STT Doubles with Large ΔM – Objects Nearby

Table 2 (continued). Photometry and astrometry results for the double star objects nearby the imaged STT objects. Date is the Bessel epoch and N is the number of images used for the reported values. iT in the Notes column indicates the telescope used with aperture. number of images and exposure time given. Observation method is "C"

Name		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
POU 2883	A													2015.291	2	iT21 0.43m stack 2x0.5s. No resolution of both components. Faintest stars in the image ~12.2 -> both components have to be fainter than that
	B															
GRV 740	A	07 45 35.941	34 31 04.45	0.08	0.10	75.971	0.128	204.172	0.097	10.738	0.102	50.36	0.10	2015.297	5	iT21 0.43m stack 5x1s
	B	07 45 33.424	34 29 55.14							11.795	0.106	29.32				
ARN 71	A	09 20 43.718	51 16 00.07	0.16	0.16	230.374	0.226	51.437	0.056	6.251	0.090	435.84	0.09	2015.376	5	iT11 0.51m stack 5x3s. Both components too bright for reliable photometry. V-coded WDS object. Comparison 2MASS to URAT1 does not support CPM - difference in pm direction is ~6.5° and difference in speed is ~15mas/yr
	D	09 21 02.911	51 18 23.68							7.880	0.090	318.64				
CBL 380	A													2015.456	4	iT24 0.61m 4x1s. WDS V-coded object No resolution of A and B – both component fainter than 13.6mag
	B															
L 17	A	17 52 30.775	15 31 31.19	0.08	0.09	2.359	0.120	291.379	2.922	11.840	0.074	44.16	0.07	2015.476	6	iT24 0.61m stack 6x1s. Overlapping star disks
	B	17 52 30.623	15 31 32.05							12.137	0.076	34.81				
WLY 20	A	17 52 30.775	15 31 31.19	0.08	0.09	38.103	0.120	121.661	0.181	11.840	0.074	44.16	0.07	2015.476	6	iT24 0.61m stack 6x1s
	C	17 52 33.019	15 31 11.19							12.447	0.077	33.60				
STF 2396	A	18 48 29.358	10 44 36.74	0.06	0.06	82.005	0.085	336.723	0.059	7.869	0.070	399.98	0.07	2015.555	5	iT24 0.61m stack 5x3s. A too bright for reliable photometry. A shows high speed proper motion resulting in a rapid change also in separation
	B	18 48 27.159	10 45 52.07							11.158	0.071	108.92				
STF 2396	A	18 48 29.358	10 44 36.74	0.06	0.06	203.176	0.085	4.743	0.024	7.869	0.070	399.98	0.07	2015.555	5	iT24 0.61m stack 5x3s. A too bright for reliable photometry. A shows high speed proper motion resulting in a rapid change also in separation
	C	18 48 30.498	10 47 59.22							9.948	0.070	172.62				
STF 2396	A	18 48 29.358	10 44 36.74	0.06	0.06	203.651	0.085	34.878	0.024	7.869	0.070	399.98	0.07	2015.555	5	iT24 0.61m stack 5x3s. A too bright for reliable photometry. A shows high speed proper motion resulting in a rapid change also in separation
	D	18 48 37.260	10 47 23.81							10.934	0.071	122.12				
BRT 1310	A	18 47 43.502	10 27 59.97	0.07	0.07	3.811	0.099	21.334	1.488	12.005	0.104	36.23	0.10	2015.557	5	iT24 0.61m stack 5x1s
	B	18 47 43.596	10 28 03.52							12.929	0.111	21.94				

Table 2 continues on next page.

STT Doubles with Large ΔM – Objects Nearby

Table 2 (continued). Photometry and astrometry results for the double star objects nearby the imaged STT objects. Date is the Bessel epoch and N is the number of images used for the reported values. iT in the Notes column indicates the telescope used with aperture. number of images and exposure time given. Observation method is "C"

Name		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
BPM 1005	A	19 16 11.013	16 12 10.25	0.06	0.06	73.267	0.085	267.340	0.066	13.942	0.069	31.11	0.06	2015.555	5	iT24 0.61m stack 5x3s. SNR B <20. This object is WDS listed with V-code. Comparison 2MASS to URAT1 does definitely not support CPM
	B	19 16 05.932	16 12 06.85							15.527	0.104	12.31				
BPM 1006	A	19 16 22.761	16 12 18.55	0.04	0.05	4.730	0.064	336.870	0.776	15.011	0.088	16.29	0.06	2015.557	5	iT24 0.61m stack 5x3s. SNR A <20 and B <10
	B	19 16 22.632	16 12 22.90							16.181	0.146	7.67				
BPM 1006	A	19 16 22.761	16 12 18.55	0.04	0.05	93.979	0.064	311.441	0.039	15.011	0.088	16.29	0.06	2015.557	5	iT24 0.61m stack 5x3s. SNR A and B <20
	C	19 16 17.870	16 13 20.75							15.473	0.103	12.48				
TDT 1508	A	19 30 21.270	50 14 36.49	0.04	0.04	-	0.057	-	-	11.515	0.051	90.44	0.05	2015.632	5	iT24 0.61m stack 5x3s. No resolution of B, not even a hint of an elongation. Bogus assumed
	B										-					
J 3032	A	19 54 55.888	06 36 53.34	0.08	0.11	4.425	0.136	21.741	1.761	12.929	0.056	41.23	0.05	2015.569	5	iT24 0.61m stack 5x3s. 2MASS positions give 4" separation per 2000.671 but A shows some proper motion in about the opposite direction of the PA leading to an increase of sep over time
	B	19 54 55.998	06 36 57.45							14.011	0.064	26.68				
SLE 383	A	21 18 08.629	35 00 04.40	0.03	0.03	15.170	0.042	58.439	0.160	10.437	0.050	170.12	0.05	2015.621	5	iT24 0.61m stack 5x3s
	B	21 18 09.681	35 00 12.34							11.916	0.051	89.32				
BU 289	A	21 18 18.240	34 55 36.41	0.03	0.03	12.988	0.042	251.412	0.187	8.596	0.050	325.33	0.05	2015.621	5	iT24 0.61m stack 5x3s. Mag A is combined A+B (with 0,8" too close for resolution)
	C	21 18 17.239	34 55 32.27							13.018	0.054	51.97				
SLE 384	A	21 18 18.240	34 55 36.41	0.03	0.03	43.309	0.042	189.298	0.056	8.596	0.050	325.33	0.05	2015.621	5	iT24 0.61m stack 5x3s. Mag A is combined A+B (with 0,8" too close for resolution)
	D	21 18 17.671	34 54 53.67							12.075	0.052	83.18				
FYM 142	A	21 18 18.240	34 55 36.41	0.03	0.03	36.714	0.042	94.014	0.066	8.596	0.050	325.33	0.05	2015.621	5	iT24 0.61m stack 5x3s. Mag A is combined A+B (with 0,8" too close for resolution)
	E	21 18 21.218	34 55 33.84							14.326	0.064	26.90				
FYM 142	A	21 18 18.240	34 55 36.41	0.03	0.03	45.882	0.042	199.836	0.053	8.596	0.050	325.33	0.05	2015.621	5	iT24 0.61m stack 5x3s. Mag A is combined A+B (with 0,8" too close for resolution). SNR F <20
	F	21 18 16.974	34 54 53.25							15.006	0.076	18.57				
FYM 142	A	21 18 18.240	34 55 36.41	0.03	0.03	68.786	0.042	271.574	0.035	8.596	0.050	325.33	0.05	2015.621	5	iT24 0.61m stack 5x3s. Mag A is combined A+B (with 0,8" too close for resolution)
	G	21 18 12.649	34 55 38.30							13.977	0.062	29.74				
FYM 142	A	21 18 18.240	34 55 36.41	0.03	0.03	61.547	0.042	274.370	0.039	8.596	0.050	325.33	0.05	2015.621	5	iT24 0.61m stack 5x3s. Mag A is combined A+B (with 0,8" too close for resolution)
	H	21 18 13.250	34 55 41.10							14.913	0.073	19.80				
SLE 384	D	21 18 17.671	34 54 53.67	0.03	0.03	8.583	0.042	267.195	0.283	12.075	0.052	83.18	0.05	2015.621	5	iT24 0.61m stack 5x3s. SNR F <20. WDS data for Sep and PA seems in error
	F	21 18 16.974	34 54 53.25							15.006	0.076	18.57				

Table 2 concludes on next page.

Table 2 (conclusion). Photometry and astrometry results for the double star objects nearby the imaged STT objects. Date is the Bessel epoch and N is the number of images used for the reported values. iT in the Notes column indicates the telescope used with aperture. number of images and exposure time given. Observation method is "C"

Name		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
FYM 142	E	21 18 21.218	34 55 33.84	0.03	0.03	9.137	0.042	272.886	0.266	14.326	0.064	26.90	0.05	2015.621	5	iT24 0.61m stack 5x3s. SNR I <10. WDS data for Sep and PA seems in error. URAT1 values per 2013.532 are 9.357" and 273.66°
	I	21 18 20.476	34 55 34.30							16.316	0.145	7.51				
FYM 142	G	21 18 12.649	34 55 38.30	0.03	0.03	7.904	0.042	69.252	0.308	13.977	0.050	325.33	0.05	2015.621	5	iT24 0.61m stack 5x3s. WDS data for Sep and PA seems in error. URAT1 values per 2013.532 are 7.775" and 69.452°
	H	21 18 13.250	34 55 41.10							14.913	0.062	29.74				
ES 1585	A	21 21 29.283	43 00 52.58	0.04	0.05	19.249	0.064	229.622	0.191	10.095	0.060	183.92	0.06	2015.621	5	iT24 0.61m stack 5x3s
	B	21 21 27.946	43 00 40.11							13.745	0.068	34.22				
ES 1585	A	21 21 29.283	43 00 52.58	0.04	0.05	26.872	0.064	221.454	0.137	10.095	0.060	183.92	0.06	2015.621	5	iT24 0.61m stack 5x3s. ES1585 is actually a triple
	C	21 21 27.661	43 00 32.44							14,651	0,078	21,48				
ES 1585	B	21 21 27.946	43 00 40.11	0.04	0.05	8.283	0.064	202.174	0.443	13.745	0.068	34.22	0.06	2015.621	5	iT24 0.61m stack 5x3s. ES1585 BC might be a potential CPM pair
	C	21 21 27.661	43 00 32.44							14.651	0.078	21.48				

STT Doubles with Large ΔM – Objects Nearby

Table 3: Catalog research for some objects of specific interest. CPM rating according to Knapp and Nanson 2016

Name	RA	Dec	Sep "	PA °	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Spc1	Spc2	Ap	Me	Date	CPM Rat	Source/Notes
ARN 71 AD	09:20:43.759	+51:15:57.8	231.1	52	6.19	7.89	-36	145		-37	140						2008		WDS09207+5116 data per 08/2016
	140.18233500	51.2660410	231.083	51.461	6.1	7.7									1.3	E2	1998.928		2MASS. M1 and M2 estimated from J- and K-band
	140.18211780	51.2666283	230.794	51.479			-32.51	140.48	6.13	-44.68	125.69	6.17			0.2	Eu	2013.923	CBA	URAT1. PM data calculated from position comparison with 2MASS. Result does not support CPM - difference in pm direction is ~6.5° and difference in speed is ~15mas/yr
	140.18210366	51.2666639	230.811	51.480			-32.42	139.53	5.74	-42.61	125.38	5.74			0.96	Hg	2015	BBA	GAIA DR1. PM data calculated from position comparison with 2MASS. Result does not fully support CPM - some difference in pm direction and speed and Sep/PM >3000yrs
Name	**RA**	**Dec**	**Sep "**	**PA °**	**M1**	**M2**	**pmRA1**	**pmDec1**	**e_pm1**	**pmRA2**	**pmDec2**	**e_pm2**	**Spc1**	**Spc2**	**Ap**	**Me**	**Date**	**CPM Rat**	**Source/Notes**
CBL 380	12:22:44.440	+03:24:40.1	39.7	339	14.4	18	-125	62		-120	54						2010		WDS12227+0325 data per October 2016. CPM well confirmed by URAT1 and GAIA DR1 positions in comparison with 2MASS
	185.68521300	3.4111540	39.702	338.773	13.1	15.5									1.3	E2	2000,795		2MASS. M1 and M2 estimated from J- and K-band
	185.68472560	3.4113497	39.716	338.904	14.48		-127.21	51.17	9.74	-122.86	55.15	9.86			0.2	Eu	2013,841	AAB	URAT1. PM data calculated from position comparison with 2MASS
	185.68468711	3.4113710	39.731	338.869			-133.04	54.99	5.97	-129.42	58.60	5.97			0.96	Hg	2015	AAA	GAIA DR1. PM data calculated from position comparison with 2MASS. Sep/PM<1000yrs
Name	**RA**	**Dec**	**Sep"**	**PA°**	**M1**	**M2**	**pmRA1**	**pmDec1**	**e_pm1**	**pmRA2**	**pmDec2**	**e_pm2**	**Spc1**	**Spc2**	**Ap**	**Me**	**Date**	**CPM Rat**	**Source/Notes**
BPM 1005 AB	19:16:10.999	+16:12:10.6	73.2	267	14.02	15.55	1	-24		5	-8						2001		WDS19162+1612 data per 08/2016
	289.04583300	16.2029250	73.174	267.228	13.8	15.1									1.3	E2	1999.803		2MASS. M1 and M2 estimated from J- and K-band
	289.04589060	16.2028561	73.272	267.419	13.98	15.56	14.22	-17.71	6.06	6.38	-0.59	6.05	K3	K4	0.2	Eu	2013.819	CCC	URAT1. PM data calculated from position comparison with 2MASS does definitely not support CPM. Spc according to B-V color index

Table 3 concludes on next page.

STT Doubles with Large ΔM – Objects Nearby

Table 3 (conclusion). Catalog research for some objects of specific interest. CPM rating according to Knapp and Nanson 2016

Name	RA	Dec	Sep "	PA °	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Spc1	Spc2	Ap	Me	Date	CPM Rat	Source/Notes
BPM 1006 AB	19:16:22.748	+16:12:18.6	4.2	337	14.90	16.00	17	-28									2000		WDS19164+1612 data per 08/2016
	289.09482300	16.2051680	4.199	337.032	14.4										1.3	E2	2000.319		2MASS. M1 estimated from J- and K-band
	289.09483470	16.2051617	4.120	336.299	14.91		2.99	-1.68	6.27	1.69	-8.62	6.29	>M4		0.2	Eu	2013.819	CCC	URAT1. PM data calculated from position comparison with 2MASS - result does definitely not support CPM. Spc according to B-V color index
Name	RA	Dec	Sep"	PA°	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Spc1	Spc2	Ap	Me	Date	CPM Rat	Source/Notes
BPM 1006 AC	19:16:22.748	+16:12:18.6	94.0	312	14.90	14.80	17	-28		3	-18						2001		WDS19164+1612 data per 08/2016
	289.09482300	16.2051680	94.112	311.429	14.4										1.3	E2	2000.061		2MASS. M1 estimated from J- and K-band
	289.09483470	16.2051617	94.105	311.456	14.91	15.30	2.99	-1.68	6.27	5.39	0.46	6.07	>M4		0.2	Eu	2013.819	CCC	URAT1. PM data calculated from position comparison with 2MASS - result does definitely not support CPM. Spc according to B-V color index
Name	**RA**	**Dec**	**Sep"**	**PA°**	**M1**	**M2**	**pmRA1**	**pmDec1**	**e_pm1**	**pmRA2**	**pmDec2**	**e_pm2**	**Spc1**	**Spc2**	**Ap**	**Me**	**Date**	**CPM Rat**	**Source/Notes**
BRT 1204 AC	06 31 33.91	+15 34 44.9			10.50		-11	-11									2000		WDS06315+1535 data per 08/2016 for A, C not listed
	97.89127900	15.5791400	11.129	80.372	11.8	15.7									1.3	E2	1997.800		2MASS. M1 estimated from J- and K-band
	97.89128361	15.5790934	11.121	79.583			0.93	-9.76	6.29	-1.05	-1.05	6.29			0.96	Hg	2015	CCC	GAIA DR1. PM data calculated from position comparison with 2MASS - result does definitely not support CPM
Name	**RA**	**Dec**	**Sep"**	**PA°**	**M1**	**M2**	**pmRA1**	**pmDec1**	**e_pm1**	**pmRA2**	**pmDec2**	**e_pm2**	**Spc1**	**Spc2**	**Ap**	**Me**	**Date**	**CPM Rat**	**Source/Notes**
ES 1585 BC	21 21 27.946	43 00 40.11			13.75	14.65	4.92	-21.21	5.23	6.68	-20.63	5.23						BAC	So far no WDS object. Potential CPM pair even if rather slow PM, but Sep/PM<1000yrs
	320.36640300	43.0112460	8.378	202.112	13.7	14.7									1.3	E2	1998.782		2MASS. M1 and M2 estimated from J- and K-band
	320.36643329	43.0111505	8.358	201.954			4.92	-21.21	5.23	6.68	-20.63	5.23			0.96	Hg	2015	BAC	GAIA DR1. PM data calculated from position comparison with 2MASS

STT Doubles with Large ΔM – Objects Nearby

Star	RA	Dec	Mags	PA	Sep	1900+	N	Obs
Anon AB	05175	+3312	7.7,9.5	104.3	98.27	97.07	1	JC
Anon AC	05175	+3312	7.7,9.5	282.3	113.57	97.07	1	JC
Anon AD	05175	+3312	7.7,9.5	269.9	102.77	97.07	1	JC
Anon AE	05175	+3312	7.7,10.	0 268.7	116.24	97.07	1	JC

Webb Society Double Star Circular No. 7 (1998), p. 8

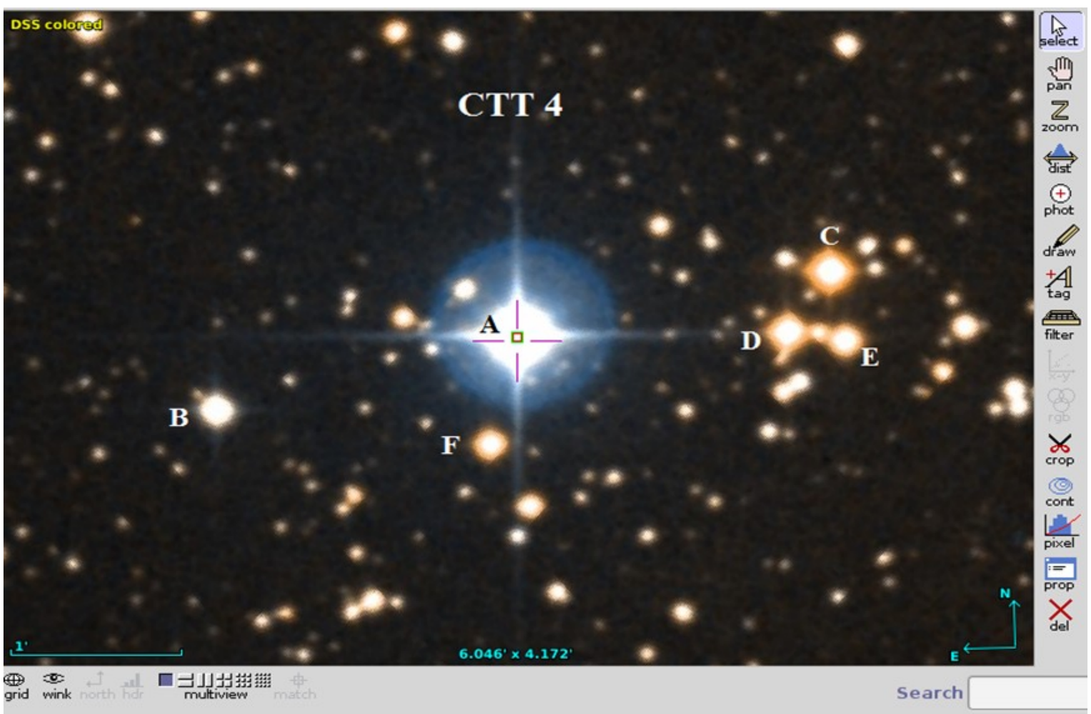
Figure 1. Original observational data for CTT 4.

(Continued from page 299)

CTT 4: This is an interesting multiple star with A, B, C, D, and E components. There's also an additional star not included in the WDS which we've added to our measurements (see Table 1.) because it's closer than the other components and is similar in magnitude (our report identifies that star as the F component). J-F. Courtot published what appear to be the first measures of this multiple star in Webb Society Double Star Circular No. 7 (1998). The measures for the AB, AC, AD, and AE pairs are all labeled as ANON, and all are dated 1997.07 (Figure 1.) The WDS shows first measures for those pairs with dates of 1940, 1934, 1981, and 1982, respectively (Figure 2.), which is an indication they were culled from photographic plates.

There is no distance published for any of the components, but a check of GAIA found a parallax for the primary of 7.15, which works out to 456 light years (no parallax was listed for the other components). Proper motion data was absent in the most recent GAIA data (I/337), but we found URAT1 had PM data for all of the components, including the star we added as F. (That data is shown at the bottom of Figure 2).

BRT 1204: The WDS lists data for just two components, but Aladin's image (Figure 3.) shows three components, all of which are virtually in a straight line with each other. The third one, however is faint and probably wasn't seen by Barton – the derived visual magnitude from URAT1 J and K values is 15.614. The exposure time for our image of BRT 1204 was too short to reveal the third star, so we turned to the GAIA data in Aladin to get measures. The AC pair measured 11.12" and 79.6°, and the BC pair measured 5.742" and

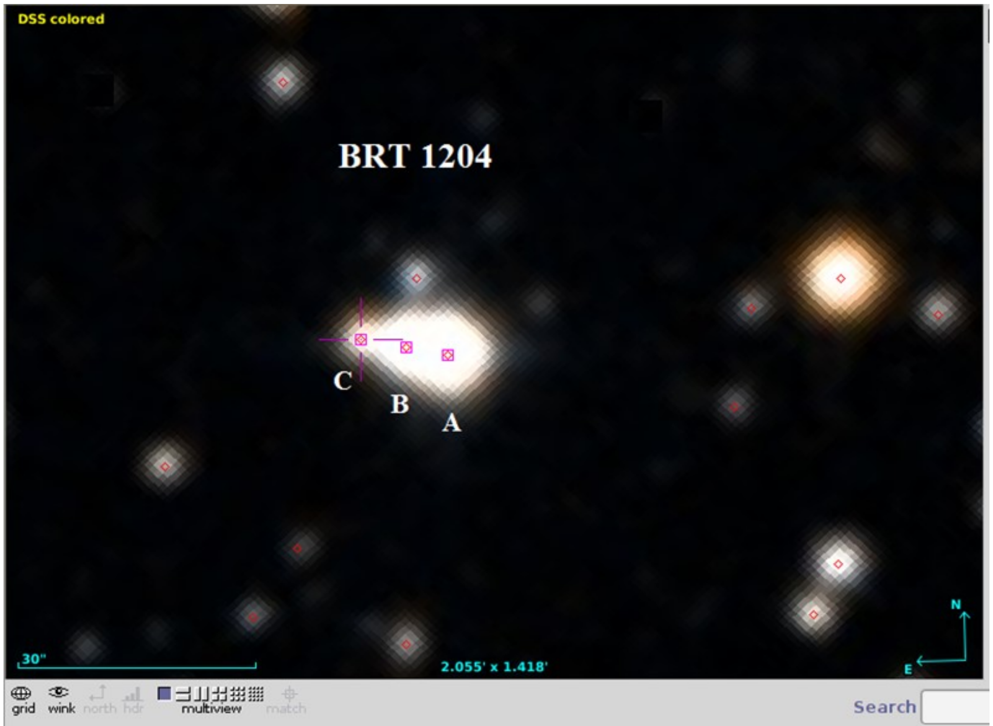


V	WDS	Disc	Comp	Obs1	Obs2	pa1	pa2	sep1	sep2	mag1	mag2	DM	RAJ2000	DEJ2000
VizieR	05175+3312	CTT 4	AB	1940	2002	106	105	111.7	108.8	7.74	11.73	+33 994	05 17 31.71	+33 12 05.9
VizieR	05175+3312	CTT 4	AC	1934	2011	281	283	111.2	111.6	7.74	10.96		05 17 31.71	+33 12 05.9
VizieR	05175+3312	CTT 4	AD	1981	2002	270	271	94.2	94.3	7.74	11.35		05 17 31.71	+33 12 05.9
VizieR	05175+3312	CTT 4	AE	1982	2002	269	269	114.4	114.3	7.74	12.27		05 17 31.71	+33 12 05.9

	URAT1	RAJ2000	DEJ2000	Epoch	f.mag	e f....	pmRA	pmDE	Jmag	Hmag	Kmag	Vmag
A	617-089416	79.3821847	33.2015536	2013.658	7.99	0.041	20.9	-32.4	7.557	7.592	7.566	
B	616-087526	79.4170275	33.1937336	2013.652	11.815	0.012	5.5	-10.5	11.287	11.29	11.242	11.732
C	617-089291	79.345855	33.2084783	2013.693	9.843	0.019	0.4	-5.9	7.76	6.958	6.721	10.96
D	617-089305	79.3507717	33.2019697	2013.674	10.544	0.013	6.7	-6	8.905	8.364	8.204	11.354
E	617-089284	79.3441342	33.2011281	2013.672	11.627	0.012	3.1	-10.1	10.202	9.689	9.554	12.273
F	616-087396	79.3853047	33.1901292	2013.697	11.806	0.012	5.6	-6.9	9.99	9.331	9.138	12.738

Figure 2. Aladin image of CTT 4 with WDS and URAT1 data. Note the identification of the F component.

STT Doubles with Large ΔM – Objects Nearby



	URAT1	RAJ2000	DEJ2000	Epoch	f.mag	e f....	pmRA	pmDE	Jmag	Hmag	Kmag	Vmag
A	528-093931	97.8912843	15.5791028	2013.723	11.669	0.013	1.2	-8.4	10.927	10.718	10.701	11.613
B	528-093939	97.8927872	15.5794108	2014.123	12.774	0.134	-0.1	-0.9	12.419	12.302	12.227	
C	528-093948	97.8944184	15.5796603	2013.583	14.566	0.11	-5.4	0.8	13.614	13.051	12.879	

Figure 3. Aladin image of BRT 1204 with the additional component labeled as C.

81.1° (Epoch 2015.0 for both measures). URAT1 has proper motion data for all three stars, which is shown at the bottom of Figure 3. GAIA has PM data for A (-010.5 -010.9) and B (+015.7 +003.9) which is considerably different from URAT1, but shows no data for the third star. At any rate, there is no evidence of common proper motion between the three stars (see Table 3. for AC evaluation).

There's a marked difference between the first and last position angles shown in the WDS (96 degrees in 1904, 79.2 degrees in 2000), as well as a notable difference between first and last and separations (4.5" and 5.338"). Our measures (Table 2) showed the AB pair with a position angle of 77.558° and a separation of 5.430" (2015.281). In addition, the WDS shows only three observations of the pair.

POU 2883: The WDS lists magnitudes of 12.7 and 12.9 for the A and B components of POU 2883, but in the Aladin image the secondary appears to be at least equivalent in magnitude to the primary, if not brighter (right half of Figure 4.). A look at the 2MASS infrared image clearly shows the secondary to be brighter (left half of Figure 4.), as does a 1993 POSSII.F image. However, 1995 POSSII.F and 2000 POSSII.N images showed the pair to be very similar in size. But in looking at the URAT1 data we again find the secondary is the brighter of the two stars with an f.mag of 12.764, compared to an f.mag of 12.914 for the primary. The J and K magnitudes in URAT1 follow the same pattern, working out to visual magnitudes of 13.285 for the secondary and 13.351 for the primary. Turning to the UCAC4 catalog, we also find the secondary is brighter with an fmag of 13.027 and the primary with an f.mag of 13.156. (UCAC4 list a Vmag for the secondary of 13.022, but has no Vmag value for the primary). It should also be noted that based on the URAT1 and UCAC4 data, it appears the WDS magnitudes are too bright for both stars. Our attempt to photograph the pair was unsuccessful because the glare from 3.7 magnitude STT 179 limited our magnitude resolution to 12.2.

STF 2396: This is another multiple star, which also includes a high proper motion primary. F.G.W. Struve first measured the AB pair in 1829 at 11.74" and 232.8 degrees. The most recent WDS measure shows a separation of 76.5" and 336 degrees, which is indicative of the high proper motion. In his 1906 Double Star Catalog, S.W. Burnham included a graph showing the

STT Doubles with Large ΔM – Objects Nearby

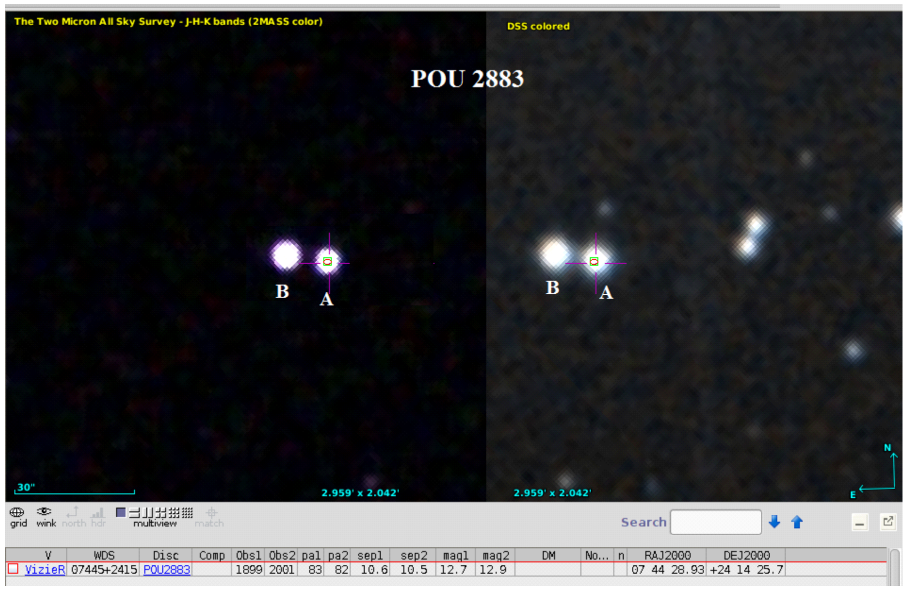


Figure 4. POU 2883, 2MASS IR image on left, Aladin image on right.

primary's motion based on measures from 1825 through 1905 (left half of Figure 5.). STF 2396 also found its way into his 1913 Proper Motion Catalog, which credits B. von Engelhardt with the first measures of the C and D components in 1891. The most recent proper motion from GAIA (bottom right of Figure 5.) shows the primary with motion of +129 in RA and -437.1 in declination. B has motion of +003.7 +006.3, C of 000.2 -009, and D of +004 +007, indicating these are optical components with the possible exception of the similarity in motion between the B and D components. However, a CPM check of those components showed no shared motion.

J 3032: Jonckheere first measured this pair in 1944 at 4" and 30° (top half of Figure 6.). The most recent measure in the WDS from 2000 is 3.991" and 20.8 degrees, which results in a considerable change in position angle and virtually no change in separation. Our 2015.569 measure of the pair is 4.425" and 21.741°. There are only a total of three measures listed in the

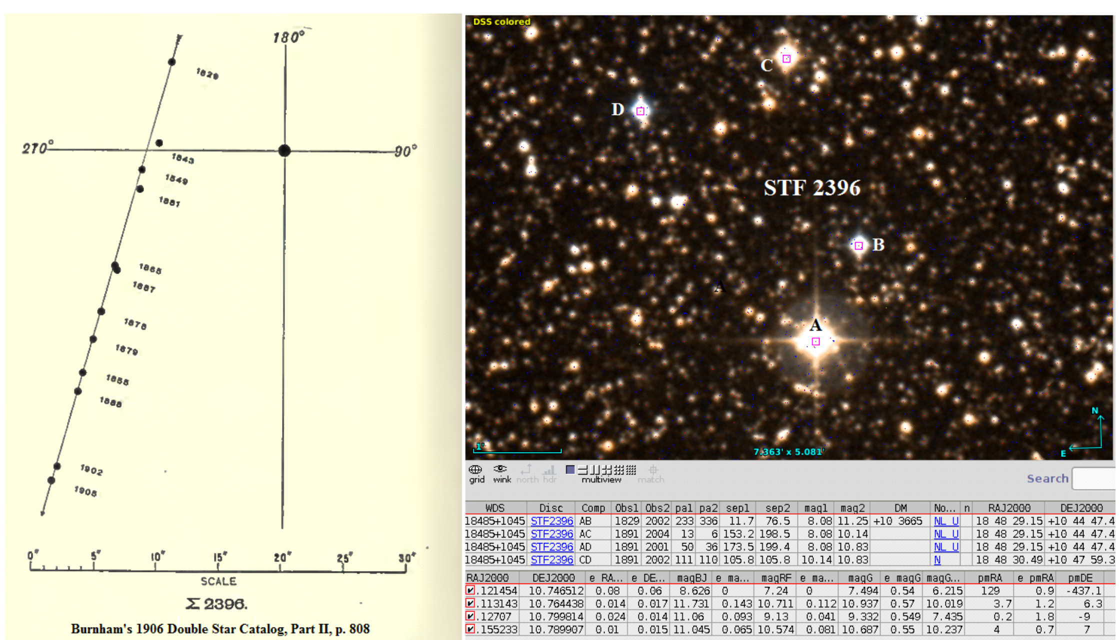


Figure 5. STF 2396, S.W. Burnham's PM chart on left, Aladin image on right with WDS and GAIA data.

WDS, so our measure would bring the total to four.

The most recent GAIA data shows the A component with proper motion of -020.3, -059.0 and B with proper motion of -005.5, +033.6, which results in a gradual increase in separation and a northerly shift in position angle. So there's enough individual motion in the two stars to account for the difference between the 1944 measures and the later measures. In fact, Jonckheere's 1944 separation of 4" was most likely too wide. Based on the PM data, this is an optical pair, which is noted in the WDS as well.

The magnitudes shown in the WDS (11.0 and 13.8) are from Jonckheere's 1944 observation. We measured magnitudes of 12.929 and 14.011, which fits the general pattern of Jonckheere's magnitudes being too bright.

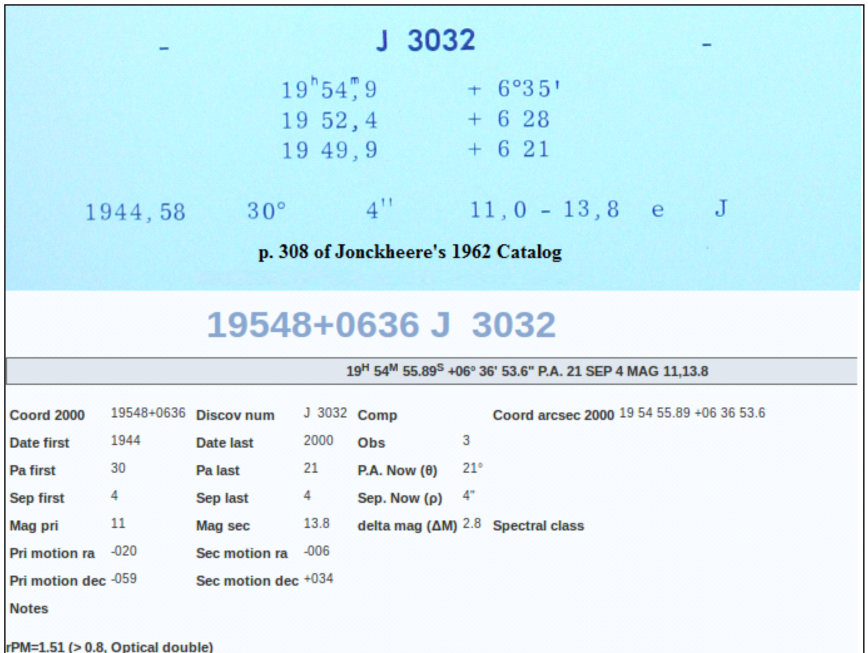


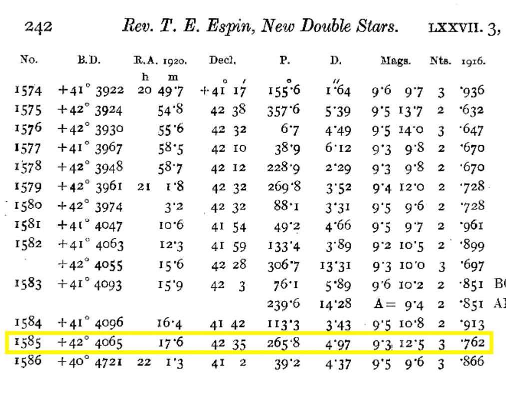
Figure 6. Jonckheere's 1962 catalog entry for J 3032 and WDS data from Stelledoppie below it.

ES 1585: The WDS shows only A and B components for ES 1585, but an obvious third star slightly fainter than the B component is located about 7.5" southwest of B (our photometry recorded a magnitude of 14.651 for that star, which is .9 of a magnitude fainter than the 13.745 we measured for the B component). A check of Espin's catalog entry in the MNRAS for 1917 shows his original observation identified only the A and B components (left half of Figure 7.). We've chosen to include the third component in our measurements, identifying it as C in our table.

The primary of ES 1585 has significant proper motion, especially given the parallax for it shown in GAIA, which works out to 424 light years. URAT1 shows PM data for A of +102.5 +107, for B of +004.2 -021.7, and for the star we labeled as C of +005.8 -020.9. There is enough similarity in the proper motion of the B component and the suggested C component to suggest CPM, which we've shown in Table 3.

2.1 Additional WDS Discrepancies

BPM 151: The WDS assigns a "V" code to this object, which is explained as: "Proper motion or other technique indicates that this pair is physical." The proper motion shown in the WDS for this pair is +004 -



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No.	B.D.	R.A. 1920. h m	Decl. ° ′	P. °	D. ″	Mags.		Nts.	1916.	
1574	+41° 3922	20 49·7	+41 17	155·6	1·64	9·6	9·7	3	·936	
1575	+42° 3924	54·8	42 38	357·6	5·39	9·5	13·7	2	·632	
1576	+42° 3930	55·6	42 32	6·7	4·49	9·5	14·0	3	·647	
1577	+41° 3967	58·5	42 10	38·9	6·12	9·3	9·8	2	·670	
1578	+42° 3948	58·7	42 12	228·9	2·29	9·3	9·8	2	·670	
1579	+42° 3961	21 1·8	42 32	269·8	3·52	9·4	12·0	2	·728	
1580	+42° 3974	3·2	42 32	88·1	3·31	9·5	9·6	2	·728	
1581	+41° 4047	10·6	41 54	49·2	4·66	9·5	9·7	2	·961	
1582	+41° 4063	12·3	41 59	133·4	3·89	9·2	10·5	2	·899	
	+42° 4055	15·6	42 28	306·7	13·31	9·3	10·0	3	·697	
1583	+41° 4093	15·9	42 3	76·1	5·89	9·6	10·2	2	·851	BC
				239·6	14·28	A=	9·4	2	·851	AB
1584	+41° 4096	16·4	41 42	113·3	3·43	9·5	10·8	2	·913	
1585	+42° 4065	17·6	42 35	265·8	4·97	9·3	12·5	3	·762	
1586	+40° 4721	22 1·3	41 2	39·2	4·37	9·5	9·6	3	·866	

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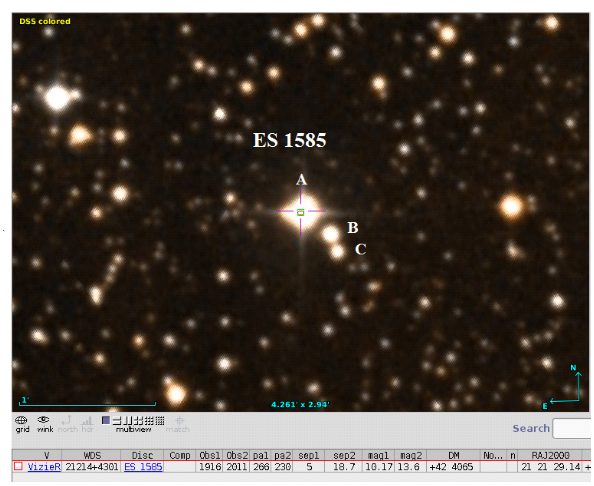

Figure 7. T.E. Espin's original observation record and Aladin image with WDS data.

007 for the primary and +010 +004 for the secondary, indicating the primary has a westward component of motion and the secondary an eastward component of motion. However, URAT1 shows proper motion for the pair of +002 +001.8 and +002.3 +001.6, which is more indicative of shared proper motion. The most recent data release from GAIA does not include proper motion data for either of the components, nor does it include parallax data for either of the pair, which would be helpful. At any rate, the WDS numbers argue against shared motion and the URAT1 rate of proper motion would seem to be too minor to use as a basis for concluding this pair is physical. It's not clear what other technique might indicate a physical connection between the two stars since parallax data is lacking.

BPM 282: This pair also has a WDS "V" code assigned to it, but again the proper motion numbers listed in the WDS are not indicative of shared motion (000 -006 for the primary, -004 -029 for the secondary). The URAT1 data is even more indicative of a lack of shared motion, with +005.7 -014.5 listed for the primary and -001.5 -009.5 for the secondary. Again, no proper motion or parallax data numbers are shown in the most recent GAIA data.

There are also discrepancies between the WDS data and our measures for this pair with regard to astrometry and photometry (Table 2). The WDS shows this pair with a separation of 73.9" and a position angle of 324° (2010). Our measures are 69.013" and a position angle of 333.739° (2015.281). The URAT1 data computes to a separation of 69.233" and a position angle of 333.563° (2013.628), while GAIA data results in a separation of 69.244" and a position angle of 333.566° (2015.0). Looking at magnitudes, the WDS shows values of 12.79 and 15.27, whereas we measured 12.663 and 13.401. UCAC4 and URAT1 both have Vmags for the pair of 12.740 and 13.343, so it appears the WDS value for the secondary is too faint by almost two magnitudes, which is also indicated by the Aladin image of BMP 282.

BPM 1005: This is another pair shown with a WDS "V" code and proper motion numbers that are not indicative of shared motion (+001 -024 and +005 -008). Nor does the proper motion data in URAT1 support shared motion, with numbers of +014.3 -017.7 and +006.4 and -000.6 (see Table 3.). And again, no data for either of the pair is shown in the recent GAIA release.

ARN 71: This is the AD pair of 37 UMA. The WDS also list this pair with a "V" code, and in this case the WDS proper motion data clearly shows a shared motion for the pair: -036 +145 and -037 +140. However the URAT1 data is more divergent, showing motion of -032.5 +140.5 and -044.6 +125.7. We used our CPM spreadsheet to compare 2MASS and URAT1 data, which showed the two components diverging by ~6.5° and with a speed difference of ~15mas/yr., numbers which argue against shared motion. (See first listing in Table 3.)

TDS 4042: The WDS lists this pair with a separation of 1.7" and a PA of 80°, and shows only one observation for it. However, TDS 4042 B isn't identified by either URAT1 or GAIA DR1. A look at the composite 2MASS J-H-K band image in Aladin shows a faint hint of an elongation, but at the wrong PA (~230°), and again no catalog object for B is identified in 2MASS. That elongation essentially disappears when individual J, H, and K band FITS images in Aladin are looked at closely. Nor is any elongation apparent in a 1949 POSSI.O image or in a 1996 POSSII.J image (both FITS images). Given the 1.7" separation and the close magnitudes (10.09 and 11.65) of the two stars it would seem a definite hint of elongation should be present, so it appears TDS 4042 is likely a bogus object.

TDT 1508: This pair is listed in the WDS with a separation of 2.1" and a PA of 207° and also with just one observation. Here again, no object for TDT 1508 B is identified in either URAT1 or GAIA DR1, although the latter catalog shows an object at a position angle of 273° with a separation of 4.736". The only magnitudes available in GAIA for the two objects are G magnitudes of 11.16 and 16.103, which at least from a magnitude differential standpoint differs considerably from the WDS magnitudes of 11.45 and 11.77. The composite 2MASS J-H-K band image in Aladin shows a slightly more defined elongation at a PA of about 285° and a separation of about 4.8". A look at the individual J, H, and K band FITS images in Aladin clearly show the elongation at 273°, but not the 285° elongation mentioned above, nor at the 207° position shown in the WDS. The 273° to 275° elongation is quite pronounced in both 1953 POSSI.O and 1988 POSSII.J FITS images in Aladin. We found a hint of the GAIA object at 273° by stacking two 5x3s images to 10x3s and measured a quite faint 15.6 magnitude star at the position in question. With SNR values of <10 and >5 for the two stacked images, our measure is not very reliable, but nevertheless it's obvious there's an object at the 273 degree location.

Here again, given the similar 11.45 and 11.77 magnitudes of this pair in the WDS, if an object was present at the WDS position of 207° and 2.1" separation, the elongation should be apparent in Aladin images. On the other hand, the object at 273° offers the possibility of a companion not identified previously.

POU 2442: The WDS lists this pair with magnitudes of 12.4 and 12.6 separated by 3.6" with a PA of 351°. We were unable to resolve either of the components during our imaging. The faintest stars visible in our images were in the 13.5 magnitude range, leading to the possibility that both stars are fainter than that, and a check of various catalogs tends to support that possibility. 2MASS lists J and K magnitudes for both components which convert to visual magnitudes of 14.300 for the primary and 14.340 for the secondary. UCAC4 shows a Vmag for the primary of 13.43, but has no Vmag for the secondary; however it includes f.mags for both components, showing the primary at 14.073 and the secondary at 14.376. GAIA lists only Gmags for the pair, 13.835 for the primary and 14.143 for the secondary, and URAT1 identifies the primary only, listing it with a Vmag of 13.449.

DAM 1026: The WDS shows a separation for this pair of 5.4" and 346° (2010), but our efforts resulted in slightly different numbers of 6.817" and 348.494° (2016.108). URAT1 data computes to a separation of 6.258" and a position angle of 344.345 (2013.596) and GAIA data results in a separation of 6.260" and a position angle of 344.473° (2015.0).

FYM 142 DF: There's a significant discrepancy between our measures for this pair and the WDS data. The latter measures, dated 2012, show FYM 142 DF with a separation of 4.9" and a position angle of 277° (2012), whereas our measures (2015.621) show the separation at 8.583" and the position angle at 267.195°. URAT1 data (2013.558) for this pair of stars shows a separation of 8.587" and a PA of 267.672°, while GAIA (2015.0) data shows a separation of 8.588" and a PA of 267.662.

FYM 142 EI: We also found some discrepancy between the WDS data and our measures for this pair. The WDS lists the pair at 7.1" and 279° (2012), while our measures are 9.137" and 272.886° (2015.621). Both the URAT1 and GAIA data show slightly larger numbers than ours: URAT1 data computes to 9.357" and 273.660° (2013.532) and GAIA's data comes out to 9.352" and 273.827° (2015.0).

FYM 142 GH: Here again we found significant discrepancy between the WDS data and our measures. The 2012 data shown in the WDS shows a separation of 4.7" and a position angle of 81°, while our measures show the separation at 7.904" and the position angle at 69.252° (2015.621). Again, the URAT1 and GAIA data result in measures similar to ours: URAT1 data computes to 7.775" and 69.452° (2013.554) and GAIA data results in measures of 7.789" and 69.409° (2015.0).

Acknowledgements

The following tools and resources have been used for this research:

- Washington Double Star Catalog as data source for the selected objects
- iTelescope: Images were taken with
  - ◊ iT24: 610mm CDK with 3962mm focal length. CCD: FLI-PL09000. Resolution 0.62 arcsec/pixel. V-filter. Located in Auberry. California. Elevation 1405m
  - ◊ iT11: 510mm CDK with 2280mm focal length. CCD: FLI ProLine PL11002M. Resolution 0.81 arcsec/pixel. B- and V-Filter. Located in Mayhill. New Mexico. Elevation 2225m
  - ◊ iT18: 318mm CDK with 2541mm focal length. CCD: SBIG-STXL-6303E. Resolution 0.73 arcsec/pixel. V-filter. Located in Nerpio. Spain. Elevation 1650m
  - ◊ iT21: 431mm CDK with 1940mm focal length. CCD: FLI-PL6303E. Resolution 0.96 arcsec/pixel. V-filter. Located in Mayhill. New Mexico. Elevation 2225m
- AAVSO VPhot for initial plate solving
- UCAC4 catalog
- URAT1 catalog
- Aladin Sky Atlas v9.0
- SIMBAD, VizieR
- 2MASS All Sky Catalog
- GAIA DR1 catalog
- AstroPlanner v2.2 for object selection. session planning and for catalog based counterchecks
- MaxIm DL6 v6.08 for plate solving on base of the UCAC4 catalog
- Astrometrica v4.9.1.420 for astrometry and photometry measurements

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$$Sep = \sqrt{\left[\left(RA_2 - RA_1\right)\cos\left(Dec_1\right)\right]^2 + \left(Dec_2 - Dec_1\right)^2}$$

in radians. and

STT Doubles with Large ΔM – Objects Nearby

$$PA = \arctan\left[\frac{(RA_2 - RA_1)\cos(Dec_1)}{Dec_2 - Dec_1}\right]$$

in radians depending on quadrant.

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Astrometric and Photometric Measurements of WDS 20210+1028

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Abstract: We report CCD astrometric and photometric measurements of the components of the double star system WDS20210+1028 (J 838) using the iTelescope network. Combined with historical observations, our measurements suggest that the existing fitted orbital solution may need to be modified.

Introduction

This research project was part of an Astronomy Research Seminar offered by Cuesta College, supported by the Institute for Student Astronomical Research (InStAR), and conducted by Boyce Research Initiatives and Education Foundation (BRIEF).

As a proof of concept of our data analysis process, we decided to observe a double star system listed in the Washington Double Star Catalog (WDS) as having a "known" orbital solution. The double star system we selected had to be observable from the Northern hemisphere in June, with an angular separation greater than six arc seconds, and with a listed maximum magnitude difference of 2.5 between the stars. WDS 20210+1028 J838 (hereafter referred to as J 838) satisfied these criteria. Motivations for these criteria are discussed in the telescope selection section below.

Observations of J 838 were first reported by Jonckheere (1912), who found a separation of only 2.9". Robert Jonckheere (1888-1974) discovered and published measurements of over 3000 doubles in a career spanning circa 1908 to 1962, as described in detail by Knapp (2016a). Among others studying J 838 in the twentieth century, Jonckheere published four more observations between 1948 and 1958, which showed the pair's angular separation increasing to 3.5". Jonckheere (1952) noted (translated from French):

"Rapid movement on the arc clearly confirmed. This couple is probably formed by stars of very small mass located about 8 parsecs."

Another veteran observer, George van Biesbroeck, made micrometer measurements of J 838 in 1966, and published them with measurements of other doubles in van Biesbroeck (1974). From that paper's Introduction:

"The present measures are a continuation of previous ones (Van Biesbroeck 1966). They will be the last ones that I made. My present physical condition precludes further work at the telescope. There has been no change in the method of observing or the telescopes used, except that on my 90th birthday in 1970 I was granted the use of the 90-inch (2.3-m) Steward Observatory telescope on Kitt Peak."

Note: Dr. Van Biesbroeck observed last on the nights of 1974 January 1 and 2 with the 84-inch (2.1m) telescope. He wrote the above paragraph and compiled his last manuscript in the same month just before his 94th birthday. Immediately thereafter his health failed rapidly and he died on 1974 February 23.

This final paper, published posthumously, marked the end of a remarkable career in astronomy that began in 1904 (Tenn 2012).

The first calculated orbital elements for J 838 were published by Olević (2002) and give a period of 239.84 years, with periastron occurring at 1967.510. Eccentricity, semi major axis and inclination were given as 0.784, 7.451", and 77.6°, respectively. The Sixth Catalog of Orbits of Visual Binary Stars (Hartkopf et al.

2011) classifies this orbit as category 5, "poorly determined". The fitted orbit suggests that the pair is currently (2016) nearing maximum angular separation, which warrants further observations to more accurately constrain its shape and size.

The first CCD measurements (in 2001) were reported by Hartkopf et al. (2013), and the first published results for the system using speckle interferometry were by Mason et al. 2004. Cvetković and collaborators in Eastern Europe made seven measurements of J 838 with CCD astrometry between 2009 and 2013 (see Cvetković et al. 2016, and references therein). They also provide relative photometry (B and V band) for the pair: $\Delta B = 0.35 \pm 0.02$ mag, and $\Delta V = 0.06 \pm 0.01$ mag.

Three earlier papers in the JDSO include measurements of this system. Muller et al. (2006, 2007) report CCD astrometry from 2005, while Knapp (2016b) reported V-band photometry for A and B members of the pair (12.54 ± 0.01 mag and 12.58 ± 0.01 mag, respectively) based on 3-second exposures using iTelescope in 2015.

Equipment, Observations, and Data Reduction Procedures

CCD images were taken using the T11 and T18 telescopes, part of the iTelescope network. T11 is a CDK Planewave 0.50 m f/6.8 reflector with f/4.8 focal reducer, located in Mayhill, New Mexico. The CCD camera is 4008 by 2672 array with a pixel scale of 0.81". Additional images were taken using the T18 telescope located in Nerpio, Spain, using a Planewave 0.32 m f/8.0 reflector equipped with a 3072 by 2048 array imaging at a pixel scale of 1.69". Both cameras can easily resolve separations above five arc-seconds, as shown in Figure 1.

A total of 22 images were acquired between epoch 2016.499 and 2016.574. Six images were taken with the T11 Telescope: two in R with exposure times of 120 seconds, two in B with exposures of 180 s, and two in hydrogen-alpha with exposure times of 180 s for a total of 6 images. Sixteen images were taken with the T18 Telescope, all with 90 s exposure times: four images each with the red, blue, hydrogen alpha, and no filter ("luminance"). We subsequently excluded the six images taken with the hydrogen alpha filter due to their inferior signal-to-noise ratio. The exposure times provided good signal-to-noise without saturation in the B and R bands which allows for both astrometric and photometric analysis.

The remaining sixteen images were preprocessed (dark and flat subtraction) by the iTelescope data reduction pipeline. MaximDL v6 was used to insert World Coordinate System (WCS) positions into the FITS headers through comparison of the image star field against the Fourth U.S. Naval Observatory CCD Astrograph Catalogue (UCAC4). During this process MaximDL typically used approximately 400 stars out of a database of 3000 stars for this particular star field. Mirametrics Mira Pro x64 was used to compute accurate position angles and separations of the component

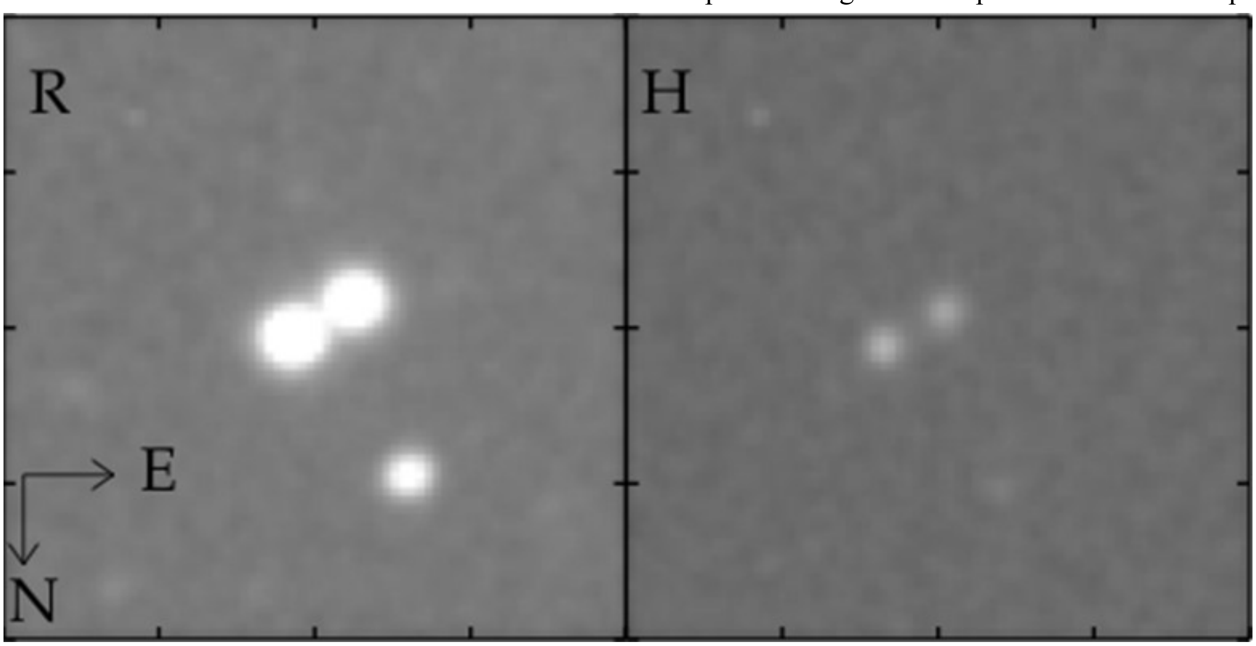

Figure 1. *Example images of J 838 from the T11 telescope. Left: R filter. Right: Hα filter. The distance between tics on the edge is 15″. The top side is North and the left is East.*

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Table 1. *Results of Mira Pro astrometric measurements of WDS 20210+1028.*

WDS 20210+1028 = J 838 Astrometry			
Telescope: (number of images used in each filter)	**Epoch 2016.511**	**θ(degrees)**	**ρ(arcseconds)**
T11: (2 R), (2 B) T18: (4 R), (4 B), (4 luminance) 16 images total	Mean	119.27	6.75
	Standard deviation	0.21	0.03
	Std. error of mean	0.06	0.01
2013.5285 measurement (Last one previous to this investigation)		118	6.64

stars. The A and B stars were identified, marked, and then measured using the algorithms of Mira Pro to find the centroids of each component.

We also performed a photometric analysis of J 838 using our custom IDL (Interactive Data Language) scripts to calibrate our data. A zeropoint magnitude was calculated by querying auxiliary data within each image's field of view and performing relative photometry for each star in the image. The calibration process used 38 stars for B-band photometry in the Tycho Catalog (Høg, 2000) and 66 stars for R-band photometry in the USNO-B1 Catalog (Monet et. al., 2003). The magnitude values were then plotted in a histogram, with each image's list of calculated magnitudes returning a normal distribution. We fitted a Gaussian curve for each histogram and calculated a reduced χ^2 of about unity. We measure an average magnitude zeropoint for the 20.9 and 19.4 with a standard deviation of 0.4, 0.3 for the B-band and R-band images, respectively.

In order to measure the integrated flux of each star, including J 838, we measured the average FWHM of the PSF (~ 4") and used this as the aperture size. The uncertainties in this integrated flux were measured through the variation of the background counts. The variation in the background was calculated by measuring the standard deviation of the integrated flux of non-overlapping apertures of the same size, all 20" away from the listed coordinates of each star. We also note that our photometric uncertainties also account for the error associated with measuring an average zeropoint magnitude. The results of our photometric analysis are all listed in Table 2.

Results

Table 1 shows our calculated angular separation and position angle for J 838, and the uncertainty in each. We find a mean and position angle of 119.27º ± 0.06º and an angular separation of 6.75" ± 0.01", slightly but significantly larger than the 2013.5285 measurement of 6.64" reported by Cvetković et al. (2016), and the largest angular separation for this system measured to date.

Table 2 summarizes our new photometry for each star, from the T11 images. We also report differential magnitudes between the components, which we can determine more accurately. Note that our results are in disagreement with those of Cvetković et al. (2016), who report ΔB = 0.35±0.02 mag.

Discussion

Our astrometry, derived from our sixteen images, are plotted together with historical data from the WDS

Table 2. Photometry results for J 838.

WDS 20210+1028 = J 838 Photometry			
Filter	**Star A**	**Star B**	**Δm**
B image #1	13.68 ± 0.07	13.42 ± 0.07	0.26
B image #2	13.63 ± 0.08	13.38 ± 0.08	0.25
R image #1	11.68 ± 0.03	11.91 ± 0.03	0.23
R image #2	11.67 ± 0.03	11.91 ± 0.03	0.24

(Figure 2). Olević's (2002) fitted orbit does not include data points taken since 1995. Inclusion of the more recent measurements suggests that the apparent orbit is more elongated than the model, which predicts that the maximum angular separation occurs close to the current epoch. Further observations over the next decade can reveal whether J 838's angular separation will continue to increase or reach a maximum.

Our own photometry and that of Knapp (2016b) suggest that these stars are either of late spectral type (K or M), or significantly reddened by interstellar dust, or a combination of both. Even if we include the published near-infrared photometry of each component from the 2MASS (Skrutskie et al. 2006), we conclude that only spectroscopy of each component star will be able to separate these effects reliably.

Conclusions

We obtained astrometry and B and R band photometry in 2016.5 of the double star system J 838 using the T11 and T18 telescopes of the iTelescope network. Our astrometry, combined with other recent observations, shows that this double star system has a maximum angular separation larger than that predicted by the orbital model of Olević (2002). We have demonstrated that this system is fairly easy to observe with small-to-moderate-sized telescopes. Astrometric observations of such systems as their relative path on the sky approaches maximum separation and curvature can improve their fitted orbits. We encourage astronomers to obtain imaging and spectra of J 838's component stars to determine their orbits, spectral types, and metallicities, as a prerequisite to estimating their masses.

Acknowledgements

The authors thank the United States Naval Observatory for providing historical measurement data and iTelescope for the use of their service. Additionally, we thank the Boyce Research Initiatives and Education Foundation (BRIEF) for their generous financial donation that allowed us to use the iTelescope robotic telescope system and remote server and software. The authors thank Russell Genet for providing guidance.

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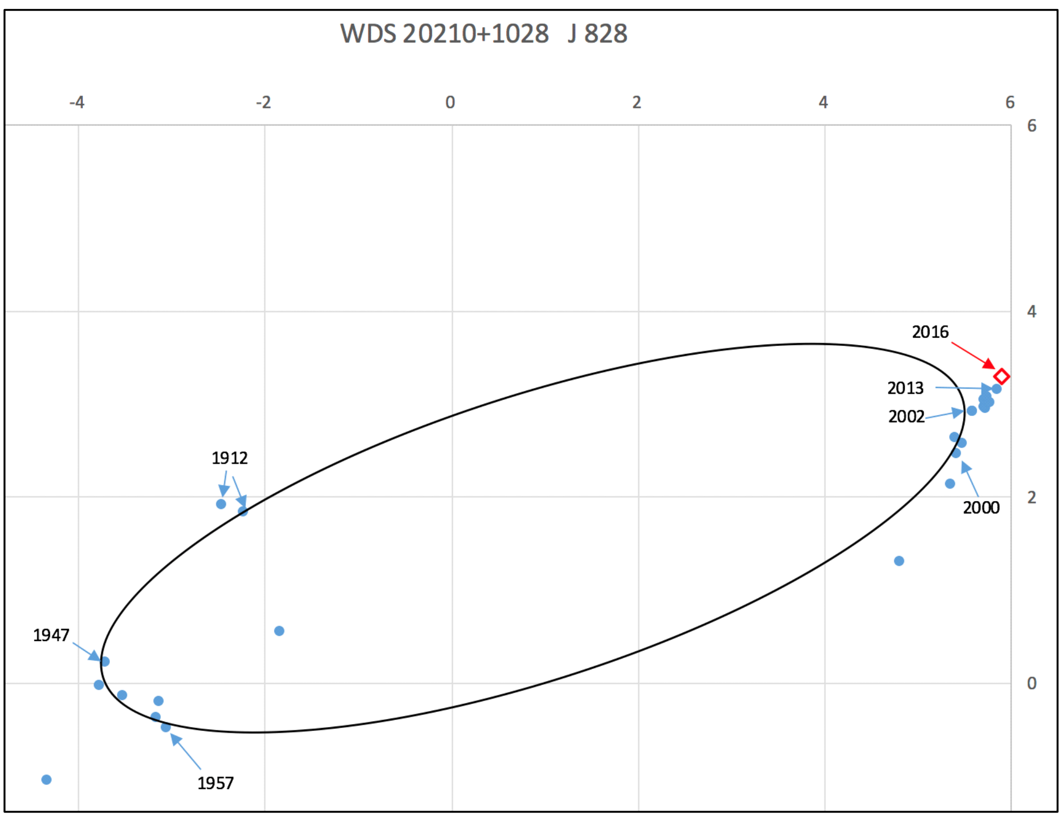

Figure 2. *XY plot of historical observations of J838 A&B's relative position (solid blue circles). Our result (Table 1) is shown as a red diamond. The included ellipse is a reproduction of the orbit determined by Olević 2002 which included data from 1912 until 2002.*

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Double Star Measures Using the Video Drift Method - VIII

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Abstract: Position angles and separations for 206 multiple star systems are presented using the video drift method.

Introduction

This is Paper VIII in our continuing series on double star measurements using the video drift method first proposed by Nugent and Iverson 2011. We continue our practice of preferentially measuring multiple star systems listed in the Washington Double Star Catalog (WDS) that have not been measured for a minimum of 10-15 years and have less than 10 measurements.

Methodology

The methods used in this paper are the same as the methods used in our previous paper (Nugent and Iverson, 2016). All measurements were made with a pair of Meade 14-inch LX-200 telescopes (focal length 3556 mm at f/10, scale factor 0.6"/pixel). Astronomical video data collection systems require a onetime aspect ratio calibration. The reader is referred to our previous discussion of the problem and calibration procedure (Nugent and Iverson, 2014).

For systems in which either the primary and/or secondary star is faint, image enhancement techniques were employed. Iverson used a variation of the drift method employing an integrating video camera (Iverson and Nugent 2015) while Nugent used a Collins I^3 image intensifier with a non-integrating camera. The faintest system measured in Table 1 had primary/secondary magnitudes of +10.8, +15.5. Twelve systems had WDS magnitudes in the +14.0 to +15.5 range.

Acknowledgements

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

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Double Star Measures Using the Video Drift Method - VIII

Table 1. Results of 206 double stars using the video drift method.

WDS	Designation	PA°	σ-PA	Sep"	σ-Sep	Date	(x,y) pairs	Mag Pri	Mag Sec	Drifts	Nights
00057+1750	STF3061	148.6	1.0	7.8	0.13	2015.918	3198	8.40	8.51	5	1
00099+0827	STF 4	276.0	1.5	5.2	0.17	2015.918	2291	9.51	9.60	8	1
00174+1631	STF 20	233.3	0.7	11.9	0.14	2015.918	3112	8.87	9.67	5	1
00305+2208	HJ 1027	218.2	0.4	18.4	0.12	2015.918	3225	10.41	10.51	5	1
00310-1005	HJ 1981A,BC	88.7	0.1	78.4	0.15	2015.956	2522	6.91	8.43	5	1
01178-1220	STF 110	352.8	0.9	7.0	0.10	2015.915	6321	8.76	9.18	10	2
01220-0927	HJ 2039AB,C	244.7	0.1	51.4	0.11	2015.956	5538	9.17	10.64	10	2
01256+3133	STT 30AC	105.6	0.1	56.7	0.12	2015.918	3131	8.09	8.06	5	1
01295+3054	BUP 20	257.6	0.1	87.1	0.13	2015.918	2854	8.06	9.79	5	1
01301-1215	GAL 44	5.0	2.3	8.8	0.28	2015.718	9022	10.15	11.6	2	1
01307-1227	GAL 309	343.3	0.6	14.0	0.13	2015.718	3093	9.27	10.3	5	1
01348+2935	MLB1058AC	35.6	0.1	79.8	0.12	2015.918	3107	10.23	10.06	5	1
01413+1007	STF 146	306.3	0.3	24.2	0.14	2015.956	2978	8.87	9.04	5	1
01434-0705	STF 150	196.1	0.3	35.7	0.18	2015.956	3062	7.73	8.19	5	1
01434-1127	GAL 312	326.2	0.2	43.5	0.15	2015.718	2952	9.15	10.74	5	1
01510+2107	STF 175AB	360.0	0.1	28.0	0.09	2015.956	6637	8.99	9.36	8	1
02042-1039	GAL 318	281.5	0.3	32.6	0.18	2015.915	2863	11.25	11.47	5	1
02097+2021	STF 221AB	145.2	0.9	8.5	0.12	2015.956	3249	8.13	9.45	5	1
02147+3024	STF 232	66.2	1.3	6.5	0.12	2015.918	3580	7.82	7.90	5	1
02233+1525	AG 38AB	260.7	0.2	34.8	0.14	2015.956	2950	8.87	9.41	5	1
02391+1430	BU 1315AC	57.9	0.1	83.0	0.15	2015.956	2612	8.66	9.73	5	1
02410+3450	AG 44	287.5	0.8	9.9	0.12	2015.918	3688	9.64	9.7	5	1
02497+1209	AG 54AB	2.0	0.2	29.6	0.14	2015.956	3150	9.59	9.75	5	1
02535-1151	GAL 79	353.7	1.4	5.6	0.16	2015.915	3185	10.59	10.81	5	1
03003+1432	AG 60	159.4	1.1	6.4	0.12	2015.956	3139	9.56	10.0	5	1
03018+1051	STF 338	201.9	0.4	19.6	0.12	2015.956	3071	9.20	9.49	5	1
03280+2028	STF 394AB	163.2	1.2	6.9	0.12	2015.956	3261	7.05	8.16	5	1
03345+1948	STF 414	185.9	0.9	7.5	0.13	2015.956	3249	8.15	8.28	5	1
03463-1235	GAL 355	346.5	0.3	31.9	0.18	2015.912	3052	10.57	11.81	5	1
03597-1301	GAL 361	329.9	0.3	32.7	0.17	2015.912	3005	11.42	11.62	5	1
04140-1222	GAL 364	46.2	0.5	20.9	0.16	2015.912	3010	11.36	11.43	5	1
04198+2344	STF 523AB	163.8	0.7	10.4	0.13	2015.956	3220	7.58	9.86	5	1
04233-0500	HJ 342AB	234.4	0.5	17.3	0.16	2015.915	2879	7.76	9.58	5	1
04233-0500	HJ 342AC	79.8	0.6	22.3	0.23	2015.912	8530	7.76	13.5	2	1

Table 1 continues on next page.

Double Star Measures Using the Video Drift Method - VIII

Table 1 (continued). Results of 206 double stars using the video drift method.

WDS	Designation	PA°	σ-PA	Sep"	σ-Sep	Date	(x,y) pairs	Mag Pri	Mag Sec	Drifts	Nights
04240+2418	STF 534AB	289.1	0.3	28.9	0.13	2015.956	3146	6.36	7.94	5	1
04352-0944	STF 570	259.8	0.6	12.8	0.14	2015.915	3038	6.71	7.64	5	1
04433-0937	STF 588AC	267.8	0.2	45.4	0.15	2015.915	2770	8.13	10.62	5	1
05301+2933	STF 719AC	352.6	0.6	14.2	0.14	2015.956	3513	7.50	9.39	5	1
05413+2929	STF 764	14.5	0.3	25.7	0.13	2015.956	3490	6.38	7.08	5	1
08221-0348	ABH 71AD	234.3	0.2	47.5	0.19	2015.247	8256	10.88	13.27	3	1
08221-0348	ABH 71AE	188.9	0.2	66.9	0.21	2015.247	9916	10.88	15.38	3	1
08221-0348	ABH 71AF	29.2	0.5	36.8	0.30	2015.247	8133	10.88	15.49	2	1
08221-0348	HJ 90AB	157.0	0.6	15.8	0.15	2015.247	3005	10.88	11.76	5	1
08221-0348	HJ 90AC	345.9	0.3	42.5	0.18	2015.247	3003	10.88	11.60	5	1
09571-0121	A 1766AB,C	1.8	0.5	17.3	0.16	2015.247	10673	8.96	14.31	4	1
15353-0545	BRT 458	30.2	3.1	4.6	0.27	2016.501	1473	11.62	12.2	2	1
15370-2748	BRT3022	197.6	2.1	5.4	0.19	2016.501	1627	11.98	13.11	2	1
15382-3059	HJ 2787	134.7	1.5	15.3	0.39	2016.501	1715	10	10.5	2	1
15383-2901	SWR 179	78.4	2.0	15.4	0.48	2016.501	1649	12.2	12.4	2	1
15385-1556	UC 3035	252	1.9	22.2	0.73	2016.501	1472	14.36	14.54	2	1
15399-2235	ARA1808	240.5	2.3	13.2	0.45	2016.501	1589	12.4	12.8	2	1
15404-1919	ARA 702	97.1	2.4	7.9	0.34	2016.501	1558	12.5	13.4	2	1
15412-2603	J 3235	336.6	1.7	10.7	0.30	2016.501	1677	11.38	11.3	2	1
15414-0647	J 3251AB	65.4	0.8	40.1	0.47	2016.501	1359	11.07	12.64	2	1
15418-2607	J 1614	342.2	1.7	10.4	0.32	2016.501	1676	11.5	11.8	2	1
15420-3043	HJ 2789AB	303.4	0.8	29.3	0.39	2016.501	1627	9.48	10.65	2	1
15420-3043	DAW 211BC	94	2.8	7.2	0.47	2016.501	835	10.65	13.3	1	1
15452-2239	SWR 181	108.8	0.7	31.2	0.37	2016.501	1500	10.93	11.36	2	1
15455-2830	CPO 442	357.5	1.3	11.4	0.35	2016.501	1736	10.62	10.65	2	1
15457-1443	HU 478AC	261.2	0.4	63.8	0.43	2016.501	1310	9.8	11.32	2	1
15457-1511	GLP 11	203.9	0.9	19.9	0.28	2016.501	2302	10.84	11.58	3	1
15506-2043	RSS 387	209.3	1.1	22.5	0.41	2016.501	1552	10.23	12.86	2	1
15510-2503	B 2792	62.7	1.0	13.0	0.25	2016.501	1556	9.29	13.2	2	1
15511+0538	UC 214	177.2	1.2	16.4	0.49	2016.501	1490	13.73	14.35	2	1
15521-0554	HJ 1279	181.7	0.7	17.4	0.36	2016.501	2001	10	13	3	1
16002+1412	AG 348BC	170.2	0.2	40.5	0.12	2015.529	3152	10.39	10.41	5	1
16002+1412	CLL 9AB	66.1	0.1	63.6	0.13	2015.529	2741	8.99	10.39	5	1
16002+1412	CLL 9AC	102.2	0.1	66.4	0.13	2015.529	2688	8.99	10.74	5	1
16004+1437	STF1995	318.5	0.5	14.2	0.12	2015.529	3083	9.28	10.1	5	1
16107-1947	J 2665AB	311.8	2.3	6.6	0.28	2016.499	1577	11.8	13.3	2	1
16107-1947	J 2665AC	81.7	1.2	17.9	0.38	2016.499	1558	11.8	12.23	2	1

Table 1 continues on next page.

Double Star Measures Using the Video Drift Method - VIII

Table 1 (continued). Results of 206 double stars using the video drift method.

WDS	Designation	PA°	σ-PA	Sep"	σ-Sep	Date	(x,y) pairs	Mag Pri	Mag Sec	Drifts	Nights
16116-2050	UC 3130	29.4	0.9	19.9	0.28	2016.499	1601	11.43	11.82	2	1
16122-2355	B 2801AB	185.6	0.9	12.2	0.22	2016.499	1624	8	14	2	1
16148-2114	J 1590	245.9	2.0	9.4	0.32	2016.499	1601	10.5	10.6	2	1
16164-2503	HDS2300	176.6	1.1	13.9	0.28	2016.499	1609	8.43	11.73	2	1
16167-2514	B 2806	34.9	0.8	12.6	0.20	2016.499	1614	8.92	13.1	2	1
16202-1825	HLD 128AC	339.1	0.2	94.7	0.28	2016.499	1417	9.32	13.12	2	1
16224-3115	FAB 14	271.2	0.6	18.2	0.35	2016.499	1654	8.39	11.75	2	1
16229-3104	HJ 4847	223.5	0.9	15.3	0.25	2016.499	1719	9.66	9.82	2	1
16231-1845	UC 3160	53.1	0.2	68.9	0.34	2016.499	1384	9.68	10.68	2	1
16260-1407	LMP 13AB,C	260.6	0.2	91.9	0.36	2016.499	1188	10.06	11.88	2	1
16290-0104	BAL 888	169	1.2	19.6	0.40	2016.501	1473	10.38	12.74	2	1
16299-2145	ARA1494	86.2	1.9	8.8	0.39	2016.501	1570	12.2	13.7	2	1
16300-2225	ARA1811	146.8	1.7	12.9	0.39	2016.501	1600	12.45	12.8	2	1
16306-1432	LDS4673	90.1	0.3	74.9	0.58	2016.501	1234	9.97	14.43	2	1
16307-2127	JKS 11	326.6	0.6	25.2	0.27	2016.499	1558	10.39	11.18	2	1
16308-1308	STF2050AC	294.9	0.1	140.7	0.40	2016.501	924	8.33	9.32	2	1
16308-1308	SIN 126AD	44.2	0.2	81.3	0.33	2016.501	1273	9.72	12.92	2	1
16310-1953	UC 3180	358	0.9	33.7	0.66	2016.499	1570	13.4	13.91	2	1
16310-2046	UC 3181	31.1	2.4	19.0	0.73	2016.501	1543	11.8	14.4	2	1
16323+0009	BU 9013AB	114	3.4	10.0	0.69	2016.501	1459	12.7	14	2	1
17199-1121	STF 2148	219.7	1.4	5.7	0.13	2015.562	3133	9.18	9.88	5	1
17348-1115	HJ 4964	224.2	0.2	54.9	0.16	2015.562	2807	5.54	9.88	5	1
17362+0637	STF2188	202.8	1.4	5.5	0.13	2015.529	3065	9.22	9.98	5	1
17593-0651	STF2250AB	343.4	1.1	7.8	0.14	2015.562	3075	8.79	9.24	5	1
18004-1521	FOX 212	9.1	0.8	20.1	0.30	2016.499	1539	9.68	11.83	2	1
18004-2258	ARA1834	223.7	1.1	15.1	0.30	2016.499	1611	9.91	12.8	2	1
18006-1506	FOX 213	318	1.2	12.5	0.28	2016.499	1529	10.59	12.4	2	1
18009-1858	HJ 2815	103.5	0.9	14.4	0.24	2016.499	1521	9.16	12.2	2	1
18011-1804	A 2256AB,E	123.8	0.8	21.9	0.37	2016.499	1495	8.4	12.4	2	1
18011-2252	ARA1835	303.5	2.5	9.8	0.46	2016.499	1611	12.6	12.8	2	1
18013-1522	FOX 214AB	252.8	0.6	30.3	0.40	2016.499	1413	8.61	11.39	2	1
18015-2221	ARA1836	19.6	2.0	8.4	0.32	2016.499	1634	11.4	12.4	2	1
18018-2208	ARA1837	289.3	1.1	12.8	0.27	2016.499	1584	11.1	12.2	2	1
18021-2820	BRT3055	47.9	2.7	4.9	0.31	2016.499	1687	12.62	12.61	2	1
18022-2318	B 2851	155.7	1.3	10.5	0.24	2016.499	1641	10.2	11.4	2	1
18028+0137	BU 635AB	301.2	0.1	68.7	0.14	2016.592	2610	8.63	9.93	5	1

Table 1 continues on next page.

Table 1 (continued). Results of 206 double stars using the video drift method.

WDS	Designation	PA°	σ-PA	Sep"	σ-Sep	Date	(x,y) pairs	Mag Pri	Mag Sec	Drifts	Nights
18030-2233	ARA1838AB	137.5	2.1	8.3	0.47	2016.501	1595	10.95	11.8	2	1
18030-2233	ABH 93AE	159.1	0.9	40.7	0.62	2016.501	1549	10.95	14.43	2	1
18030-2233	ABH 93AF	185.8	0.5	66.0	0.48	2016.501	1580	10.95	12.68	2	1
18030-2233	ABH 93AG	221.6	1.3	24.9	0.50	2016.501	1543	10.95	13	2	1
18030-2233	ABH 93AH	255.3	1.1	28.4	0.58	2016.501	1497	10.95	12.9	2	1
18030-2233	ABH 93AI	233.8	0.6	73.3	0.66	2016.501	1348	10.95	15.11	2	1
18030-2233	ABH 93AJ	283.6	0.3	104.1	0.49	2016.501	1191	10.95	13.71	2	1
18039-1832	ARA 450	65.8	1.7	8.0	0.26	2016.501	1555	9.11	11.69	2	1
18045-1505	HJ 5013	333.9	1.5	12.7	0.31	2016.501	1536	10.47	12.5	2	1
18060+0434	STTA165AB	141.1	0.1	66.7	0.19	2016.641	2724	8.51	8.52	5	1
18162+0434	STTA167	73.9	0.2	52.7	0.15	2016.641	2671	8.00	9.07	5	1
18286+0451	SLE 179AD	209.5	0.0	251.7	0.20	2016.641	9615	7.68	12.22	2	1
18286+0451	SLE 179AE	225.7	0.0	304.1	0.29	2016.641	9626	7.68	12.41	2	1
18286+0451	SLE 179AF	232.6	0.0	288.5	0.22	2016.641	9625	7.68	12.83	2	1
18286+0451	STTA168AB	161.5	0.2	47.2	0.15	2016.641	2950	7.68	8.80	5	1
18286+0451	STTA168AC	217.1	0.0	244.2	0.13	2016.641	3829	7.68	9.34	8	1
18423-0903	H 5 36AC	130.9	0.2	52.3	0.17	2015.562	2800	4.73	10.56	5	1
18487-0600	STF2391AB	331.6	0.2	37.7	0.17	2016.666	2972	6.52	9.59	5	1
18487-0600	STF2391BC	124.3	0.8	14.4	0.19	2016.666	9051	9.59	14.3	2	1
18490-0828	ABH 105AD	156.5	0.3	43.8	0.22	2016.666	9331	7.81	12.62	2	1
18490-0828	ABH 105AE	275.4	0.2	72.2	0.23	2016.666	9160	7.81	12.93	2	1
18490-0828	STF2388AB	344.0	0.2	53.6	0.17	2016.666	2962	7.81	10.94	5	1
18490-0828	STF2388BC	17.6	0.4	21.1	0.16	2016.666	3008	10.94	11.24	5	1
18497-0555	H 6 50AB	358.2	0.5	24.8	0.22	2016.666	9030	6.15	12.5	2	1
18497-0555	H 6 50AC	170.7	0.1	111.8	0.18	2016.666	2877	6.15	8.23	5	1
18509-0821	J 1638	263.8	1.0	7.9	0.14	2015.562	3022	11.20	11.2	5	1
19249+0150	H 6 47	94.7	0.1	96.5	0.16	2016.679	2294	7.99	9.03	5	1
19305+1135	AG 384	159.7	0.4	22.5	0.14	2016.603	3047	9.91	9.43	5	1
19313-0207	STF2535AC	296.5	0.3	24.4	0.16	2015.704	2558	7.22	10.51	5	1
19354+1156	AG 386	315.5	0.3	27.7	0.16	2016.660	2931	8.13	10.48	5	1
19395+0431	BAL2949	237.5	0.4	17.9	0.14	2016.641	2946	10.55	11.01	5	1
20014+0657	STF2612AB	54.0	0.1	42.5	0.11	2016.641	5648	8.29	9.87	10	2
20014+0657	STF2612BC	40.8	0.4	26.9	0.17	2016.641	18135	9.9	12.3	10	2
20038+1436	HJ 1469	215.1	0.2	17.6	0.07	2016.660	9196	10.08	10.26	15	3
20048+1554	STT 397	179.2	0.2	46.1	0.15	2016.603	3178	7.40	9.60	5	1
20066+0735	GMC 6AD	315.6	0.2	33.8	0.12	2016.660	25403	7.12	13.9	6	2

Table 1 continues on next page.

Double Star Measures Using the Video Drift Method - VIII

Table 1 (continued). Results of 206 double stars using the video drift method.

WDS	Designation	PA°	σ-PA	Sep"	σ-Sep	Date	(x,y) pairs	Mag Pri	Mag Sec	Drifts	Nights
20066+0735	STTA198AC	173.6	0.2	36.1	0.14	2016.660	18110	7.12	13.4	4	2
20087+1223	J 1338	72.8	0.8	10.0	0.14	2016.584	9047	11.75	12.3	2	1
20123+1524	CHE 191AB	334.2	0.6	11.9	0.11	2016.592	3100	9.13	9.65	5	1
20123+1524	CHE 191AC	336.0	0.8	18.1	0.25	2016.592	9355	9.13	11.5	2	1
20126+1506	CHE 194	223.3	0.5	22.2	0.21	2016.592	9131	10.48	12.82	2	1
20127+1508	CHE 196	51.9	0.8	11.5	0.14	2016.660	18280	11.1	12.4	4	2
20132+1541	BKO 532BC	185.5	1.2	7.1	0.13	2016.660	18132	11.57	12.5	4	2
20132+1541	CHE 207AB	263.3	0.3	23.5	0.12	2016.660	18093	10.13	11.57	4	2
20136+1613	CHE 214	333.6	0.4	26.5	0.21	2016.666	9084	8.29	13.09	2	1
20139+1441	CHE 221	7.0	0.3	17.5	0.10	2016.660	6272	9.98	10.41	10	2
20156+1526	CHE 246AC	87.0	0.5	15.9	0.14	2016.660	18162	8.85	11.0	4	2
20156+1526	CVP 1AD	340.1	0.2	39.7	0.12	2016.660	18243	8.85	12.75	4	2
20170+1538	CHE 269	285.0	0.3	26.8	0.14	2016.666	2977	8.97	9.92	5	1
20188+1442	CHE 300	318.9	0.3	40.4	0.19	2016.666	9081	9.39	9.93	2	1
20196+1300	STF2664	321.3	0.3	27.5	0.15	2016.641	3011	8.07	8.34	5	1
20222+1623	ABH 139AD	142.5	0.1	93.0	0.14	2016.666	18177	8.99	11.67	4	2
20222+1623	GUI 31AC	129.4	0.2	37.0	0.11	2016.666	5904	8.99	10.60	10	2
20222+1623	STF2670AB	153.5	0.2	30.0	0.10	2016.666	6054	8.99	9.19	10	2
20222+1623	STF2670BC	77.7	1.2	15.6	0.28	2016.666	772	9.19	10.60	5	1
20227+1320	STF2673AC	99.6	0.1	76.5	0.15	2016.641	2526	8.29	8.60	5	1
20227+1320	STF2674CD	1.0	0.5	15.0	0.22	2016.641	9152	8.60	11.43	2	1
20308+1347	STF2688	174.6	0.8	7.7	0.11	2016.677	6111	9.35	10.41	10	2
20310+2036	BU 363AC	206.4	0.2	55.9	0.19	2016.679	9034	6.18	13.0	2	1
20312+1116	HJ 269AD	107.7	0.3	23.0	0.12	2016.677	18074	7.12	12.1	4	2
20329+1357	A 3108AB,D	340.0	0.1	98.4	0.16	2016.641	2875	9.12	10.02	5	1
20368+1444	STF2703AB	289.8	0.3	25.3	0.14	2016.677	2988	8.35	8.42	5	1
20368+1444	STF2703AC	233.5	0.1	77.8	0.16	2016.677	2693	8.35	8.76	5	1
20368+1444	STF2703AD	346.7	0.2	84.7	0.23	2016.677	9032	8.35	12.78	2	1
20368+1444	STF2703BC	215.2	0.1	67.0	0.16	2016.677	2854	8.42	8.76	5	1
20386+0950	OL 218	274.2	1.2	5.4	0.13	2016.718	13962	10.7	11.2	9	2
20409+1035	STF2713	62.4	1.0	5.0	0.10	2016.718	5106	9.80	9.80	10	2
20411+2133	HJ 922	313.3	0.9	7.5	0.12	2016.679	3257	9.76	9.79	5	1
20419+2043	BU 673AC	162.6	0.1	102.6	0.13	2016.679	3015	7.46	8.07	5	1
20436+1944	STF2722	305.7	1.0	7.4	0.13	2016.679	3198	8.32	8.94	5	1
20450+1244	BU 64AD	117.0	0.1	64.3	0.13	2016.592	2653	9.14	11.06	5	1
20450+1244	D 32CD	14.9	0.1	60.8	0.13	2016.592	2995	8.17	11.06	5	1
20450+1244	STTA209AC	154.7	0.1	97.2	0.12	2016.592	2736	9.14	8.17	5	1
20585+1626	STF2738AB	253.8	0.4	15.0	0.09	2016.666	5729	7.51	8.57	9	2

Table 1 concludes on next page.

Table 1 (conclusion). Results of 206 double stars using the video drift method.

WDS	Designation	PA°	σ-PA	Sep"	σ-Sep	Date	(x,y) pairs	Mag Pri	Mag Sec	Drifts	Nights
20585+1626	STF2738AC	103.8	0.03	209.4	0.10	2016.666	2698	7.51	8.14	8	2
20585+1626	STF2738BC	101.9	0.03	222.7	0.11	2016.666	2504	8.57	8.14	8	2
21033+1259	HJ 272	253.1	0.8	11.3	0.15	2016.718	16704	9.71	13.6	6	2
21105+2227	STF2769AB	298.8	0.4	18.0	0.13	2016.660	3217	6.65	7.42	5	1
21289+1105	STF2799AC	331.0	0.05	135.9	0.12	2016.718	5100	7.37	10.20	10	2
21442+0953	S 798AC	317.7	0.1	144.6	0.14	2016.718	4555	2.53	8.74	10	2
21458+1545	STTA224	359.6	0.1	59.4	0.10	2016.679	6282	7.81	9.27	10	2
21586+0601	SHJ 336AB	222.1	0.1	93.5	0.12	2016.718	5164	7.98	8.93	10	2
21586+0601	SHJ 336AC	100.8	0.1	84.1	0.17	2016.718	18197	7.98	12.0	4	2
22045+1551	BU 696AC	322.3	0.1	63.3	0.09	2016.679	5732	7.95	8.96	10	2
22045+1551	BU 696AE	3.3	0.0	121.0	0.10	2016.679	6255	7.95	10.02	10	2
22045+1551	BU 696CE	32.8	0.1	84.1	0.10	2016.679	5627	8.96	10.02	10	2
22143+1711	STF2877AB	24.5	0.3	23.6	0.14	2016.677	3132	6.65	9.23	5	1
22143+1711	STF2877AC	43.9	0.1	97.3	0.24	2016.677	9024	6.65	12.42	2	1
22143+1711	STF2877AD	309.0	0.1	101.2	0.18	2016.677	9033	6.65	11.31	2	1
22143+1711	STF2877BC	49.8	0.2	75.5	0.21	2016.677	9058	9.23	12.42	2	1
22143+1711	STF2877BD	295.6	0.1	97.9	0.17	2016.677	9036	9.23	11.31	2	1
22173-0042	STF2887	30.7	0.9	7.7	0.14	2015.704	3072	9.85	9.93	5	1
22226+0956	STTA231	112.6	0.1	90.6	0.12	2016.718	4864	8.02	8.97	10	2
22326+0725	STF2915AB	125.0	0.4	15.2	0.11	2016.718	6021	9.46	9.52	10	2
22345+0413	STF2920AB	143.5	0.5	13.7	0.13	2015.704	3067	7.55	8.85	5	1
22357+1719	HJ 967	16.5	0.6	20.2	0.18	2016.679	9021	9.95	11.50	2	1
23188+0510	STF2999AB	166.9	0.1	78.6	0.11	2016.718	5856	8.90	9.17	10	2
23188+0510	STF2999AD	19.5	0.3	26.8	0.15	2016.718	15901	8.90	11.9	4	2
23188+0510	STF2999BC	172.1	0.9	10.3	0.16	2016.718	18079	9.17	10.86	4	2

Table 1 Notes:

- All magnitudes taken from the WDS catalogue. All position angle/separation measurements are for the Equator and Equinox of date.
- Column titled "**No. of (*x*,*y*) pairs**" is the total combined no. of (*x*,*y*) pairs (video frames) from all drift runs. All video frames were used, none were discarded.
- The column "**drifts**" is the number of separate drifts made. "**Nights**" is the number of nights' drift runs were made for that system.

Azeglio Bemporad and the "BEM" Double Stars

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Abstract: This paper aims to describe the scientific context and the life of early 20th century Italian astronomer Azeglio Bemporad (1875-1945), his work on double stars, and how the "BEM" doubles were incorporated into the Washington Double Star catalog. Included are new measures, a complete photo gallery of all 61 of his double star systems, and copies of his double star publications.

Azeglio Bemporad: An Italian Astronomer

Azeglio Bemporad was born in 1875 in Siena, Italy from a family that can be traced back to the larger Jewish community of Pitigliano, Tuscany. He obtained a degree in mathematics from the prestigious Scuola Normale of Pisa with maximum grades in 1898 and in January of the following year he was appointed assistant astronomer at the astronomical observatory of Turin. In 1900, with a scholarship he moved to Germany to refine his education in positional astronomy and geodesy under the guidance of Julius Bauschinger (Heidelberg Astronomisches Rechen-Institut) and Friedrich Robert Helmert (Berlin Geodetic Institute). He returned to Italy in 1904 to take up an assistant astronomer position at the Royal Astrophysical Observatory of Catania located on the east coast of Sicily (Mangano, 2015b).

The Carte du Ciel and Astrographic Catalog Project

The Catania Observatory, under the leadership of Annibale Riccò, was rapidly developing into a modern center for astrophysical studies and international collaborations (Figure 1).

The Catania Observatory was at the time one of the most developed observatories in the world with multiple reflecting telescopes, a Cooke equatorial refractor, a Reichenbach transit instrument, an Ertel meridian circle and the Steinheil astrographic telescope. The observatory was also particularly well equipped in spectroscopes and spectrographs.

Figure 1. Azeglio Bemporad (second seated from right) and director Annibale Riccò (second seated from left) together with the entire Catania observatory personnel in 1908. Photo kindly provided by Serafino Cerulli-Irelli.

At the time of Bemporad's arrival at the observatory the major focus was its participation in the Carte du

Azeglio Bemporad and the "BEM" Double Stars

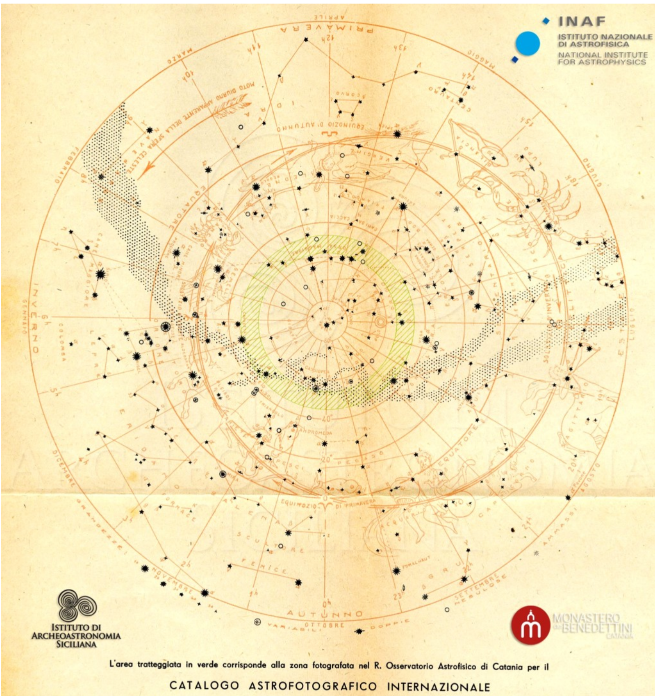

Figure 2. The +47° to +54° declination zone assigned to the Catania Observatory within the international collaboration of the Astrographic Catalog. Credits: Catania Astrophysical Observato-

Ciel - Astrographic Catalog project. This was an ambitious two-pronged task promoted by Admiral Mouchez of the Paris Observatory in 1887 with the aim of recording the position of millions of stars down to the eleventh or twelfth magnitude (the Astrographic Catalog) and to produce a photographic sky atlas of the entire sky down to magnitude 15 (the Carte du Ciel). This effort involved twenty observatories distributed throughout the northern and southern hemispheres. The Italian Observatory of Catania and the Vatican Observatory in Rome participated in this effort. Catania was assigned the +47° to +54° declination sky zone (Figure 2). Catania began its imaging effort for the project in 1894 and wouldn't complete its portion until 1932 having taken more than 1,010 plates (Urban & Corbin, 1998).

Upon his arrival at Catania, Dr. Riccò immediately recognized the mathematical ability of Azeglio and assigned him to lead the effort to calculate the stellar magnitudes and positions for the Astrographic Catalog. As it turned out, this would be the work of a lifetime for him.

The photographic plates for Carte du Ciel and Astrographic Catalog were acquired with the Steinheil astrograph (13" aperture with a focal length of 11 feet) (Figure 3). The astrograph was designed to create images on 16 x16 cm glass plates with a uniform scale of

Figure 3. The Catania Observatory Steinheil Astrograph used for the Carte du Ciel and Astrographic Catalog in a photo dating to 1894. Credits R. Osservatorio Astrofisico di Catania all'Esposizione Universale di Roma A. XX; Tav. V

approximately 60 arc-secs/mm while covering a 2° × 2° field of view (Figure 4).

For the Astrographic Catalog, multiple plates with overlapping fields of view were taken of each region of the sky to ensure that every star showed up on at least two plates. This would provide redundancy in the measurements and highlight any plate flaws or asteroid images (Urban & Corbin, 1998). Exposure times were typically 6 minutes for the Astrographic Catalog plates and 20 minutes for the Carte du Ceil plates (Riccò, 1907).

Due to his work, particularly in the budding science of astronomical photometry, the Academy of the Lincei (National Science Academy of Italy) bestowed upon Bemporad the Royal Prize for Astronomy in 1910.

In 1912 he won an open competition for the Directorship of the Astronomical Observatory of Capodimonte in Naples. Upon his arrival he found the academic atmosphere at the observatory to be more resistant to innovation, being focused more on positional astronomy than on the rising new field of "Astrophysics". He published studies on variable stars

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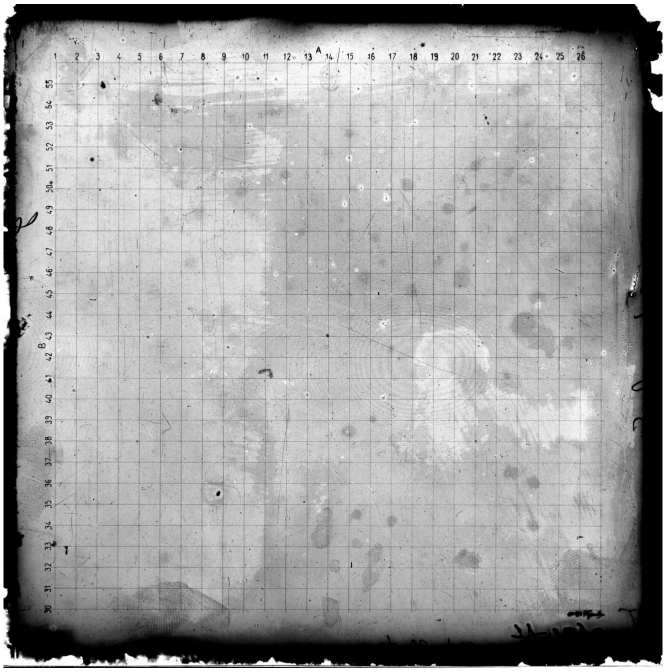

Figure 4. Original plate (plate 1692: centered at coordinates 17h 36m +50° 00’) acquired by Azeglio Bemporad during the Astrographic Catalog project. The plate shows the photographically superimposed 5mm square grid to monitor any possible shifting of the photographic emulsion as well as to aid in the astrometric measurements. Photo courtesy of Dr. Pietro Massimino and Dr. Vincenzo Greco, Catania Astrophysical Observatory.

Figure 5. Azeglio Bemporad and his family in Naples, 1917. Photo kindly provided by Serafino Cerulli-Irelli.

and novae, was a lecturer at the University of Naples, and taught Nautical Astronomy at the local naval college (Figure 5). Though he was no longer associated with the Catania Observatory, during the period 1924-1932 more than 400 plates were sent to him by the Catania’s Director Giuseppe Favaro (1876-1961) so that he could continue his work on the catalog (Mangano, 2015b).

He also applied his energy to inaugurating public outreach programs to spread the fruits of scientific research. He gave public lectures, wrote magazine and newspaper articles, and opened the observatory to the public and is now considered to have been a pioneer in this area (Fulco, 1998).

In 1933 he returned to Catania as the Director of the Observatory. Bemporad had been an early supporter of Mussolini and Italian fascism but soon his Jewish roots and the fact that he was the head of a major institution would bring him increasingly under the scrutiny of the fascist authorities. In 1938 his world was devastated by the promulgation of the “Racial Laws”, whose aim was to enforce racial discrimination directed mainly against the Italian Jews. On December 14, 1938, with World War II on the horizon, Bemporad was asked to vacate his observatory apartment and leave the direction of the Catania Observatory in the hands of Luigi Taffara (1881-1966). As a further humiliation, his request to be allowed to complete his work on the Astrographic Catalog without official position or pay was rejected (Mangano, 2015a).

Unable to continue his life’s work he moved his family to Adrano, near Mount Etna, where they lived until Sicily was liberated by the allies in December 1943. He was reinstated as Director of the Observatory, but overwhelmed by the war, his wife’s passing in 1943, and his own poor health, he passed away two years later on February 11, 1945 at age 70.

Recognized worldwide as a superb mathematician and astronomer, he co-authored more than 200 publications covering such diverse topics as stellar and cometary photometry, solar radiation, and photometric observations of variable stars (Dizionario Biografico degli Italiani, 1966). His work in stellar photometry, stellar extinction, and light absorption by the Earth’s atmosphere was pioneering and his formulas and tables for calculating air mass extinction values are still referenced to this day.

Although the Carte du Ciel project fell short in its ambitious goal of producing a complete photographic Sky Atlas, the Astrographic Catalog was essentially completed with Catania Observatory recording the positions of more than 175,000 stars, and Bemporad was a significant contributor, authoring 33 volumes of the 64 that were eventually published for the project from 1907 to 1942 (Fulco, 1998).

The BEM Doubles: Historical Background

Bemporad authored 4 publications dealing with double stars with substantially the same title: *"Misure di stelle doppie eseguite nel corso dei calcoli per il Catalogo Astrografico di Catania"* (Measurements of double stars encountered during the calculations of the Astrographic Catalog – Zone of Catania) in the journal *Astronomische Nachrichten* (AN); AN 244, 1932; AN 246, 1932, AN 248, 1933 and AN 254, 1934. As the titles suggest, these were substantially a byproduct of the calculations performed at Catania for the reduction of the magnitudes and positions of the Astrographic Catalog plates.

In the course of our research we were unfortunately unable to locate documents or letters at both Naples and Catania observatories that would allow us to describe more fully the criteria used to make selections and better describe the genesis of these four publications.

The articles contain predominately tabular data but the first paper (AN 244) contains the following commentary:

"*In General the measurement of Double stars as recorded on the photographic plates for the Astrographic Catalog can be difficult. The measures become more difficult as the brightness of the stellar image increases. For pairs of 11th magnitude resolutions on the order of 1 arc-sec can be measured while for 9th magnitude pairs 3 arc-sec separations can barely be resolved. Despite these severe limitations of the photographic method we managed to resolve nearly all double stars contained in the Burnham Catalog in the zone + 47° to 48°. In addition we found 17 new pairs, in general very faint, not previously listed in the catalogue.*"

The only BEM double not published in the *Astronomische Nachrichten* was BEM39, the only multiple system (quintuple) cataloged by Bemporad. The particulars for this system were presented in *Contributi Astrofisici No. 42, 1938.* Bemporad was very proud of this discovery and it must have been one of his last articles to be published before his removal from the Observatory. This article provides details of the discovery of the system and is reprinted in detail below. The footnotes from the article have been inserted into the text as "(…)" to enhance the flow of the narrative:

"Everyone knows that double stars are not a very frequent phenomenon; the largest catalog of Aitken ("New General Catalog of Double Stars", 1932), which goes far beyond magnitude 14 and extends from the North Pole up to 120 deg polar distance, only contains about 17,000 double or multiple stars. A statistic compiled by me on about 10,000 stars contained in vol. III, part 8 of Astrographic Catalog of Catania has established the existence of 129 double stars, ie only 1.3% of the number of single stars in area of 21h to 24h RA between parallel +48d and +50° Dec up to magnitude 12+. The number of triple stars among the10,000 stars can be counted on the fingers (In vol. IV, Part 8 of 11,265 stars only 7 triple stars were found).

"Absolutely outstanding is finding a quintuple star on plates with just 5 minutes of exposure which was generally used for the Catania Catalog and it is worth giving an account of the circumstances that led to the discovery.

"In the review of the drafts of vol. II Part 8, namely the compilation of the notes for double stars contained on Plate No. 752 (21h 40m, + 48°) my eye fell on a pair of stars on the edge of the grid constituting a rather large double which, precisely because of the unfavorable position, elements had not yet been determined. (It is obvious that the stars there [on the edge of the grid] are always elongated and often deformed by the various lens aberrations. The writer believes, however, it is useful to extend measures and calculations to the range of 3 mm around the perimeter [of the grid], as they can confirm the circumstances of stars contained in a more favorable positions on adjacent plates. The utility of this extension of measures could not be better demonstrated than with the discovery of this quintuple.)

"On closer inspection I noticed that for a minor star its corresponding image in the second exposure was missing, so it could be considered as doubtful or illusory, instead of corresponding to a real star. (To distinguish stellar images from those caused by defects during development it was decided to perform on each Plate a second exposure of two and a half minutes with the image offset from the original exposure at a convenient distance (20"). When a star was at the limit of visibility, the second exposure was usually nearly imperceptible.)

"Only a second plate, Plate 1810, could clarify the situation, where the double in question appeared near the center [of the Plate]. At first glance it confirmed the existence of the triple, but upon closer examination in the neighborhood revealed the existence of two other satellite stars, also present in the aforementioned Plate 752 and by two more recent plates still to be measured. The fairly consistent results of the measures from the two plates are summarized here. This is the first quintuple that has been observed in the course of the calculations for the Astrographic Catalog of Catania begun about 10 years ago which now contains the positions of 350,000 stars."

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Scanned images of this publication as well as the four *Astronomische Nachrichten* publications have been included in Appendix 2 at the end of this article.

Many of the double stars in these publications were incorporated into the *"Index Catalog of Double Stars"* (IDS) as BEM1-39 (IDS; Jeffers, van den Bos & Greeby 1963). Compiled by Lick Observatory, the IDS consolidated all of the various double star catalogs (ADS, BDS, SDS etc.) into a common double star database. In 1964 Lick relinquished the responsibility of maintaining the database to the U.S. Naval Observatory (USNO) where the catalog was renamed the *"Washington Double Star Catalog"* (WDS).

In 2010 Brian Mason of the USNO, with the help of Freiderich Damm, determined that not all of Bemporad's discoveries in the four AN publications had been included in the IDS, so in July 2010 an additional 24 doubles were added to the WDS under the designations BEM 9001-9024.

Also in 2010 Friedrich Damm cataloged a faint "C" component to each of four Bemporad pairs; DAM258AC (BEM9005), DAM259AC (BEM9011), DAM260AC (BEM9022) and DAM261AC (BEM9024).

Because of this protracted progression of getting the Bemporad double star observations incorporated into the mainstream catalogs, these systems have been rather neglected with most not having a follow-on measurement to Bemporad's originals until the 1990's. In the case of BEM36 a follow-on measurement was not submitted until 2006 – a span of 109 years from the date of the original Astrographic Catalog plate taken in 1897.

As is typical with most double star catalogs, the vast majority of Bemporad's systems are likely only optical associations. Based on the analysis of proper motion data for the components, only 13 systems show a possible physical relationship based on common proper motions (BEM 1, 5, 11, 12, 16, 18, 27, 38, 9002, 9017, 9018, 9019 & 9022) (Stelle Doppie website).

In the case of optical systems, BEM3 has been included in the USNO "*Catalog of Rectilinear Elements*" created to present linear solutions (non-keplerian) of the relative movement of high proper motion pairs (Hartkopf, 2011).

In the 1990's the USNO undertook the task of analyzing the original Astrographic Catalog data with the aim of refining the original plate constants and reducing the systematic errors of the original plate reductions (Urban, 1998). This data was then used to convert the Astrographic Catalog into the Hipparcos system, the result of which is the "*Astrographic Catalog 2000*" (AC2000). As a result, many of Bemporad's original measures from the AN publications have been refined or superseded using this updated Astrographic Catalog Data.

Measurements

In general the Bemporad pairs are comprised of relatively wide but dim stars, with none of the components shining brighter than magnitude 10. The majority of the pairs are located away from the galactic plane and in sparse star fields with few nearby bright stars or asterisms to make locating them easy. This makes them challenging objects in moderately sized amateur scopes and a Go-To mount was found to be indispensable for this project.

All the photos were taken using a 120 mm f7.5 apochromatic refractor (Takahashi TSA120) and an Olympus E-PL-5 14 Mega-Pixel Camera which produces a plate scale of 0.88 arcsec/pixel at prime focus. Typical exposures for these objects were in the 15 to 30 second range at ISO 800 with the lower end of the exposure range used for the systems with the closest separations. Over a thousand photos were taken with 445 being chosen as suitable for measurement. This works out to an average of 7 frames for each of the 61 systems.

The photos were taken in Camera RAW format and processed prior to making any measurements. Master Dark and Bias frames were produced prior to the start of project and were subtracted from the science frames. Background gradients and vignetting were removed using the Automatic Background Extraction tool in the software package PixInsight to produce a flat-field image. The green channel was then extracted and the resulting image converted to FITS format. These green channel images which approximate the band pass of a photometric V-Band filter image (AAVSO, 2016, Sect 6.1) were used for our astrometric and photometric measurements.

The photos were plate-solved using Astrometrica and the Separation (Sep) and Position Angle (PA) calculated from the coordinates of the components using the formulas found in Buchheim (2008). Astrometrica will calculate the magnitude of selected star(s) based on comparison to reference stars in the photographic frame. The URAT1 Catalog was selected as the reference catalog used by Astrometrica for both plate-solving and photometric comparisons as it is up-to-date (released in 2015) and optimized to target stars in the 9 to 17 magnitude range - a good match to magnitudes found in the Bemporad catalog.

The quality and accuracy of the current visual magnitude values for these pairs is very uneven and almost non-existent for more than a few of these systems. Tycho2 VT magnitudes are available for only 20 systems and AAVSO-APASS visual magnitudes (excluding overlaps with the Tycho2 values) are available for another 13 of the pairs. The most uniform source of recorded magnitudes is the 2MASS catalog which provides H, J & K band magnitudes for all the systems with the exception of BEM9016.

To compensate for the scarcity of visual magnitude data, equivalent V-band magnitudes were calculated for all the systems using the equation below (Warner, 2007) which converts J and K band magnitudes of a given star to an equivalent V-Band Magnitude in the BV(RI)c system:

$$V_{mag} = J + 0.1496 + 3.5143(J-K) - 2.325(J-K)^2 + 1.4688(J-K)^3$$

Provided: $-0.1 < J\text{-}K < 1.0$ [1]

These values are recorded in Table 1 as M1 and M2 in the "Measures" section and referred to herein as "Calculated Vmag". These values were used as a baseline number to compare both the current WDS magnitudes and our own Astrometrica generated magnitudes. The J and K Band magnitudes used to calculate the Vmag values have not been tabulated herein but are available through the on-line Aladin Sky Atlas and are also recorded in the WDS Historical Data files for these systems.

Table 1 lists measures for all 61 Bemporad systems which are comprised of 68 secondary components. The following is an explanation of the data presented:

- **BEM Catalog Number (WDS) & Constellation**
- **WDS Values** – The Current WDS Values: Separation (Sep), Position Angle (PA) & Magnitudes (M1, M2) of the components.
- **Primary RA & Dec** – The coordinates of the Primary star based on the average of our plate solved results.
- **Sep & PA** – The calculated Separation and Position Angle of the system based on the plate solved coordinates – the reported error is the Standard Error: SE = Std Dev/(No. of frames)$^{1/2}$
- **M1 & M2** – The calculated V magnitude (Vmag) from Equation 1. Astrometrica measured magnitudes (Ma) are presented in the "Comments" section when the calculated Vmag differs significantly from the current WDS values.
- **Date** - Bessel Epoch of the observation(s)
- **Number of Frames** - Number of Photos (independent measures) used in the data reduction for the given system.

Measures that vary significantly from the current WDS values or that highlight some anomaly in the current record have been highlighted in red

We found that there was a very good correlation between the calculated Vmag values and the Astrometrica photometry measurements. Excluding measures for stars fainter than Magnitude 15 due to poor SNR, the average difference between the two metrics was 0.120 mag, with a maximum difference of 0.42 magnitude for BEM32. The standard deviation taken across all the components was 0.10 magnitude.

A summary of our results are:

- Magnitude revisions recommended for 32 systems.
- Location Errors: 1 (BEM36)

A photo gallery of all of the Bemporad Doubles can be found in Appendix 1 at the end of this article. All of the separations and magnitudes shown on the photos are from our measurements presented herein. Magnitudes shown for the reference field stars are UCAC4 or URAT1 V-Band magnitudes. Separation and PA values for other double stars that may be in the frames are the current WDS values.

Notes on Selected Systems

In the discussion of specific Bemporad systems below, the historical Separation and Position Angles used in the plots are from the WDS Historical Data files available through the USNO.

BEM1: The current WDS listing has the secondary at 0.74 magnitude brighter (11.44, 10.7) than the primary while UCAC4 has the components listed as equal in magnitude at 11.157. The photos clearly show the primary as being brighter. The calculated Vmag values (11.42 & 12.23) and the Astrometrica magnitudes (11.36 & 12.20) are nearly identical; in both cases a Δ M of ~0.8. No significant changes to Separation and PA from 2003 were noted.

BEM2: Similar to BEM1, the WDS has the secondary listed as being brighter (12, 11.4) while the photos clearly show the primary as being significantly brighter. Calculated Vmag values are 12.17 & 13.07 - a ΔM of 0.9 magnitude. The Astrometrica measures (11.89, 12.90) show a ~1.0 magnitude difference and ~0.3 mag brighter than the calculated Vmag values.

BEM3: Calculated Vmag values and Separation are similar to the current WDS values. The PA measurement however shows a 2 Degree change (206.90 vs 204.95) from the 2003 WDS measures.

BEM5: Current WDS values show the components to be nearly equal in magnitude with the secondary being slightly brighter (12.85, 12.6) but examination of our photos along with DSS images show the primary to be slightly brighter. The calculated Vmag

(Text continues on page 336)

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Table 1.

		WDS VALUES		MEASURES					
SYSTEM	CON	SEP	PA	Primary RA	SEP (Err)	PA (Err)	Date	No.	Comments
		M1	M2	Primary DEC	M1	M2	2000+	Frm	
BEM 1	CVn	9.59	202.90	RA 12 : 43 : 59.13	9.558 (.028)	202.781 (.177)	16.121	9	UCAC4 = 11.16, 11.16
		11.44	10.70	DEC + 49 : 50 : 39.614	11.42	12.23			**Ma = 11.36, 12.20**
BEM 2	Uma	5.00	271.40	RA 12 : 54 : 14.026	4.901 (.035)	270.942 (.214)	16.461	5	UCAC4 M1 = 11.771
		12.00	11.40	DEC + 52 : 51 : 23.332	12.17	13.07			**Ma = 11.89, 12.90**
BEM 3	CVn	18.20	206.90	RA 12 : 59 : 30.082	18.124 (.007)	**204.951 (.072)**	16.461	4	Last Measure 2003
		11.74	12.17	DEC +49:00:17.708	11.67	12.06			Ma = 11.83, 12.17
BEM 4	CVn	22.33	356.28	RA 13 : 07 : 46.672	22.123 (.057)	356.33 (.038)	16.138	4	Last Measure 2013
		11.51	11.70	DEC + 49 : 54 : 46.742	11.64	11.77			WDS MAG=UCAC4
BEM 5	Uma	9.51	214.50	RA 13 : 25 : 39.232	9.502 (.015)	216.108 (.161)	16.622	6	Last Measure 2015
		12.85	12.60	DEC + 52 : 26 : 13.018	11.62	12.13			**Ma = 11.64, 12.20**
BEM 6	UMa	8.37	189.90	RA 13 : 33 : 45.121	8.306 (.025)	189.865 (.147)	16.140	7	Last Measure 2013
		10.43	11.19	DEC + 54 : 18 : 4.336	10.49	11.24			Ma = 10.61, 11.18
BEM 7	UMa	4.60	84.80	RA 14 : 05 : 7.518	4.468 (.02)	84.834 (.115)	16.455	10	Last Measure 2015
		11.80	11.98	DEC + 49 : 13 : 36.996	11.86	11.98			Ma = 11.92, 11.86
BEM 8	Boo	24.55	240.10	RA 14 : 11 : 44.586	24.448 (.082)	240.4 (.182)	16.253	6	Last Measure 2013
		9.85	11.04	DEC + 49 : 46 : 20.455	9.78	11.15			UCAC4 = 9.76, 11.16
BEM 9	Boo	11.60	284.00	RA 14 : 13 : 8.341	11.571 (.009)	283.525 (.053)	16.253	5	M2 = APASS
		12.00	12.48	DEC + 50 : 31 : 14.294	12.13	12.23			**Ma = 11.94, 12.02**
BEM 10	Boo	14.60	16.00	RA 14 : 15 : 9.74	NA	NA	NA	-	Bogus Pair
		11.62	11.10	DEC + 50 : 48 : 11.8	NA	NA			No secondary found
BEM 11	Boo	14.60	16.00	RA 14 : 28 : 30.654	14.66 (.017)	16.281 (.083)	16.253	5	Last Measure 2002
		12.00	12.20	DEC + 49 : 32 : 9.728	11.80	11.70			**Ma = 11.75, 11.61**
BEM 12	Boo	8.70	185.80	RA 14 : 30 : 28.219	8.719 (.033)	185.779 (.11)	16.253	7	Last Measure 2003
		12.00	11.60	DEC + 50 : 13 : 2.937	11.84	12.53			**Ma = 11.71, 12.45**
BEM 13	Boo	28.70	129.10	RA 14 : 31 : 32.677	29.006 (.092)	130.147 (.049)	16.253	6	Last Measure 2002
		11.47	11.89	DEC + 50 : 16 : 19.047	11.43	11.87			Ma = 11.33, 11.73
BEM 14	Boo	27.35	151.00	RA 14 : 55 : 50.539	27.174 (.064)	151.11 (.082)	16.253	7	Last Measure 2015
		10.92	12.11	DEC + 49 : 14 : 14.508	10.98	12.11			Ma = 10.72, 12.04
BEM 15	NA								Bogus Pair
									No Pri or Sec Found
BEM 16	Boo	25.14	66.00	RA 15 : 09 : 41.703	25.16 (.023)	65.976 (.022)	16.253	6	WDS Mags =APASS
		11.58	12.31	DEC + 49 : 41 : 45.00	11.67	12.01			Ma = 11.57, 12.45
BEM 17	Boo	23.19	119.40	RA 15 : 14 : 31.395	23.137 (.016)	119.285 (.04)	16.253	10	Last Measure 2003
		13.16	12.99	DEC + 50 : 19 : 28.935	13.28	12.95			Ma = 12.94, 12.64
BEM 18	Boo	8.60	13.66	RA 15 : 18 : 36.179	8.646 (.016)	12.963 (.15)	16.338	10	UCAC4 M1 = 10.29
		10.51	11.40	DEC + 51 : 58 : 58.359	10.42	12.09			**Ma = 10.26, 11.99**
BEM 19	Boo	26.95	240.50	RA 15 : 45 : 18.54	26.775 (.141)	240.504 (.282)	16.283	6	WDS Mags =APASS
		10.59	11.85	DEC + 49 : 6 : 8.678	10.74	12.05			Ma = 10.58, 11.70
BEM 20	Dra	22.32	283.70	RA 15 : 59 : 11.241	22.454 (.04)	283.705 (.152)	16.253	4	WDS Mags =APASS
		12.22	12.27	DEC + 51 : 10 : 2.968	12.41	12.23			Ma = 12.26, 12.3

Table 1 conitinues on next page.

Azeglio Bemporad and the “BEM” Double Stars

Table 1 (cointinued).

SYSTEM	CON	WDS VALUES SEP / M1	WDS VALUES PA / M2	MEASURES Primary RA / Primary DEC	SEP (Err) / M1	PA (Err) / M2	Date 2000+	No. Frm	Comments
BEM 21	Dra	19.04	103.60	RA 16 : 02 : 58.279	19.121 (.052)	104.004 (.114)	16.283	8	URAT1 = 10.33, 10.92
		10.33	10.92	DEC + 51 : 11 : 39.384	10.41	10.01 N.G.			Ma = 10.28, 10.73
BEM 22	Dra	7.60	104.80	RA 16 : 42 : 13.872	7.544 (.014)	104.766 (.053)	16.606	8	URAT1 M1 = 10.723
		11.00	11.30	DEC + 52 : 35 : 16.83	10.97	11.69			**Ma = 11.00, 11.70**
BEM 23	Her	24.87	21.30	RA 16 : 57 : 12.226	24.918 (.022)	21.336 (.042)	16.390	6	Last Measure 2003
		12.89	12.83	DEC + 49 : 3 : 17.197	12.89	12.85			Ma = 12.86, 12.84
BEM 24	Her	31.68	196.60	RA 17 : 00 : 9.373	32.38 (.036)	196.011 (.156)	16.390	7	Last Measure 2003
		12.35	12.45	DEC + 50 : 40 : 59.084	12.32	12.38			Ma = 12.42, 12.57
BEM 25	Her	24.17	27.30	RA 17 : 00 : 54.4	24.143 (.047)	28.069 (.118)	16.390	7	Last Measure 2003
		12.98	13.24	DEC + 49 : 29 : 13.393	12.93	13.23			Ma = 13.12, 13.17
BEM 26	Dra	15.40	198.00	RA 17 : 08 : 36.711	15.448 (.01)	**195.994 (.151)**	16.390	7	UCAC4 = 11.06, 13.33
		11.06	13.34	DEC + 50 : 22 : 45.397	10.94	12.84			**Ma= 10.90, 12.85**
BEM 27	Dra	13.05	204.90	RA 17 : 31 : 48.03	13.042 (.031)	204.578 (.104)	16.422	6	WDS MAGS = APASS
		11.53	11.81	DEC + 53 : 48 : 44.978	11.49	12.00			Ma = 11.80, 12.13
BEM 28	Her	3.18	359.60	RA 17 : 38 : 48.081	2.959 (.064)	358.016 (.399)	16.422	7	URAT1 M1 = 10.945
		12.00	12.40	DEC + 49 : 22 : 32.766	11.41	11.68			**Ma= 11.42, 11.72**
BEM 29	Her	5.04	136.40	RA 17 : 49 : 24.189	5.035 (.049)	**134.534 (.427)**	16.425	9	Blue - Gold
		10.47	12.60	DEC + 48 : 22 : 36.133	10.56	12.61			Ma = 10.39, 12.43
BEM 30	Her	14.52	113.60	RA 17 : 51 : 13.354	14.75 (.031)	**114.44 (.046)**	16.425	4	Last Measure 2003
		12.20	12.60	DEC + 50 : 06 : 20.89	11.20	12.64			**Ma = 11.25, 12.60**
BEM 31	Dra	11.95	305.70	RA 18 : 09 : 41.211	11.986 (.033)	305.412 (.046)	16.450	6	Yellow-Blue
		9.90	12.30	DEC + 53 : 29 : 31.412	9.87	12.30			Ma = 9.91, 12.28
BEM 32	Dra	7.97	315.70	RA 18 : 22 : 2.715	7.931 (.011)	315.108 (.196)	16.450	6	Last Measure 2010
		10.52	9.60	DEC + 53 : 36 : 8.692	10.25	13.13			**Ma = 10.27, 12.72**
BEM 33	Dra	8.24	45.80	RA 18 : 24 : 23.317	7.972 (.038)	46.056 (.232)	16.450	6	Last Measure 2010
		10.40	11.30	DEC + 53 : 31 : 46.475	11.91	11.43			**Ma = 11.90, 11.20**
BEM 34	Dra	10.44	27.00	RA 18 : 34 : 25.739	10.494 (.005)	26.418 (.047)	16.450	6	Last Measure 2008
		11.08	11.06	DEC + 52 : 39 : 33.417	11.12	11.64			**Ma = 11.17, 11.69**
BEM 35	Dra	17.19	156.90	RA 18 : 51 : 10.831	17.125 (.041)	156.236 (.08)	16.606	7	URAT1 M1 = 11.094
		10.80	11.70	DEC + 52 : 09 : 51.505	11.14	12.51			**Ma= 11.01, 12.47**
BEM 36	Dra	11.31	338.50	**RA 18 : 58 : 33.336**	**11.835 (.039)**	**336.778 (.386)**	16.461	7	Location Incorrect
		10.05	8.90	**DEC + 53 : 07 : 2.111**	10.05	11.89			**Ma = 10.13, 11.94**
BEM 37	Dra	11.50	309.10	RA 19 : 01 : 25.457	11.235 (.032)	309.329 (.128)	16.461	6	Last Measure 2008
		12.00	11.90	DEC + 53 : 27 : 48.800	12.21	12.07			Ma = 12.03, 12.03
BEM 38	Cyg	13.30	104.40	RA 19 : 08 : 55.531	13.296 (.02)	104.113 (.132)	16.466	6	Last Measure 2012
		11.80	11.73	DEC + 53 : 32 : 00.608	10.94	11.87			Ma = 11.85, 11.86
BEM 39AB	Cyg	15.74	328.80	RA 21 : 37 : 12.335	15.678 (.021)	328.776 (.088)	16.529	6	Last Measure 2011
		10.06	11.20	DEC + 47 : 39 : 14.287	9.93	11.27			Ma = 9.82, 11.12
BEM 39BC	Cyg	6.57	124.70	RA 21 : 37 : 11.53	6.532 (.013)	124.395 (.16)	16.529	6	
		11.20	11.70	DEC + 47 : 39 : 27.693	11.27	12.56			**Ma = 11.12, 12.85**
BEM 39AD	Cyg	25.92	7.30	RA 21 : 37 : 12.335	25.853 (.016)	7.478 (.059)	16.529	6	
		10.06	14.20	DEC + 47 : 39 : 14.287	9.93	13.19			**Ma = 9.82, 12.91**
BEM 39AE	Cyg	25.15	124.30	RA 21 : 37 : 12.335	25.125 (.043)	124.484 (.025)	16.529	6	
		10.06	13.16	DEC + 47 : 39 : 14.287	9.93	13.07			Ma = 9.82, 13.03

Table 1 conitinues on next page.

Azeglio Bemporad and the "BEM" Double Stars

Table 1 (continued).

SYSTEM	CON	WDS VALUES SEP	PA	MEASURES Primary RA	SEP (Err)	PA (Err)	Date	No.	Comments
		M1	M2	Primary DEC	M1	M2	2000+	Frm	
BEM9001	CVn	22.07	134.20	RA 12 : 29 : 27.311	22.238 (.069)	133.94 (.146)	16.622	7	WDS Mags are UCAC4
		11.42	12.58	DEC + 47 : 2 : 39.911	11.35	12.09			**Ma = 11.48, 12.22**
BEM9002	CVn	8.95	223.20	RA 13 : 10 : 40.927	8.941 (.039)	223.01 (.165)	16.622	5	WDS Mags= UCAC4
		11.70	12.40	DEC + 46 : 34 : 16.868	11.80	12.27			**Ma = 11.45, 12.01**
BEM9003	Boo	8.50	240.80	RA 14 : 28 : 04.818	8.458 (.013)	240.751 (.072)	16.253	4	UCAC4 M1 = 12.77
		11.80	13.10	DEC + 46 : 02 : 25.458	13.38	13.66			**Ma = 13.16, 13.48**
BEM9004	Boo	22.70	316.40	RA 14 : 33 : 50.902	22.825 (.019)	316.512 (.008)	16.253	3	Last Measure 2002
		12.00	12.12	DEC + 47 : 07 : 17.007	11.94	11.95			Ma = 12.03, 11.96
BEM9005 AB	Boo	20.29	203.30	RA 15 : 25 : 52.516	20.285 (.021)	203.367 (.073)	16.253	10	Last Measure 2002
		11.81	12.05	DEC + 45 : 43 : 50.935	11.90	12.03			Ma = 11.59, 11.64
BEM9005 AC DAM258	Boo	12.00	228.00	RA 15 : 25 : 52.575	12.016 (.066)	227.753 (.145)	16.253	10	Last Measure 2002
		11.81	14.50	DEC + 45 : 43 : 51.035	11.90	14.88			Ma = 11.59, 14.43
BEM9006	Her	5.12	256.30	RA 15 : 51 : 41.389	5.116 (.042)	256.299 (.175)	16.261	7	Last Measure 2015
		11.10	11.30	DEC + 46 : 13 : 52.133	11.90	12.13			**Ma = 11.84, 12.03**
BEM9007	Her	13.33	133.10	RA 16 : 09 : 5.633	13.348 (.031)	**132.347 (.104)**	16.337	6	Last Measure 2002
		12.00	12.20	DEC + 46 : 33 : 35.588	11.98	12.25			Ma = 12.06, 12.26
BEM9008	Her	19.50	245.30	RA 16 :09 : 45.432	19.534 (.018)	245.092 (.095)	16.338	6	Last Measure 2002
		11.03	12.05	DEC + 46 : 23 : 36.087	11.12	12.06			Ma = 10.91, 12.08
BEM9009	Her	6.36	291.20	RA 16 : 12 : 08.75	**5.686 (.079)**	292.452 (.472)	16.338	5	Last Measure 2002
		10.50	11.90	DEC + 46 : 47 : 23.17	10.43	12.06			Ma = 10.57, 12.13
BEM9010	Her	20.46	57.80	RA 17 : 02 : 54.282	20.854 (.017)	**56.451 (.019)**	16.390	6	Orange - Blue
		10.49	11.52	DEC + 46 : 42 : 39.003	10.50	11.22			Ma = 10.25, 11.04
BEM9011AB	Her	10.48	208.70	RA 17 : 26 : 43.534	10.391 (.013)	209.052 (.073)	16.743	6	Orange - Orange
		11.76	11.70	DEC + 47 : 27 : 17.137	11.23	11.33			Ma = 11.56, 11.68
BEM9011AC DAM 259	Her	10.18	21.10	RA 17 : 26 : 43.534	10.502 (.109)	17.461 (.481)	16.743	6	Last Measure 2003
		11.76	16.40	DEC + 47 : 27 : 17.137	11.23	16.91			**Ma = 11.56, 16.55**
BEM9012	Her	4.52	142.80	RA 17 : 51 : 36.76	4.493 (.024)	**141.539 (.088)**	16.422	5	Last Measure 2003
		12.30	12.30	DEC + 47 : 21 : 36.414	12.18	12.64			**Ma = 12.19, 12.47**
BEM9013	Boo	5.30	331.50	RA 14 : 40 : 43.094	5.276 (.032)	**330.529 (.265)**	16.253	4	Last Measure 2015
		10.80	11.50	DEC + 49 : 27 : 33.608	10.89	12.00			**Ma = 10.85, 11.89**
BEM9014	Her	13.98	108.20	RA 16 : 28 : 33.441	14.309 (.046)	108.69 (.069)	16.343	6	Last Measure 2003
		11.22	12.28	DEC + 48 : 19 : 5.443	11.06	12.13			Ma = 11.15, 12.24
BEM9015	Dra	12.82	266.60	RA 17 : 43 : 20.298	12.982 (.032)	264.848 (.26)	16.422	6	Last Measure 2003
		12.61	12.04	DEC + 51 : 21 : 10.935	12.12	12.32			**Ma = 12.03, 12.31**
BEM9016	Dra	3.74	17.60	RA 17 : 49 : 53.591	4.089 (.102)	17.25 (.671)	16.479	14	Last Measure 2000
		14.00	14.00	DEC + 50 : 35 : 31.173	13.55	**16.11**			**Ma = 13.61**, 16.75
BEM9017	Uma	13.00	210.40	RA 13 : 20 : 27.201	12.97 (.011)	210.64 (.079)	16.606	4	WDS Mags =APASS
		11.39	12.30	DEC + 54 : 18 : 43.009	11.40	11.84			**Ma = 11.26, 11.71**
BEM9018	Boo	16.46	31.20	RA 14 : 19 : 04.663	16.339 (.008)	31.426 (.058)	16.253	4	WDS Mags =APASS
		10.73	11.51	DEC + 51 : 33 : 28.445	10.48	11.40			**Ma = 10.44, 11.19**
BEM9019	Boo	14.06	14.20	RA 14 : 23 : 34.238	14.119 (.037)	14.173 (.175)	16.307	7	Last Measure 2013
		10.50	10.90	DEC + 52 : 4 : 56.7	10.35	10.92			Ma = 10.33, 10.80
BEM9020	Boo	13.30	3.60	RA 15 : 09 : 11.598	13.303 (.023)	**4.47 (.11)**	16.307	7	Last Measure 2003
		11.70	12.20	DEC + 52 : 56 : 39.626	12.20	12.27			**Ma = 12.01, 12.20**

Table 1 conitinues on next page.

Azeglio Bemporad and the "BEM" Double Stars

Table 1 (conclusion).

SYSTEM	CON	WDS VALUES		MEASURES						Comments
		SEP	PA	Primary RA	SEP (Err)	PA (Err)	Date	No.		Comments
		M1	M2	Primary DEC	M1	M2	2000+	Frm		
BEM9021	Her	18.32	52.00	RA 16 : 26 : 21.786	18.394 (.044)	52.482 (.052)	16.343	5		Last Measure 2015
		10.62	11.95	DEC + 50 : 47 : 29.304	10.56	11.93				Ma = 10.60, 11.91
BEM9022 AB	Dra	12.00	273.30	RA 16 : 55 : 23.911	12.058 (.016)	273.357 (.062)	16.655	10		Last Measure 2003
		11.80	12.80	DEC + 52 : 51 : 59.007	12.30	12.69				Ma = 12.34, 12.72
BEM9022 AC DAM260	Dra	6.44	197.50	RA 16 : 55 : 23.911	6.196 (.061)	202.559 (.317)	16.655	10		Last Measure 2003
		11.80	14.40	DEC + 52 : 51 : 59.007	12.30	15.43				Ma = 12.34, 15.36
BEM9023	Dra	15.33	52.20	RA 17 : 31 : 27.406	15.517 (.009)	50.854 (.042)	16.622	7		UCAC4 M2 = 12.06
		11.90	11.90	DEC + 52 : 21 : 47.93	11.89	12.07				Ma =11.98, 12.28
BEM9024 AB	Her	17.44	276.00	RA 17 : 49 : 21.325	18.336 (.009)	279.24 (.02)	16.422	7		URAT1 = 11.36, 11.61
		11.59	11.74	DEC + 49 : 04 : 20.637	11.53	11.82				Ma = 11.44, 11.78
BEM9024 AC DAM261	Her	4.85	33.10	RA 17 : 49 : 21.325	4.762 (.059)	33.452 (.692)	16.422	7		Last Measure 2003
		11.59	15.00	DEC + 49 : 04 : 20.637	11.53	14.55				Ma = 11.44, 15.60

(Continued from page 332)

values and the Astrometrica derived magnitudes correlate well at (11.62, 12.13) and (11.64, 12.20) with the Astrometrica values best fitting the visual impressions from the photos.

BEM9: WDS values show a ΔM of 0.5 mag (12.0, 12.48) while the photos seem to show a much more closely matched pair. The calculated Vmag values and Astrometrica seem to confirm this impression showing the pair to have a ΔM of ~0.1 with values of (12.13, 12.23) and (11.94, 12.02) respectively.

BEM10: BOGUS PAIR - No visible companion found in our photos or in DSS images - This reported pair has been removed from the WDS database.

BEM12: The WDS shows the secondary as being brighter with a ΔM of 0.4 (12.0, 11.6). Photos show the primary to be noticeably brighter with the calculated Vmag values yielding magnitudes of 11.84 & 12.53 (primary brighter, ΔM = 0.75) which is a close match to the Astrometrica values of 11.71 & 12.45 (primary brighter, ΔM = 0.74).

BEM15: BOGUS PAIR – Unlike BEM10 where there is a plausible candidate for the primary at the reported location, in the case of BEM15 (See AN 254 in Appendix 2 with the assumed candidate) there is no sign of a plausible primary at or near the reported location. Therefore BEM15 is not listed at all in the WDS database.

BEM17: The WDS currently has this listed as an unequal pair with the secondary being brighter by ~0.17 magnitude (13.16, 12.99) (APASS Magnitudes). The Astrometrica measures show the pair overall to be about 0.3 magnitude brighter than currently listed and with a larger ΔM of ~0.3 (12.94, 12.64). The calculated Vmag values (13.28 &12.95) appear to confirm the current WDS values.

BEM18: The WDS currently has this listed as an unequal pair with a ΔM of ~0.9 (10.51, 11.4). The calculated Vmag values (10.42, 12.09) and Astrometrica (10.26, 11.99) show the pair to have a ΔM of ~1.7 due principally to the secondary being much dimmer than currently listed. At first glance the Sep & PA values do not seem too different from the previous measures but a look at the WDS historical records show a surprising degree of variation in recent PA measurements (3.2 deg) given the moderate separation as shown in Figure 6. Two of these measures are from automated surveys (2MASS & UCAC4). Other than Bemporad's original

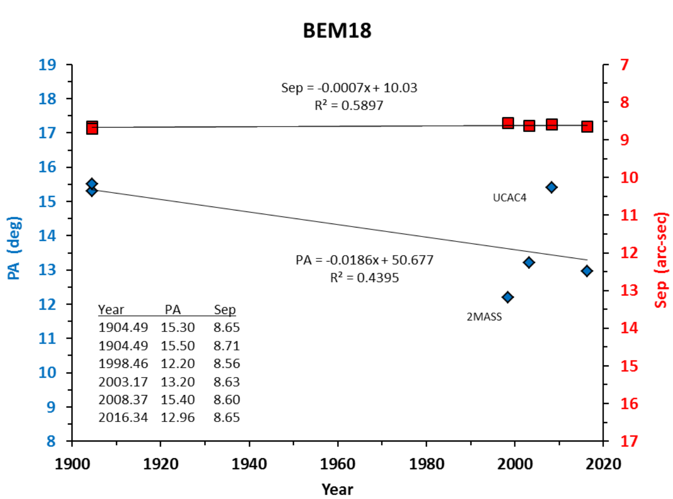

Figure 6. Historical measures of BEM 18.

1904 measurements and our own, there has only been one other independent measurement recorded in 2008.

BEM21: The current WDS magnitudes are Tycho2 VT values (10.33, 10.92). The calculated Vmag for the primary is reasonably close at 10.41 but in the case of the secondary the calculated Vmag is invalid due to the “J-K” term in EQ-1 being beyond the limits set for the equation (J-K = 1.19 > 1.0). The Astrometrica values of (10.28, 10.73) are close to the Tycho2 values.

BEM22: The calculated Vmag values and Astrometrica measures are identical at 11.0 & 11.7 for the pair. While they are in agreement with the current 11.0 mag value for the primary they show the secondary to be ~0.4 magnitude dimmer than currently listed (M = 11.3).

BEM26: Our measures roughly agree with the current WDS magnitude (UCAC4) of 11.06 for the primary. In regards to the secondary currently listed at 13.34, our measures show this star to be a half magnitude brighter (Vmag = 12.84 & Astrometrica = 12.85). Similar to BEM18, the recorded PA values for this pair show a surprising degree of scatter (± 1 deg) given the relatively large separation of the components (see Figure 7). Perhaps the only thing that can be said is that it is likely that there has been little to no change over the years as the slope of the trend line is essentially flat.

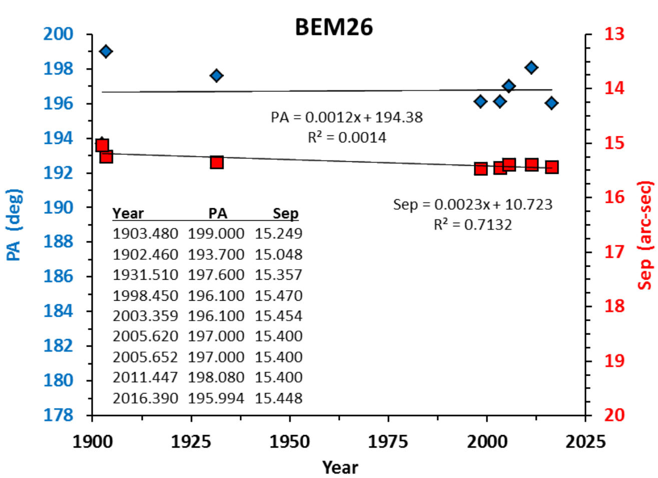

Figure 7. Historical measures of BEM 26.

BEM28: With a measured separation of 3.18” in 2003 this system is the tightest in the catalog. Our measures show that this has narrowed to 2.96”. URAT1 currently has the primary listed at V=10.95, a full magnitude brighter than the current WDS value of 12.0 (Bemporads measure). The calculated Vmag & Astrometrica values for the pair are (11.41, 11.68) & (11.42, 11.72) ~0.60 magnitude brighter than the current values. It appears that the URAT1 value for the primary is the combined magnitude for the pair which is not surprising based on the current 3” separation. If we use the Astrometrica magnitudes, the combined value for the system is 10.80 not far different from the 10.95 URAT1 value.

BEM30: The WDS currently has the primary listed at 12.2 magnitude. Visual inspection of the photos show it to be considerably brighter when compared to other 12th magnitude stars in the frame and confirmed by our measures (Vmag = 11.20 & Astrometrica = 11.25). Our measures agree with the current 12.6 value for the secondary.

BEM32: Another case where the WDS lists the secondary as being brighter (10.52, 9.6) when photos show the secondary to be significantly fainter. The calculated Vmag values and Astrometrica measures for the primary are nearly identical at 10.25 & 10.27 and URAT1 has the primary listed at 10.26. The values for the secondary do not correlate as close (12.72 & 13.13) but comparison with field stars show the Astrometrica value of 12.72 to be the best match which yields a ΔM of 2.45 for the pair. This pair was also cataloged by Rev. Thomas Espin in 1908 as ES649. As can be seen in the plot below there is a significant difference in the measures by Bemporad and Espin which were taken only a few years apart. Rev. Espin estimated the magnitudes at 9.2 & 11.5 (Espin, 1909).

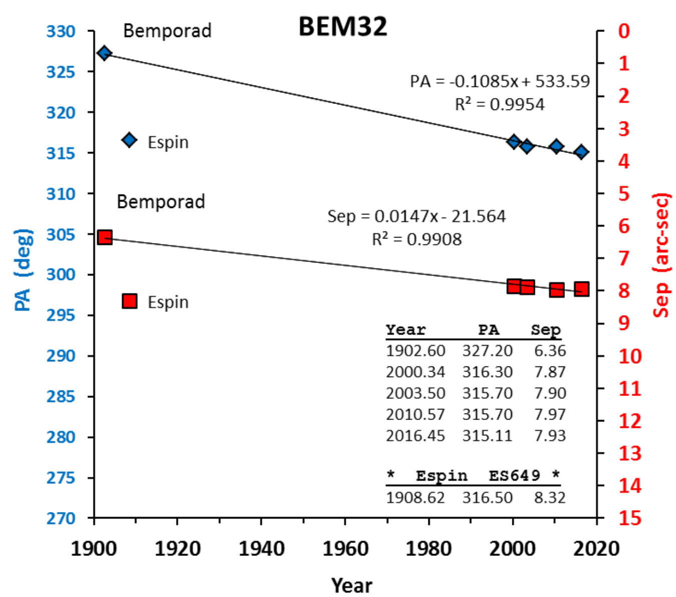

Figure 8. Historical measures of BEM 32.

Azeglio Bemporad and the "BEM" Double Stars

BEM33: The WDS currently has the primary listed as a magnitude brighter than the secondary (10.4, 11.3). Our photos and measures show the primary as being at least a half magnitude dimmer than the secondary at magnitude 11.90. The average of our magnitudes for the secondary (11.43 & 11.2) correlates well with the current WDS value of 11.3.

BEM34: Current WDS values (APASS magnitudes) show the components to be nearly equal in magnitude (11.08, 11.06) but examination of our photos along with DSS images show a noticeable difference in magnitude. The calculated Vmag values and the Astrometrica measures correlate closely at (11.12, 11.64) and (11.17, 11.69) a ΔM of 0.6 for the system.

BEM35: The calculated Vmag values and Astrometrica measures are very close (11.14, 12.51 & 11.01, 12.47) and show that the primary to be ~0.25 magnitude dimmer and the secondary to be ~0.80 magnitude dimmer than currently listed (10.80, 11.70). Our values are also in close agreement with magnitudes measured by John Daley (10.99, 12.55) (Daley, 2003).

BEM36: This system is very photogenic, located within a loose gathering of a half-dozen 9th to 10th magnitude stars. Thus it is very surprising that other than Bemporad's original 1897 measures there has been only one other recorded measure made 109 years later in 2006. Perhaps because of this neglect several items are in need of correction.

The current WDS location for this system is incorrect, actually being located 2.08 arc-min to the west (Figure 9). This same photo shows that the current WDS magnitudes for this pair (Bemporad's original magnitudes) are also incorrect. The calculated Vmag & Astrometrica values for the primary (10.05 & 10.13) are in general agreement with Bemporad's 10.05 value. His 8.5 mag for the secondary would make it significantly brighter than the primary, and is clearly in error. The calculated Vmag and Astrometrica values show the secondary to be shining about 1.8 magnitudes fainter than the primary at 11.94.

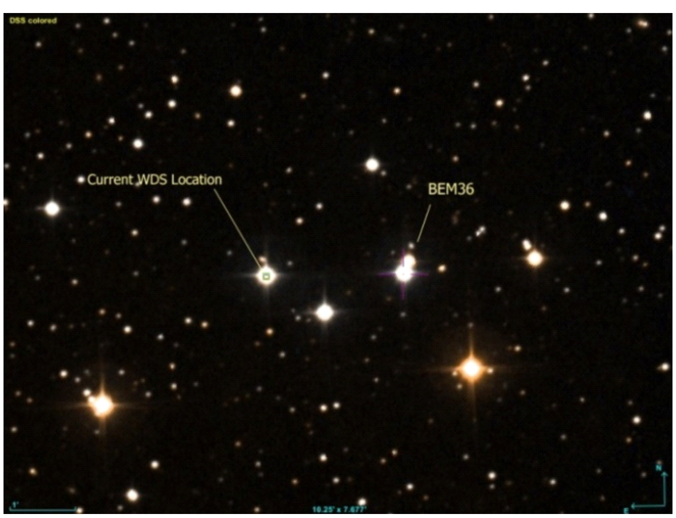

Figure 9. DSS Image showing the BEM36 location error and the relative brightness of the components.

BEM39: Though only an optical association, this quintuple is the most complex in the Bemporad catalog resembling a miniature Cassiopeia. Its members range in brightness from the 10th to 13th magnitude and subtend 42 seconds of arc. We found only minor differences in Separation and PA from the previous measures made in 2011.

In regards to magnitudes we found significant differences for components C and D. For the C component the calculated Vmag and Astrometrica measures show it to be nearly a full magnitude fainter at 12.56 and 12.85 respectively than its current listing at magnitude 11.7. For D the opposite is the case where our measures show it to be at least a full magnitude brighter at 12.91 and 13.19 from its current value of 14.2. The result is that the magnitudes for C, D & E are very closely matched at 12.6, 12.9 & 13.1 respectively and the photos seem to confirm the similarity in magnitude of these three stars.

BEM9001: The calculated Vmag and Astrometrica measures are in close agreement with each other (11.35,12.09) and (11.48,12.22) and confirm the current 11.42 value for the primary (APASS) but show the secondary to be about 0.4 magnitude brighter than currently listed (12.22 vs 12.58).

BEM9002: The WDS shows the pair to be unequal (11.70, 12.40) with a ΔM of 0.7 (UCAC4). The calculated Vmag and the Astrometrica measures all show this pair to be slightly brighter with a ΔM of ~0.5. The Astrometrica measures of 11.57 & 12.04 best fit to the photographic impression.

BEM9003: Currently the WDS listing shows this to be a very unequal pair (11.8, 13.1) ΔM = 1.3. 2Mass, UCAC4 and our own measures show this pair to have a ΔM of ~0.3. The UCAC4 magnitudes (13.11, 13.46) correlate well with our Astrometrica measures (13.16, 13.48).

BEM9006: The calculated Vmag values and Astrometrica measures are in close agreement with each other (11.90, 12.13) and (11.84, 12.03) and show this pair to be nearly a magnitude dimmer than the current WDS Values (11.10, 11.3). Visual comparisons with nearby field stars in the photos seem to confirm this. Though considered to be only an optical association, this pair appears to show a significant change in separation over the past 113 years as shown in Figure 10. However if only recent measures are considered the apparent rate of change appears to be negligible which calls into question the accuracy of the earliest measures.

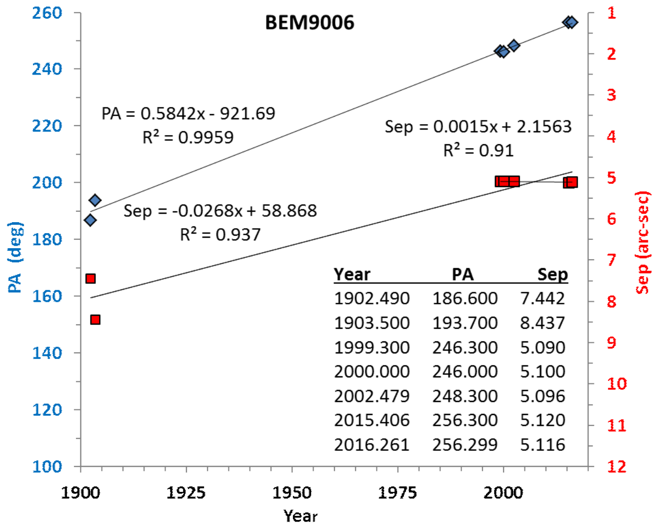

Figure 10. Historical measures of BEM9006.

BEM9011: The Current WDS magnitudes are Tycho2 VT values and show this soft orange-orange pair to be nearly equal in magnitude (11.76, 11.70). The calculated Vmag values and Astrometrica measures also show the pair to be nearly equal in magnitude but one-third to one-half magnitude brighter than the Tycho2 values (11.23, 11.33 & 11.56, 11.68). The faint C component (DAM259AC) which has a listed magnitude of 16.02 (UCAC4) was a difficult target to image being 4.26 magnitude fainter than the primary. The calculated Vmag values and Astrometrica measures show C to be at least 0.5 magnitude fainter (16.91 & 16.55).

BEM9012: The current listing shows identical magnitudes for both components (12.3,12.3). All 2Mass band passes for the system show a ΔM of ~0.3 for the components which is in line with the 0.3 ΔM reflected in our Astrometrica measures (12.19, 12.47). The calculated Vmag values show a slightly wider spread and a slightly dimmer secondary (12.18, 12.64).

BEM9015: The current listing (APASS magnitudes) shows the primary as being 0.6 magnitude dimmer than the secondary (12.61, 12.04). Our Astrometrica measures (12.03, 12.31) and the calculated Vmags (12.12, 12.32) correlate well with the UCAC4 magnitudes (11.97, 12.28) showing the primary brighter with a ΔM for the pair of ~0.3 mag.

BEM9016: The WDS currently shows this to be an equal magnitude pair with no decimal digits (14, 14) which is usually a sign that the magnitudes have not been precisely measured. These values are a significant departure from Bemporad's original 12.5 & 12.8 magnitudes which is surprising since these measures were made from plates taken in 1932, not near the turn of the century as was the case for the majority of the pairs.

The calculated Vmag of the components of 13.55 and 16.11 makes this the faintest of all the pairs and also the pair with the largest ΔM (2.55). The tight separation of 4.1" along with the faint 16 mag secondary made this a difficult target to image with our equipment - the secondary barely registering above the noise floor and makes the Astrometrica generated magnitude of 16.75 for the secondary somewhat suspect. Examination of the photos shows the calculated Vmag value for the secondary (16.11) to be a better fit.

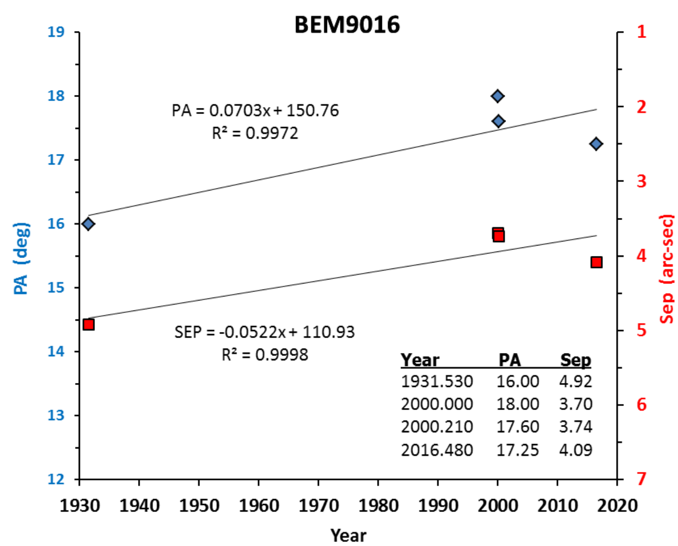

Figure 11. Historical measures of BEM9016.

BEM9018: The current listing is based on APASS magnitudes (10.73, 11.51) ΔM = 0.8. Our Astrometrica measures (10.44, 11.19) correlate well with the UCAC4 magnitudes (10.36, 11.19) showing both components to be slightly brighter (~0.3 mag) also with a ~0.8 ΔM for the pair. The calculated Vmags (10.48, 11.40) roughly correlates with the primary but gives a slightly dimmer value for the secondary.

BEM9020: The WDS currently shows this to be an unequal pair (11.70, 12.20) a ΔM of 0.5. Photos show a nearly equal magnitude pair and the calculated Vmag values yield the nearly equal magnitudes of 12.20 & 12.27. The Astrometrica measures show a slightly brighter primary (12.01, 12.20) with ΔM = 0.2. The PA measurements show a difference of nearly one degree (4.47 vs 3.6) from the 2003 values.

BEM9022AB: The current WDS listing show the AB pair at magnitudes 11.8 & 12.8, a ΔM of 1.0 which is at odds with the visual impression of a more closely matched pair in the photos. The calculated Vmag values and Astrometrica measures correlate well at (12.30, 12.69) and (12.34, 12.78) which makes the primary about 0.5 mag dimmer (ΔM = ~0.4) than currently listed and a better fit to the photos.

BEM9022AC (DAM260): The calculated Vmag and Astrometrica measures show, show the secondary to be a full magnitude dimmer at 15.43 & 15.67 mag than currently listed (14.4). A 5.0 degree difference in the PA value from the previous 2003 measure (197.5 vs 202.56) was noted which at first glance might seem excessive but when plotted seems to fall on the historical trend line (see Figure 12).

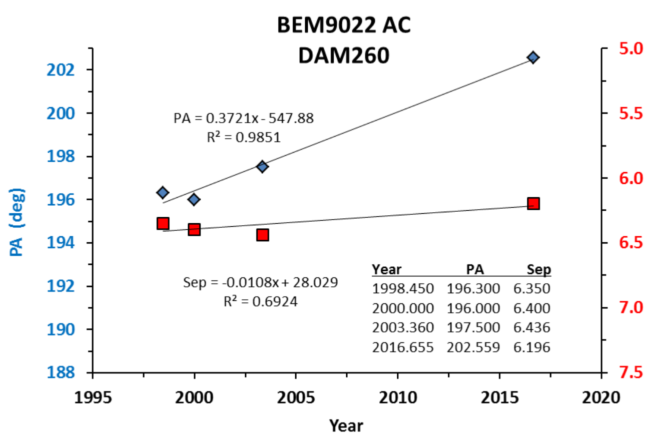

Figure 12. Historical measures of BEM9022AC.

BEM9023: The current WDS magnitudes show the pair to be identical at 11.90. The calculated Vmag values and Astrometrica measures correlate well at (11.89, 12.07) and (11.98, 12.28) a ΔM of ~0.20 magnitude for the pair.

BEM9024 AB: This triple system looks like a mirror image of BEM9022/Dam261 and curiously shows a similarly large (+3.2 Degree) difference in PA (279.2 vs 276) from its previous measure (2003). The plot below shows our measures follow the historical trends for this system. There is good agreement between the current WDS magnitudes (Tycho2) and the Calculated Vmag and Astrometrica measures for both the primary and secondary.

BEM9024 AC (DAM261): The calculated Vmag and Astrometrica measures of the "C" component (14.55, 15.60) straddle the current WDS value of 15.0 (Average = 15.08). Due to the ambiguity of the data the current 15.0 magnitude value appears to be the best fit.

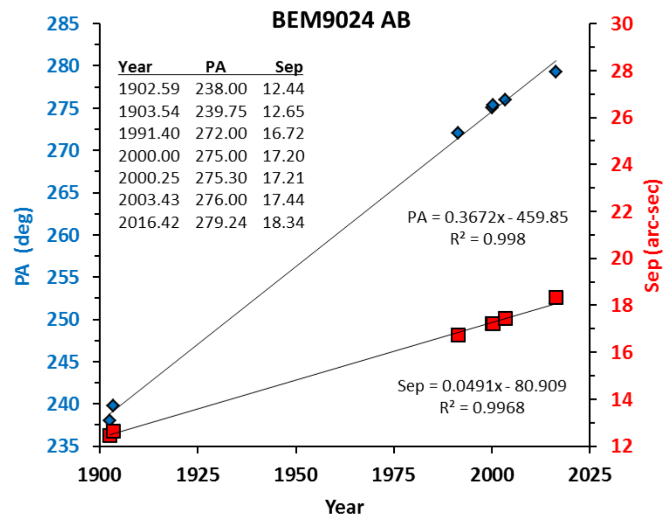

Figure 13. Historical measures of BEM9024.

Acknowledgements

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WDS, Washington Double Star Catalog, Mason,B.D & Hartkopf, W.I., 2013, http://ad.usno.navy.mil/wds/, (Accessed via Aladin and Stelle Doppie)

Resources

Adobe Photoshop Elements, Version: 5.0

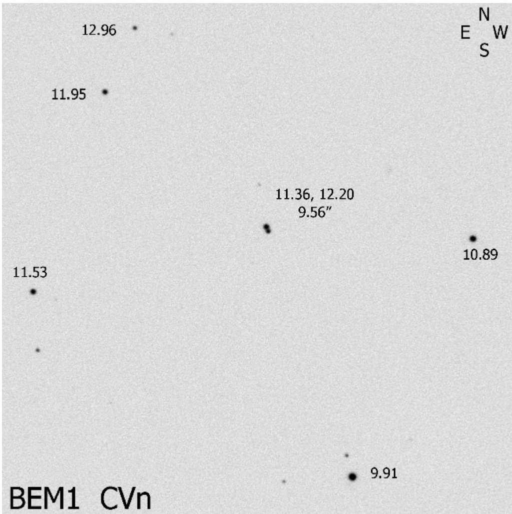
Aladin Sky Atlas, Centre de Donńees Astronomiques de Strasbourg (CDS), v9.010, http://aladin-strasbg.fr

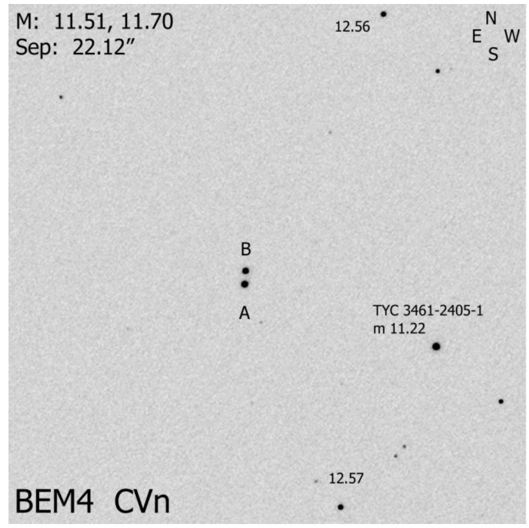
Astrometrica, Version 4.9.1.420, Herbert Raab, http://astrometrica.at

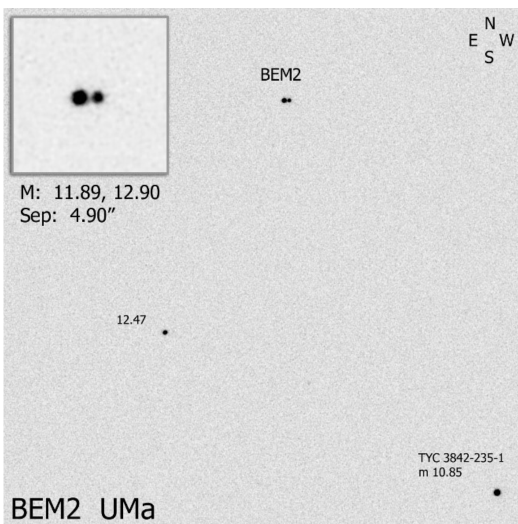
PixInsight, Pleiades Astrophoto, Version 01.08.04.1195 Ripley (x64).

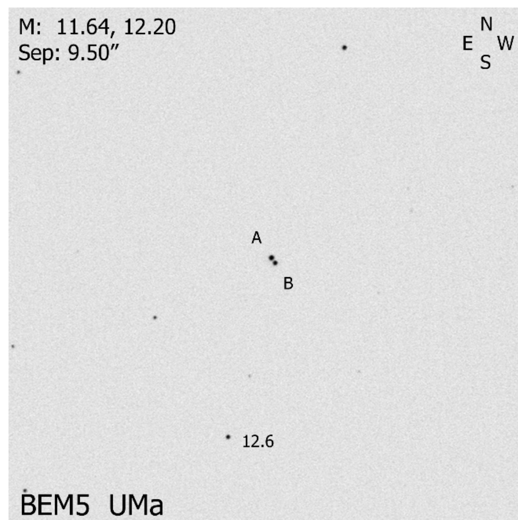
Stelle Doppie, WDS Interface, version 2.1. http://stelledoppie.goaction.it

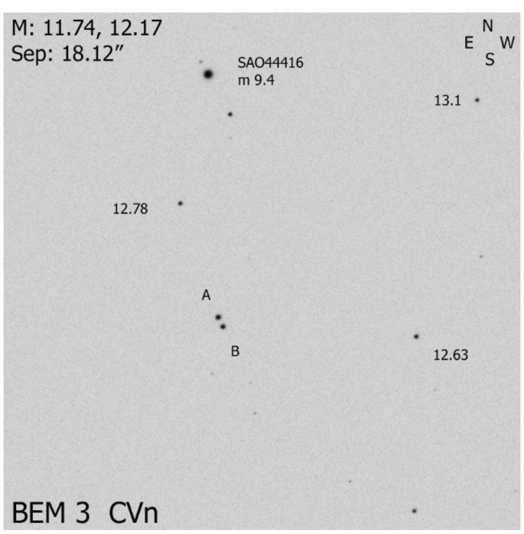
Appendix 1: Photo Gallery of all Bemporad (BEM) Double Stars

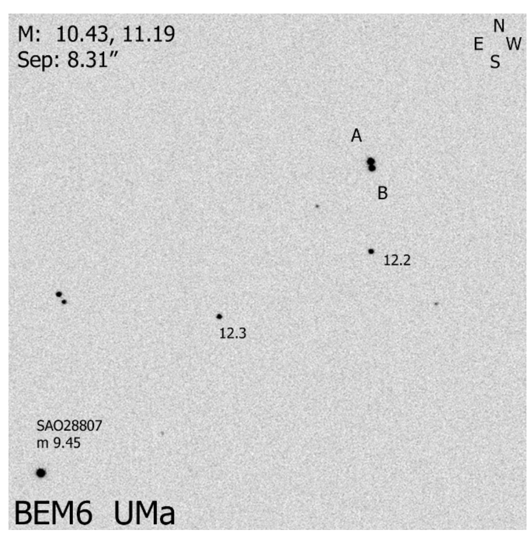












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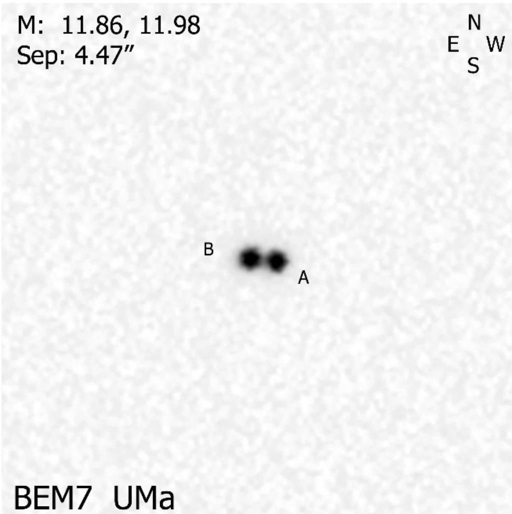

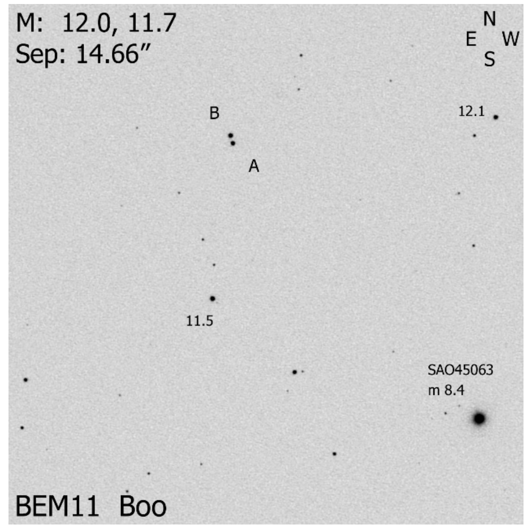

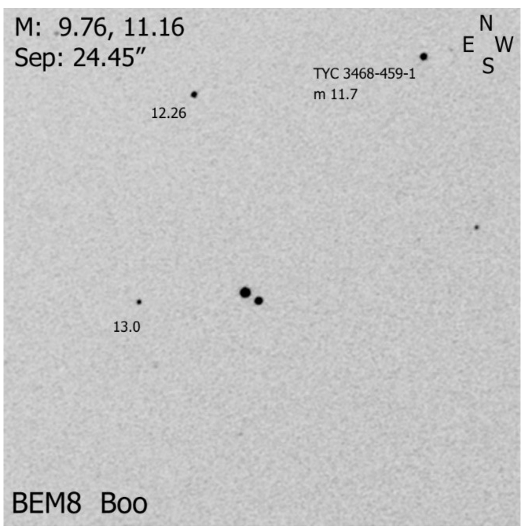

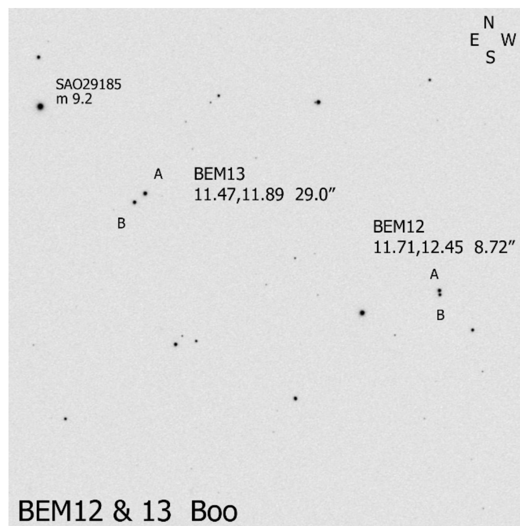

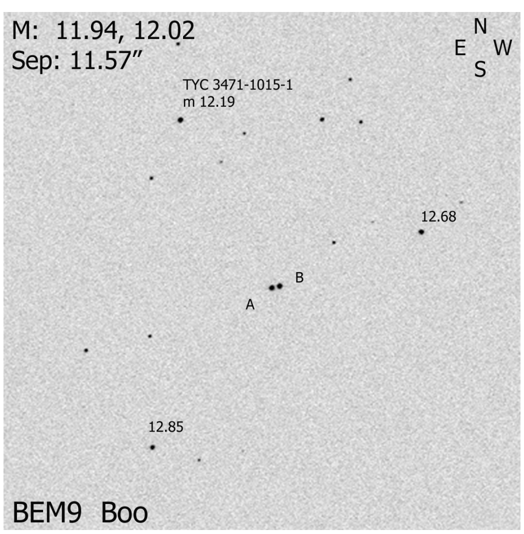

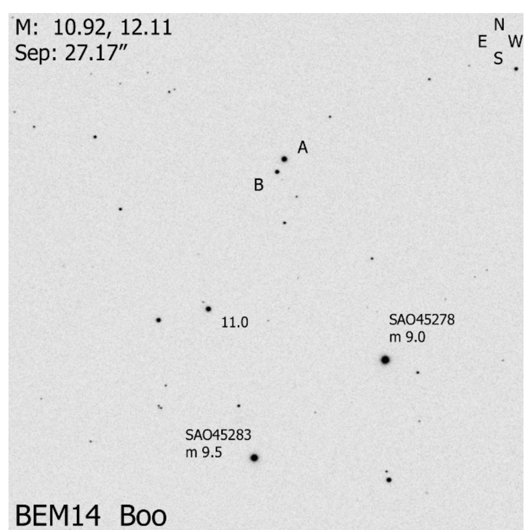

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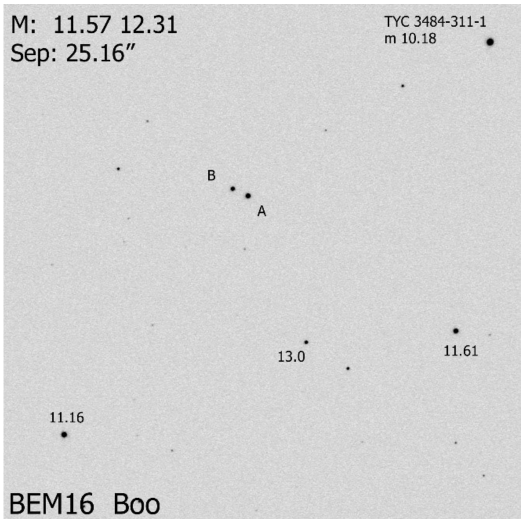

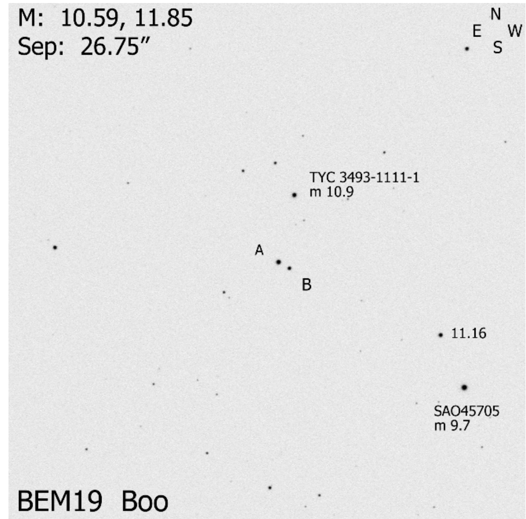

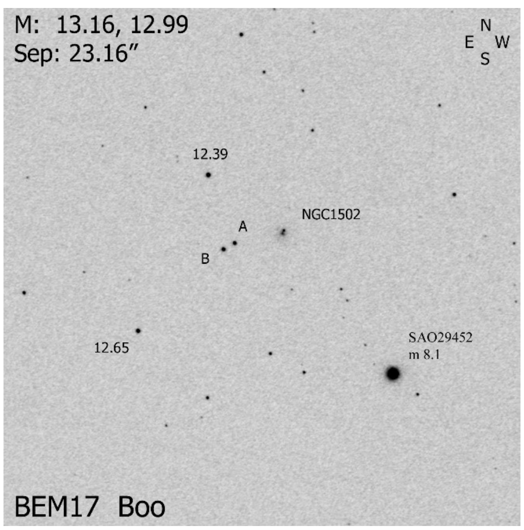

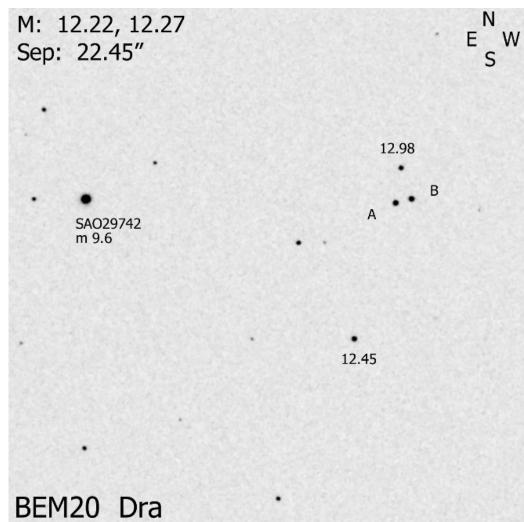

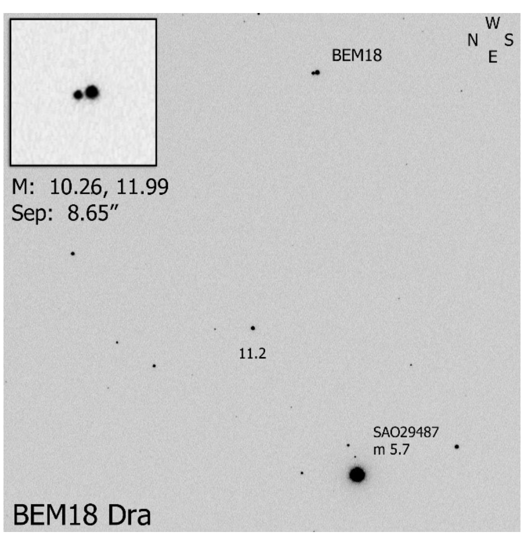

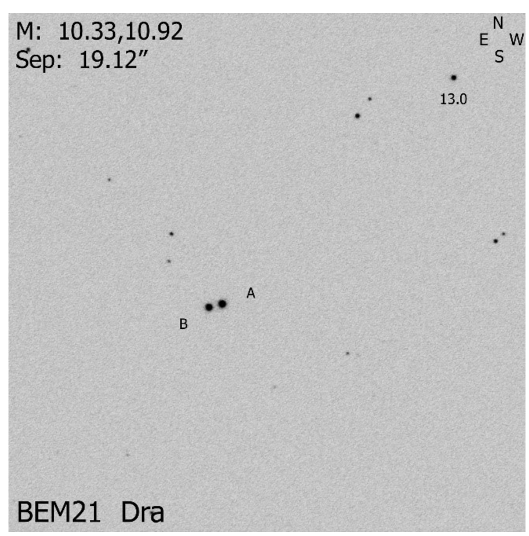

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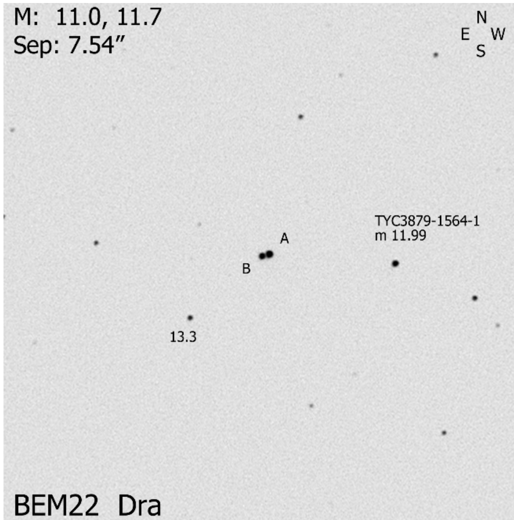

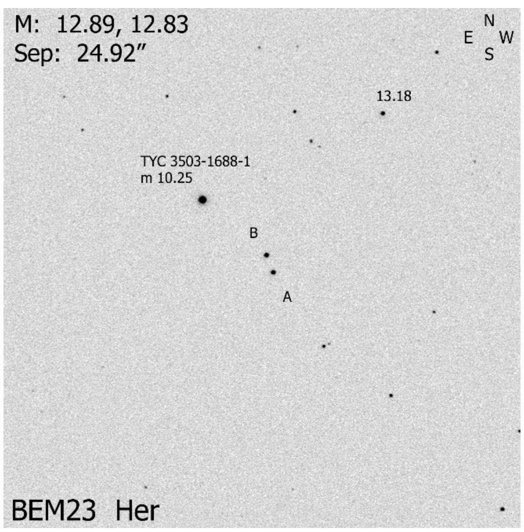

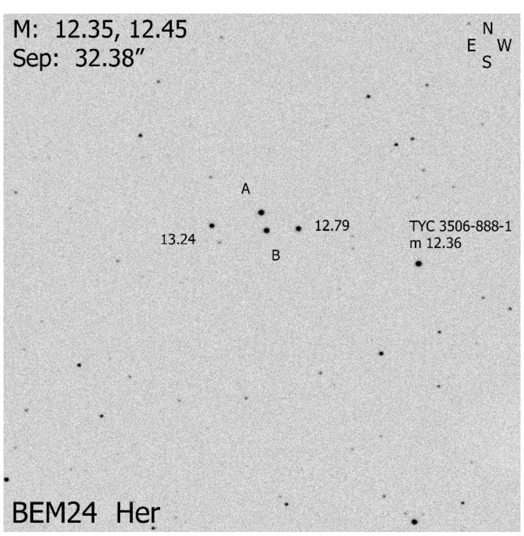

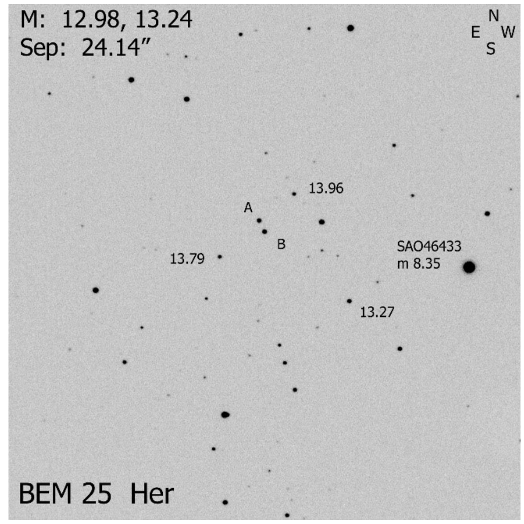

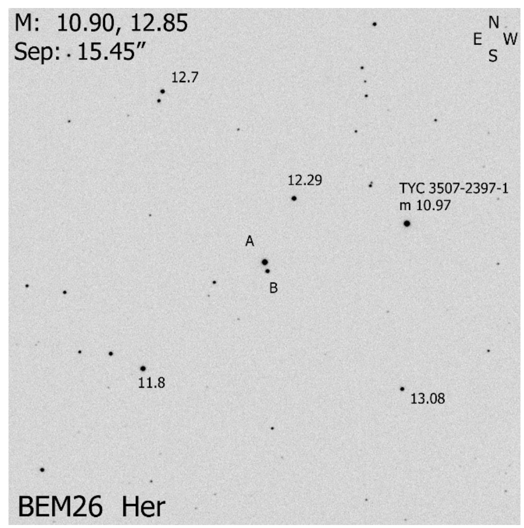

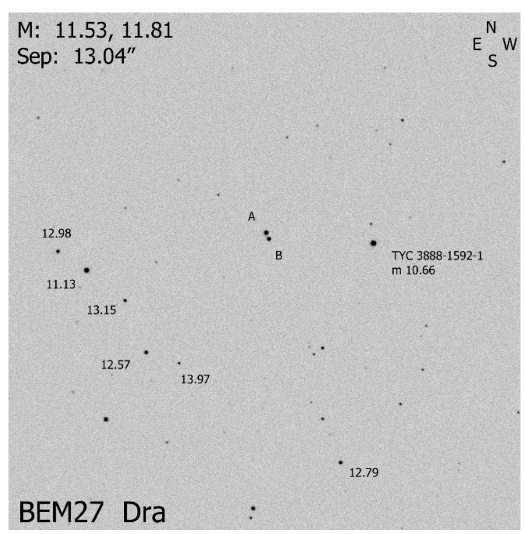

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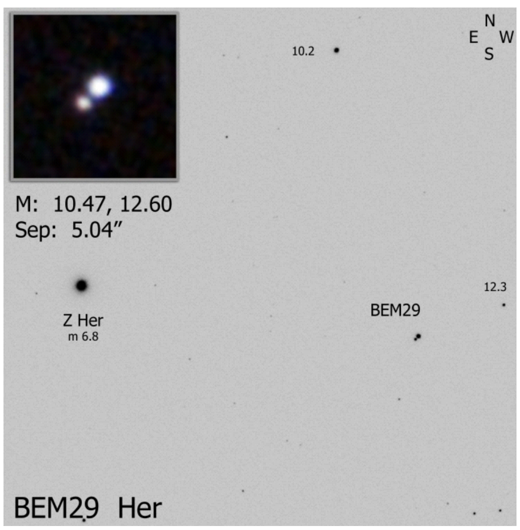

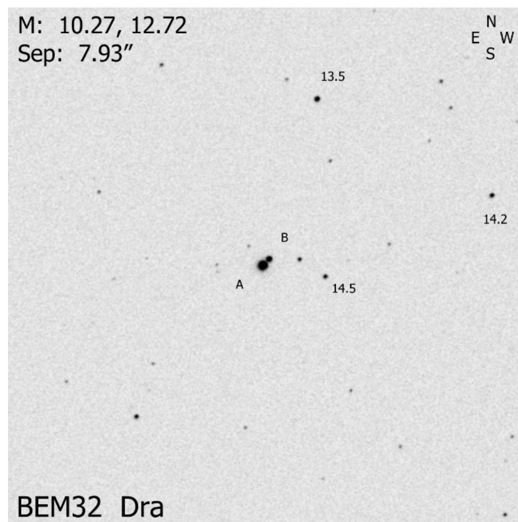

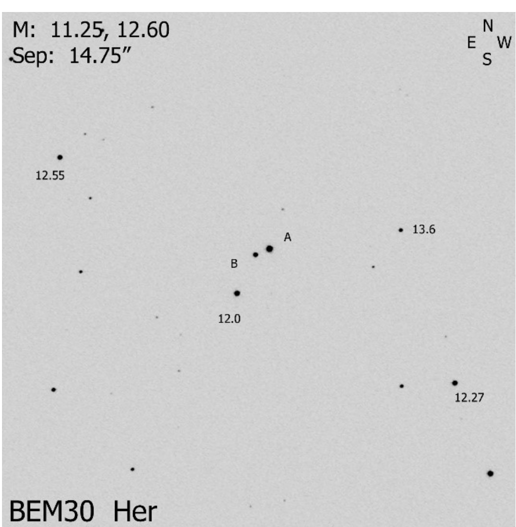

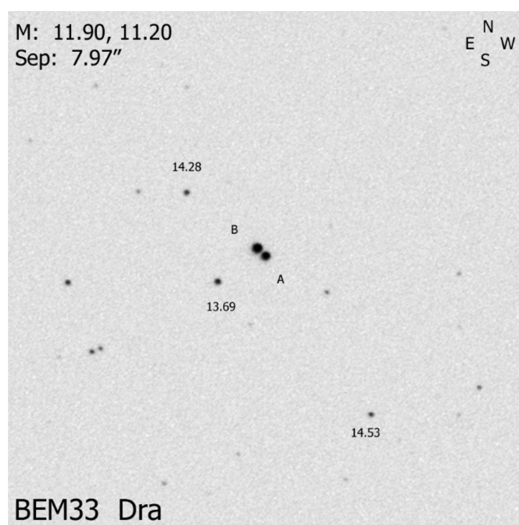

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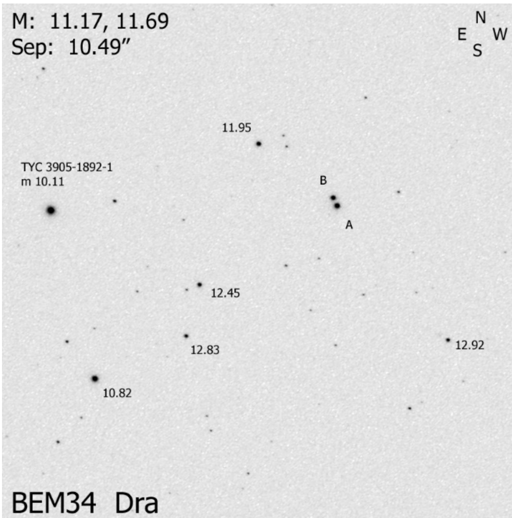

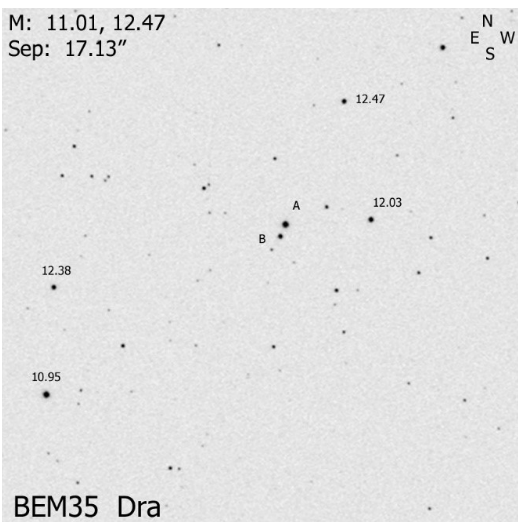

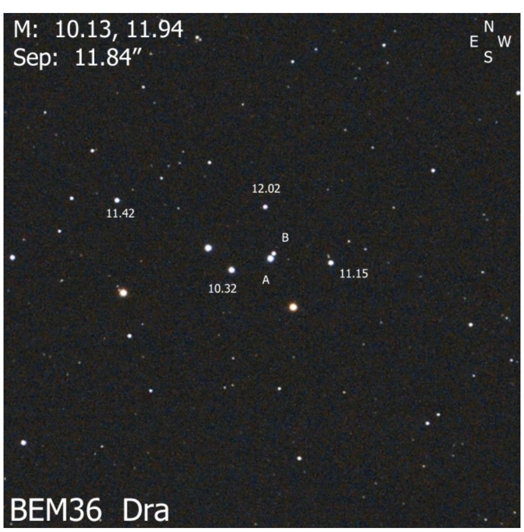

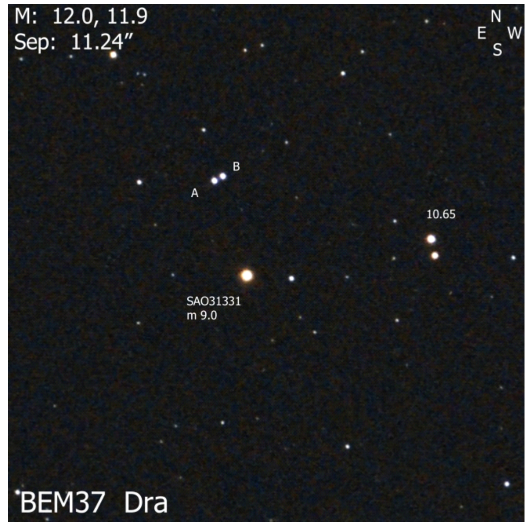

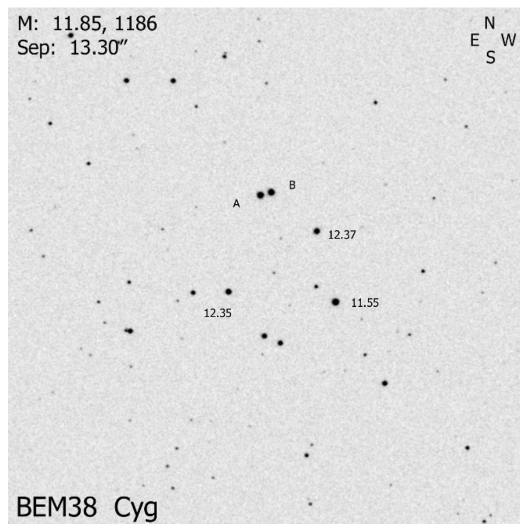

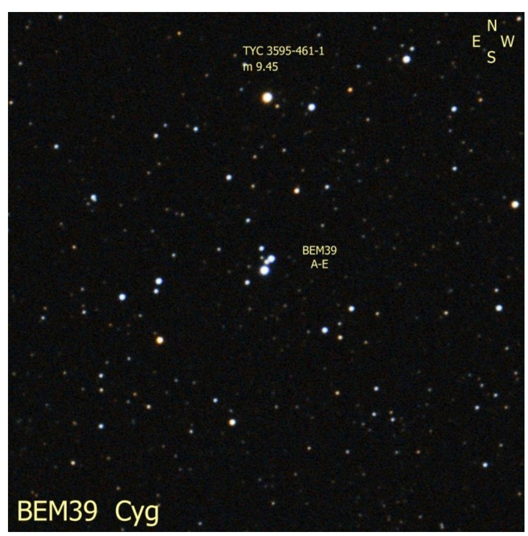

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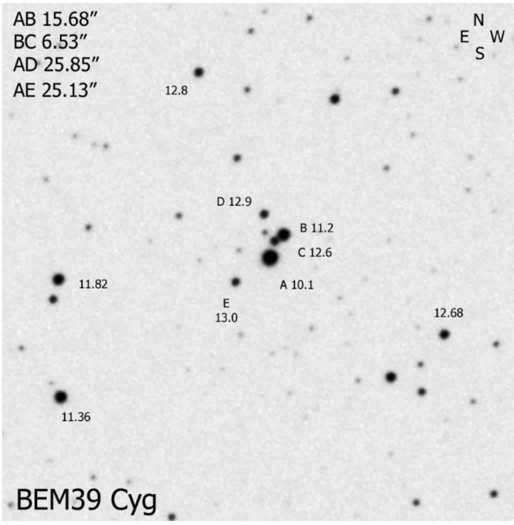
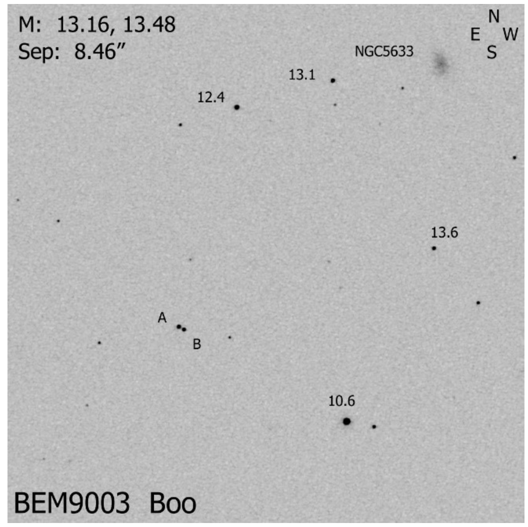
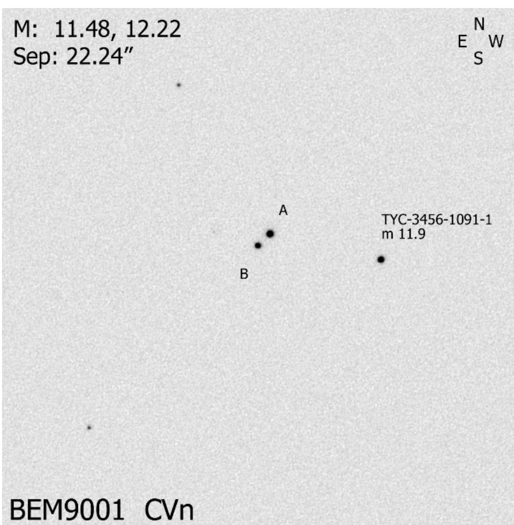
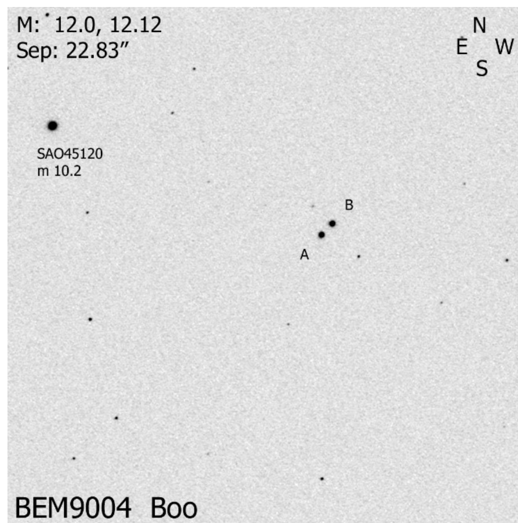
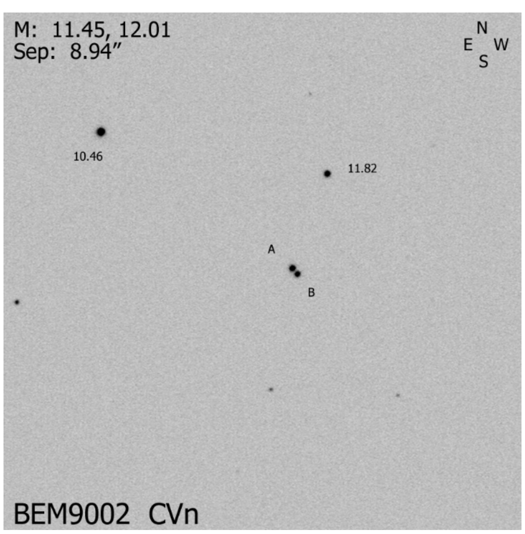
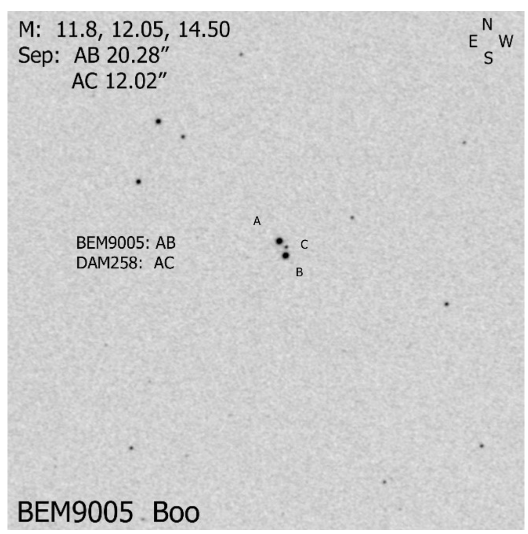




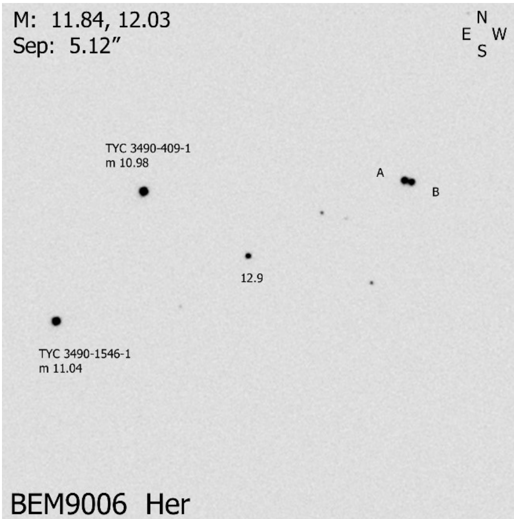


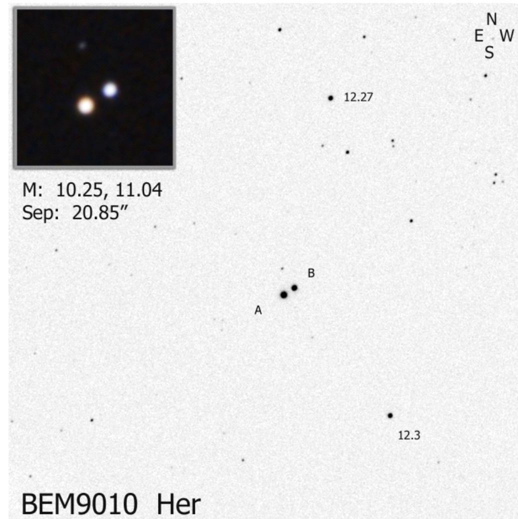


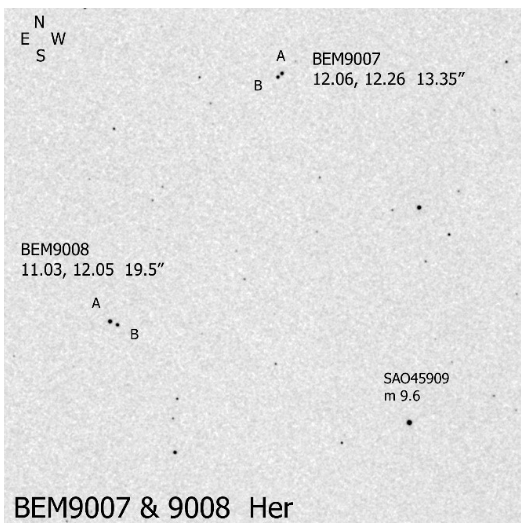


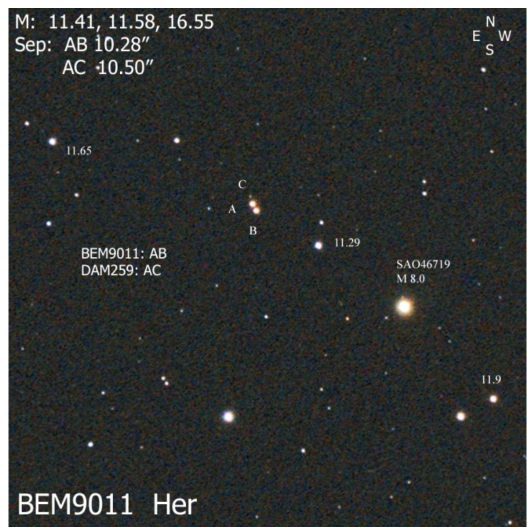


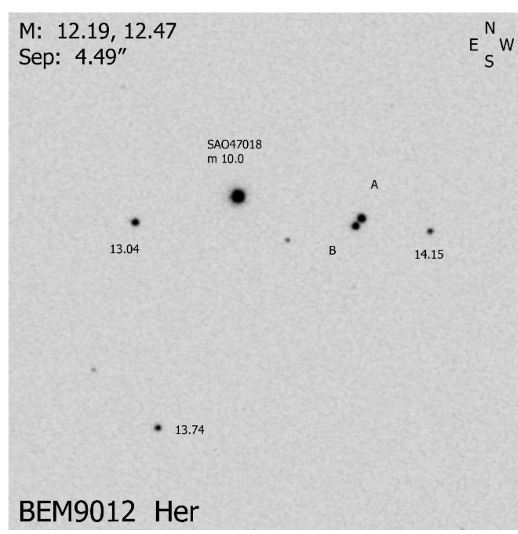
Azeglio Bemporad and the "BEM" Double Stars











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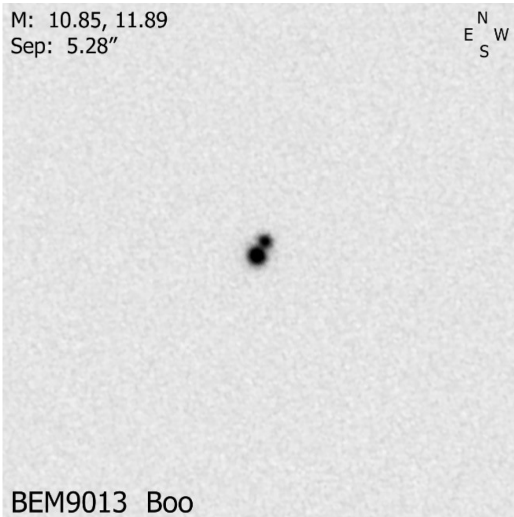
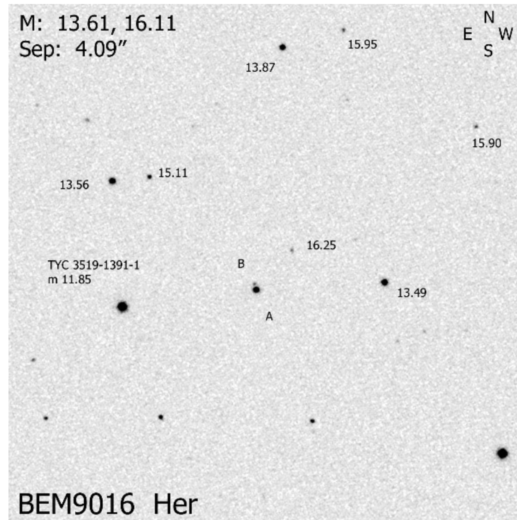
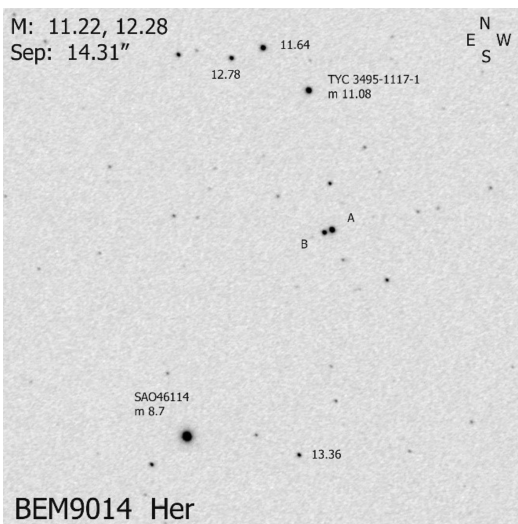
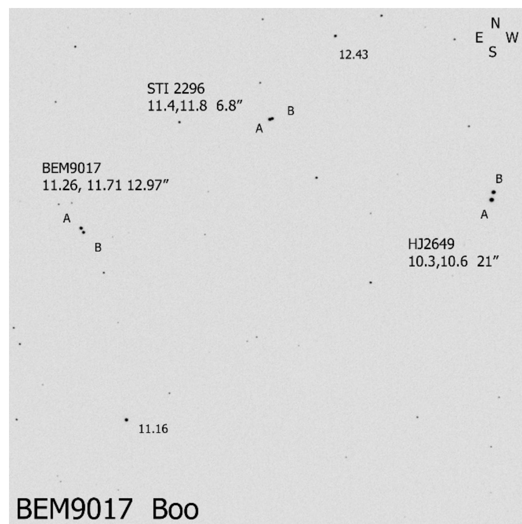
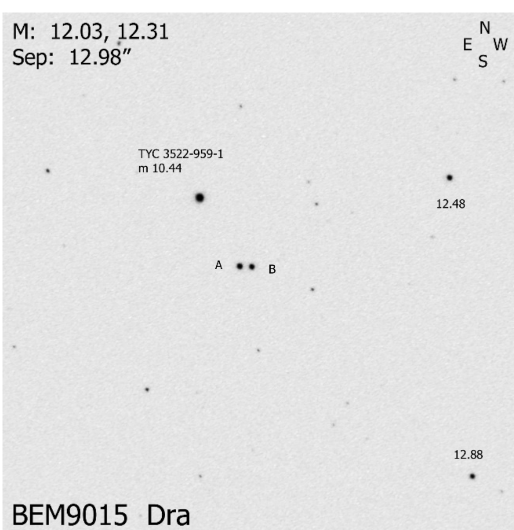
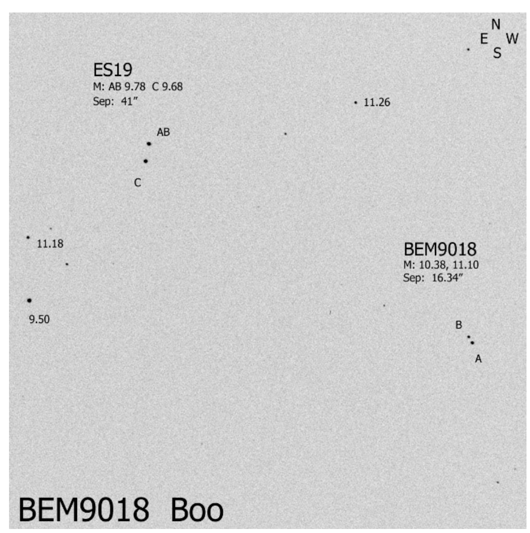




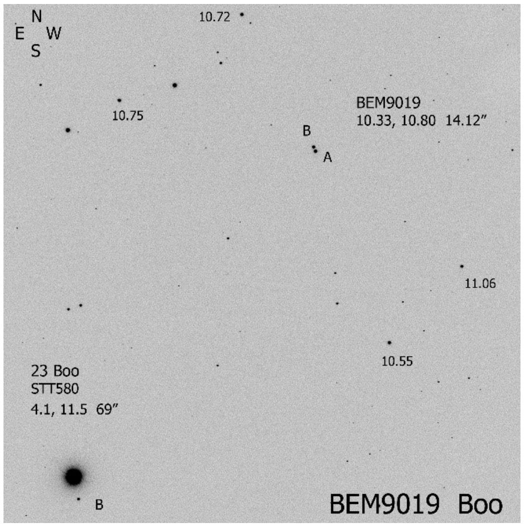


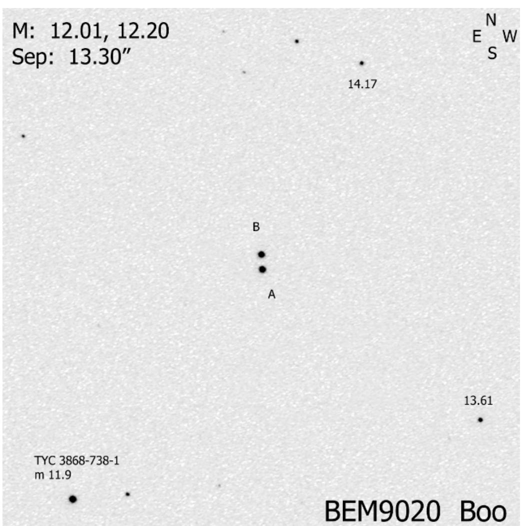


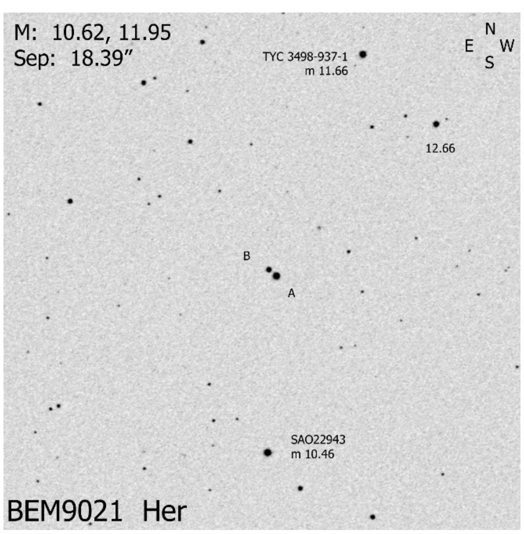


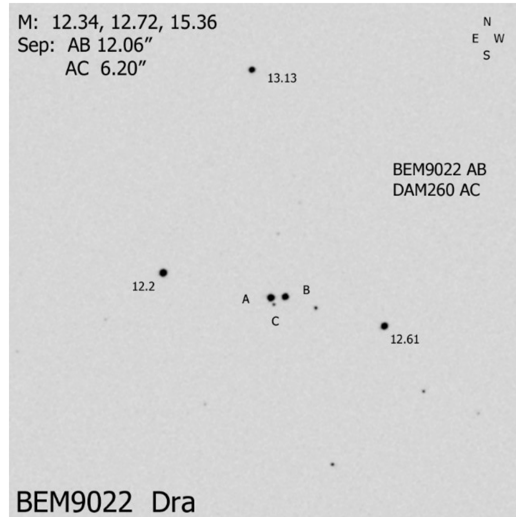


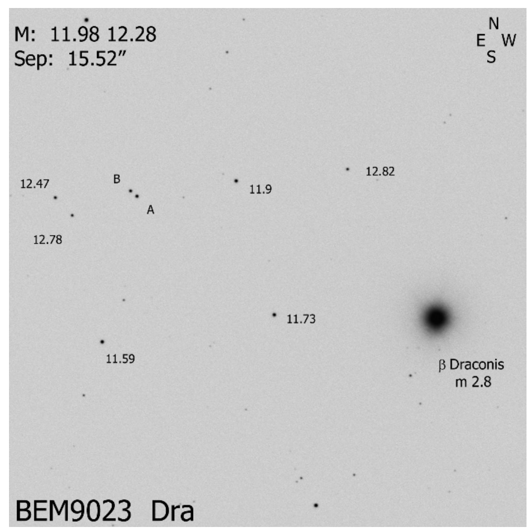
Azeglio Bemporad and the "BEM" Double Stars

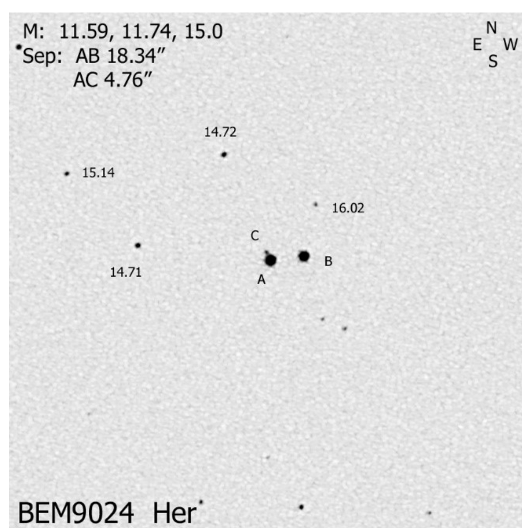












Azeglio Bemporad and the "BEM" Double Stars

Appendix 2: Bemporad Double Star Publications

The following pages contain scanned images of the publications detailing Bemporad's measurements of previously cataloged pairs along with measures of his own double star discoveries in the course of his work on the Astrographic Catalog. All of Bemporad's doubles were published in four *Astronomische Nachrichten* (Astronomical News) journals with the exception of BEM39 which was published in *"Contributi Astrofisici No. 42, 1938"*.

The **Red** annotations have been added to show the BEM Catalog numbers for the pairs that have been incorporated into the Washington Double Star Catalog. It is evident that the sequential BEM numbers do not strictly follow the chronological order of the publications which have been arranged herein to best follow the BEM numbering sequence.

It is clear from the annotations that not all of Bemporad's "discoveries" were incorporated into the catalog. For many of these entries no likely or plausible match can be found at or near the reported locations or the reported pair had been previously cataloged.

Astronomische Nachrichten, Volume 254, Issue 3, 03/1934, p.37 & 38

Misure di stelle doppie

eseguite nel corso dei calcoli per il Catalogo Astrografico di Catania. Da *A. Bemporad*.

Con riferimento alle precedenti comunicazioni col medesimo titolo in AN **244**, Nr. 5850; AN **246**, Nr. 5882; AN **248**, Nr. 5930 comunichiamo le coordinate approssimate (1900.0) e gli elementi ricavati per 60 doppie misurate sulle lastre in corso di stampa del Catalogo Astrografico (da +49° a +54° fra 12^h e 19^h A.R.).

Sono segnati in corsivo gli elementi desunti dal Burnham (General Catalogue, 1906).

	Burnham	α δ 1900.0	Angolo di posiz.	Distanza	Grandezze	Epoca	Lastra No.	Note
1		$12^h39^m21^s$ +50° 23'.5	202°.5	9".43	$12^m.0$, $11^m.3$	1899.32	923	(1)
			200.0	8.40	12.2, 11.6	1904.26	2383	
3		12 55 2 +49 32.6	220.2	20.14	11.9, 11.8	1902.36	1548	
			215.3	19.24	12.0, 11.9	1904.34	2441	
4		13 3 24 +50 26.8	21.8	21.21	11.2, 11.8	1904.29	2439	
			22.2	21.25	11.4, 11.9	1904.34	2441	
	6604	13 39 0 +50 31.9	*125.7*	*40 ±*	*8.5, 10*	*1830 +*	—	H
			129.8	26.57	8.7, 11.1	1904.29	2447	
			125.5	29.40	8.2, 11.0	1905.33	2602	
7		14 1 20 +49 42.3	85.9	2.03	11.6, 11.7	1902.36	1552	
			82.0	2.58	11.6, 11.7	1904.34	2449	
8		14 8 3 +50 14.2	241.4	24.91	11.2, 10.0	1905.33	2600	
			241.4	24.90	11.1, 10.0	1924.41	4004	
9		14 9 30 +50 59.3	283.7	11.16	12.0, 12.0	1905.33	2600	
			289.2	11.53	12.0, 12.0	1905.40	2612	
			284.0	11.49	12.0, 11.9	1924.41	4004	
	6778	14 9 54 +52 15.5	*237.7*	*12.60*	*7.2, 5.1*	*1832.50*	—	Σ 7
		(κ Bootis)	237.7	13.36	7.8, 5.6	1901.33	1350	(2)
			236.8	13.22	7.2, 5.0	1905.40	2612	
10		14 11 33 +51 16.1	273.8	13.49	12.1, 11.6	1924.41	4004	
	6802	14 12 37 +51 49.7	*33.2*	*38.05*	*4.9, 7.5*	*1836.22*	—	Σ 4
		(ι Bootis)	32.9	37.72	4.9, 8.9	1905.23	2608	(3)
			32.2	37.86	5.2, 9.3	1905.40	2612	
			31.6	37.22	5.1, 9.6	1924.41	4004	
	6813	14 14 6 +49 12.9	*321.8*	*23.67*	*8.6, 8.4*	*1892.17*	—	β 4
			321.1	23.83	9.7, 9.2	1902.35	1569	
			320.3	24.13	9.8, 9.2	1905.33	2600	
11		$14^h24^m59^s$ +49° 59'.2	196°.2	14".93	$11^m.9$, $11^m.8$	1904.34	2443	
			200.7	12.95	12.2, 11.9	1904.44	2532	
12		14 26 59 +50 39.7	185.9	8.63	11.9, 11.5	1898.37	604	(4)
			182.9	8.01	12.0, 11.6	1904.34	2443	
13		14 28 4 +50 42.7	119.4	27.24	11.2, 11.6	1898.37	604	
			120.2	27.95	11.5, 11.9	1904.34	2443	
	6963	14 36 48 +49 8.2	*106.3*	*6.98*	*7.2, 11.2*	*1848.19*	—	OΣ3
			104.0	6.53	8.0, 11.6	1897.34	319	(5)
			101.7	7.21	7.9, 12.0	1905.44	2617	
	6982	14 38 40 +49 33.1	*288.4*	*25.73*	*9.2, 7.7*	*1830.65*	—	Σ 2
			288.1	25.67	9.9, 9.4	1897.34	319	(6)
			288.0	26.32	9.9, 9.5	1905.34	2617	
	7032	14 46 18 +51 47.3	89.2	15.06	7.1, 10.5	1902.38	1580	Σ
			90.2	16.09	7.0, 10.3	1904.29	2474	
	7063	14 51 31 +51 2.7	*139.0*	*25.03*	*9.1, 9.4*	*1900.43*		Es 2
			136.6	25.11	10.0, 11.6	1902.37	1565	
14		14 52 31 +49 38.4	153.6	23.91	10.4, 11.7	1902.37	1565	
			151.5	24.55	10.8, 11.6	1904.35	2531	
15?		15 4 27 +51 18.9	64.5	5.30	10.4, 11.5	1930.48	4034	
16		15 6 30 +50 4.7	65.4	24.40	11.9, 12.2	1930.48	4034	
		15 11 27 +50 41.5	298.3	23.36	12.1, 11.9	1930.48	4034	
17		15 11 45 +51 9.8	38.7	7.07	10.7, 11.1	1904.49	2519	(7)
			41.2	6.61	11.0, 11.2	1930.48	4034	
	7291	15 25 19 +50 0.2	*226.0*	*12 ±*	*13 9*	*1830 +*		H
			228.7	17.42	11.6, 9.9	1898.39	609	
			234.1	17.80	11.5, 10.3	1903.50	2093	
			232.0	19.11	11.7, 10.3	1904.42	2463	
	—	15 37 58 +50 28.0	278.3	8.06	11.0, 10.9	1903.50	2100	
			273.6	8.21	11.2, 11.2	1904.46	2525	
19		15 42 20 +49 24.9	232.8	28.01	11.5, 10.5	1903.50	2099	
			233.8	27.85	11.6, 10.6	1903.50	2100	
			232.9	27.50	11.2, 10.4	1905.40	2611	
20		15 56 28 +51 27.0	280.8	21.36	12.3, 12.2	1903.49	2136	
			280.6	21.39	12.2, 12.1	1904.50	2522	
21		16 0 16 +51 28.2	103.4	17.86	11.3, 12.2	1903.49	2136	
			103.6	17.76	11.4, 12.0	1904.50	2522	

3*

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Burnham	α (1900.0)	δ (1900.0)	Angolo di posiz.	Distanza	Grandezze	Epoca	Lastra No.	Note
23	$16^h54^m33^s$	$+49°12'.5$	23°.4	25".17	$13^m.2$, $13^m.5$	1931.51	4053	
24	16 57 40	+50 49.8	200.5	27.85	13.1, 12.8	1931.51	4053	
25	16 58 19	+49 37.9	26.7	24.05	13.1, 13.5	1931.51	4053	
7894	17 5 50	+50 58.1	*274.0*	*17.0*	*11.8, 6.6*	*1901*	—	Es
			278.2	19.00	12.6, 6.4	1902.47	1625	
			271.6	18.04	12.2, 6.5	1903.48	2140	
			264.9	18.79	12.6, 7.3	1931.51	4053	
26	17 6 7	+50 30.3	194.1	14.96	12.6, 11.3	1902.47	1625	(8)
			199.4	15.23	12.5, 11.1	1903.48	2140	
			198.1	15.39	13.1, 11.0	1931.51	4053	
7895	17 6 9	+49 53.0	*201.8*	*3.31*	*10.5, 9.0*	*1830.63*	—	Σ3
			204.5	2.47	11.0, 10.0	1902.47	1625	
			211.9	3.11	10.8, 9.8	1902.51	1713	
			211.9	3.11	11.2, 10.0	1931.51	4053	
7909	17 9 7	+49 51.9	*116.3*	*5.33*	*6.2, 10.0*	*1830.14*	—	Σ3
			104.1	3.92	6.8, 8.7	1902.47	1625	(9)
—	17 21 52	+49 36.8	223.3	18.39	10.9, 8.1	1901.47	1370	Σ
			222.5	18.83	10.6, 8.5	1902.50	1643	
8026	17 23 8	+51 34.8	67.1	5.04	9.5, 11.7	1902.48	1623	
			59.2	3.44	9.2, 11.7	1902.56	1764	
			62.5	*4.21*	*8.0, 11.0*	*1904.36*	—	Hu
8057	17 26 34	+50 56.9	*265.3*	*3.17*	*7.2, 7.0*	*1831.29*	—	Σ6
			256.9	4.31	8.3, 7.2	1902.50	1643	
			258.6	3.25	8.0, 7.6	1902.56	1764	
27	17 29 42	+53 53.0	204.8	12.88	12.0, 11.7	1902.47	1640	
			205.1	12.73	12.0, 11.9	1902.52	1683	
8073	17 30 9	+47 57.5	*100.0*	*21.07*	*7.9, 10.3*	*1901.39*	—	β3
			100.8	21.18	7.9, 12.5	1901.48	1368	
—	17 34 10	+54 29.0	296.8	3.89	11.2, 11.0	1902.52	1683	
—	17 38 13	+54 15.8	199.3	1.88	11.7, 10.7	1902.52	1683	
			188.2	*2.57*	— —	*1908.53*	—	Es
8167	17 42 53	+51 59.2	*342.8*	*4.82*	*11.6, 8.4*	*1868.85*	—	Δ4
			334.1	4.21	12.2, 10.3	1902.45	1693	(10)
			342.7	5.61	12.2, 10.3	1931.53	4054	
30	17 48 46	+50 7.8	111.7	12.70	12.1, 12.4	1902.59	1784	
			108.5	13.27	12.2, 12.9	1931.53	4054	
8297	17 55 50	+52 13.6	*262.5*	*9.21*	*9.5, 7.5*	*1829.80*		Σ2
			261.9	9.89	10.5, 8.2	1902.56	1721	d
			262.0	9.84	10.8, 7.0	1902.59	1772	
—	17 57 51	+53 16.4	339.8	3.96	11.5, 10.5	1902.56	1721	(11)
			340.4	3.74	11.3, 10.3	1902.59	1783	
8320	17 58 7	+52 51.3	*262.3*	*1.88*	*8.3, 7.3*	*1831.48*	—	Σ3
			256.0	1.96	8.0, 8.9	1902.56	1721	
—	17 58 46	+54 52.7	74.6	8.06	9.3, 11.2	1902.59	1783	
31	18 7 34	+53 28.3	304.3	12.96	11.4, 10.9	1902.47	1635	
			305.0	13.05	11.5, 10.4	1902.50	1708	
—	18 8 58	+53 28.1	242.1	16.35	11.0, 10.4	1902.47	1635	
			241.4	16.25	10.8, 10.2	1902.50	1708	
32	18 19 56	+53 33.1	317.6	7.94	11.5, 10.3	1902.55	1736	
			321.2	7.96	11.5, 10.8	1902.60	1763	
33	18 22 16	+53 28.5	221.8	11.12	11.1, 10.2	1902.55	1736	
			224.1	9.61	11.5, 10.7	1902.60	1763	
34	18 32 11	+52 34.7	31.5	10.29	10.8, 11.2	1902.58	1770	(12)
			30.4	10.79	11.0, 11.5	1907.59	2722	
35	18 48 51	+52 2.6	160.6	15.27	10.7, 11.6	1897.51	382	
			162.4	16.47	11.0, 11.8	1902.55	1738	

Burnham	α (1900.0)	δ (1900.0)	Angolo di posiz.	Distanza	Grandezze	Epoca	Lastra No.	Note
36	$18^h56^m18^s$	$+52°58'.8$	343°.6	10".45	$11^m.5$, $10^m.4$	1897.51	382	
37	18 59 11	+53 19.1	280.4	9.93	11.2, 11.1	1897.51	382	
			290.4	9.77	11.4, 11.4	1902.47	1637	
			285.1	10.39	10.8, 10.8	1902.59	1780	
38	19 6 42	+53 22.2	103.9	13.82	11.0, 11.0	1901.61	1436	
			103.1	13.69	11.3, 11.3	1902.47	1637	
—	19 23 48	+53 57.1	104.7	11.86	9.7, 9.9	1901.59	1400	
			108.0	11.99	10.8, 10.9	1901.60	1423	
			107.4	12.54	11.0, 11.0	1902.60	1750	
9411	19 29 33	+52 46.2	*254.1*	*11.31*	*8.7, 8.2*	*1830.85*	—	Σ2
			253.0	12.34	10.4, 8.8	1902.46	1579	
			252.2	11.43	9.4, 8.7	1902.60	1750	
—	19 35 54	+51 57.5	183.4	7.81	10.5, 10.1	1899.60	1011	(13)
			184.7	7.93	10.8, 10.6	1902.45	1614	
			186.3	8.45	10.3, 10.1	1902.59	1703	
			187.2	7.11	11.1, 10.3	1902.62	1750	(14)

Note.

(1) Mediante eliminazione della differenza sistematica risultante per le due lastre da 10 stelle in zona (−0ˢ.221, +0".016) si ottengono le posizioni e i MP seguenti:

		α (1900.0)	δ	μ_α	μ_δ
Prec.	L 923	$12^h39^m20^s.30$	$+50°23'22".2$	−0ˢ.0020	−0".081
	L 2383	20.29	21.8		
Seg.	L 923	12 39 20.68	+50 23 31.0	−0.0182	−0.283
	L 2383	20.59	29.6		

(2) Dalle posizioni di AG Cbr M. ridotte al sistema di Yale mediante le correzioni −0ˢ.144 +0".8 ricavate da 10 stelle in zona si ottengono le posizioni e i MP seguenti:

	α (1900.0)	δ	Ep.
Cbr M. 4464	$14^h\ 9^m52^s.59$	$+52°15'21".20$	1871.4
CA	52.91	20.75	1903.4

μ_α	μ_δ	Boss	
+0ˢ.0100	−0".014	+0ˢ.0062	−0".032

	α (1900.0)	δ	Ep.
Cbr M. 4465	$14^h\ 9^m53^s.81$	$+52°15'27".60$	1871.4
CA	54.13	27.60	1903.4

μ_α	μ_δ	Boss	
+0ˢ.0100	0".000	+0ˢ.0072	−0".015

(3) Dalle posizioni di AG Cbr M. ridotte al sistema di Yale mediante le correzioni −0ˢ.139 +0".25 ricavate da 10 stelle in zona si ottengono le posizioni e i MP seguenti:

	α (1900.0)	δ	Ep.
Cbr M. 4480	$14^h12^m37^s.771$	$+51°49'40".55$	1875.0
CA	37.40	43.7	1905.4

μ_α	μ_δ	Boss	
−0ˢ.0122	+0".104	−0ˢ.0157	+0".086

	α (1900.0)	δ	Ep.
Cbr M. 4481	$14^h12^m40^s.071$	$+51°50'12".75$	1875.0
CA	39.65	15.6	1905.4

μ_α	μ_δ	Boss	
−0ˢ.0138	+0".094	—	—

(4) Previa riduzione della L 2443 al sistema di Yale mediante le correzioni −0ˢ.146 +0".74 ricavate da 10 stelle in

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zona si sono ottenuti per le due componenti i seguenti MP:

	μ_α	μ_δ
Prec.	$-0^s.0017$	$-0''.017$
Seg.	-0.0100	-0.117

(5) Previa riduzione sistematica della L 319 alla L 2617 mediante le correzioni $-0^s.067$ $+1''.81$ ricavate da 10 stelle in zona si sono ottenuti per le due componenti i seguenti MP:

	μ_α	μ_δ
Prec.	$-0^s.0185$	$-0''.148$
Seg.	-0.0086	-0.111

(6) Previa riduzione sistematica fra le due lastre sono state determinate le seguenti componenti del MP:

	μ_α	μ_δ
Prec.	$-0^s.0075$	$-0''.025$
Seg.	-0.0137	0.000

(7) Previa riduzione sistematica della L 2519 alla L 4034 mediante 10 stelle in zona ($-0^s.013$ $+0''.19$) sono state determinate le componenti del MP:

	μ_α	μ_δ
Prec.	$+0^s.0042$	$+0''.004$
Seg.	$+0.0046$	-0.019

Catania, R. Osservatorio astrofisico, 1934 Agosto.

(8)

	μ_α	μ_δ
Prec.	$+0^s.0021$	$+0''.003$
Seg.	$+0.0011$	-0.002

(9) Forte scarto G2.

(10) Dalla L 1693, previa riduzione alla L 4053 mediante dieci stelle in zona ($+0^s.012$, $-0''.25$) si sono ottenute le posizioni seguenti, accanto alle quali riportiamo le corrispondenti della L 4054.

	Precedente ($12^m.2$)		Seguente ($10^m.3$)	
L 1693	$17^h42^m52^s.96$	$+51°59'17''.3$	$17^h42^m53^s.14$	$+51°59'13''.5$
L 4054	52.95	19.5	53.13	14.2
Δ	-0.01	$+2.2$	-0.01	$+0.7$

L 1693 Ep. 1902.45, L 4054 Ep. 1931.53.

Probabilmente binaria.

(11) Nuove misure +34.441, +16.838; +34.468, +16.767.

(12)

	μ_α	μ_δ
Prec.	$+0^s.0160$	$-0''.120$
Seg.	$+0.0220$	-0.020

(13)

Prec.	$-0^s.0200$	$+0''.100$
Seg.	-0.0067	$+0.100$

(14) Nuove misure: +54.556 −61.935; +54.568 −61.817.

A. Bemporad.

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Misure di stelle doppie eseguite nel corso dei calcoli per il Catalogo Astrografico di Catania. Da *A. Bemporad.*

Alle misure di stelle doppie rilevate dalle negative per il Catalogo Astrografico è di ostacolo, in generale, il fenomeno della irradiazione, per cui le misure stesse riescono tanto più difficili quanto più lucide sono le stelle. Mentre intorno alla 11ª grandezza, con immagini nitide, è facile risolvere doppie con distanza dell'ordine di 1″, per stelle intorno alla 9ª riesce difficile separare immagini distanti anche 3″. Malgrado questa grave limitazione del metodo fotografico ci è riuscito di separare quasi tutte le immagini di stelle doppie contenute per le zone +47° e +48° nel Catalogo di Burnham[1]). Si aggiungono le misure di 17 doppie, in generale assai deboli, non contenute nel detto catalogo.

Nell'elenco che segue ci limitiamo a riportare i dati essenziali delle misure eseguite sulle doppie in questione: le posizioni esatte delle singole componenti (RA. e Decl.) si potranno desumere dalle zone del Catalogo in corso di stampa (zone +47° e +48° fra 12^h e 18^h di RA.). I valori desunti da Burnham per confronto sono scritti in corsivo.

Burnham	α	δ	Angolo di posizio.	Distanza	Grandezze	Epoca	Lastra No.	Note
—	$12^h\ 5^m\ 3^s$	47° 9′	34°.9	5″.81	10.8, 11.3	1903.25	2107	
			32.1	5.63	10.6, 11.2	1903.25	2116	
			55.8	7.22	10.9, 11.5	1904.25	2437	
6073	12 7 19	46 52	223.2	23.64	11.2, 12.2	1904.25	2437	
			228.3	*25 ±*	*9.10, 10*	*1830 +*		
9001	12 24 37	47 35	130.4	20.74	11.9, 12.2	1902.30	1539	
			133.7	20.65	11.7, 12.1	1903.23	2034	
			134.3	20.05	11.8, 12.3	1904.27	2390	
6321	12 52 10	46 9	352.8	12.60	8.9, 10.3	1902.33	1545	
			353.6	*13.08*	*7.5, 8.2*	*1846.73*		
6327	12 53 7	48 0	132.0	17.44	9.7, 12.1	1901.25	1355	
			132.0	17.72	10.3, 12.2	1902.33	1545	
			135.5	*16 ±*	*9.10, 11*	*1830 +*		
9002	13 6 13	47 6	218.6	6.12	11.9, 12.0	1902.30	1536	dd
			222.3	9.05	11.6, 11.7	1903.23	2028	
6597	13 37 40	46 43	202.5	7.11	9.2, 9.6	1902.33	1546	
			200.2	*7.33*	*8.0, 8.0*	*1832.09*		
6628	13 42 5	45 54	155.8	20.59	10.5, 12.4	1904.41	2471	
			161.7	*25*	*9.10, 11*	*1830 +*		
6704	13 57 3	46 54	293.1	25.45	11.4, 11.8	1904.40	2469	
			290.8	*30 ±*	*9, 10.11*			
6710	13 58 31	46 49	12.1	3.13	10.4, 10.6	1904.40	2469	
			6.7	*2.44*	*9.0, 9.0*	*1889.39*		
6739	14 5 1	46 36	203.8	4.00	9.5, 12.0	1902.38	1588	
			196.7	*4.14*	*8.5, 11.7*	*1832.14*		
6789	14 11 24	47 26	316.0	4.22	8.7, 9.9	1904.40	2426	
			318.6	3.78	9.5, 10.0	1907.38	2689	
			315.1	*4.43*	*8.9, 9.2*	*1832.11*		
6854	$14^h\ 19^m\ 8^s$	46° 50′	86°.7	5″.00	10.9, 11.0	1904.40	2468	
			88.5	4.70	11.1, 11.4	1907.38	2689	
			266.0	*3 ±*	*11, 11*	*1830 +*		
9003	14 24 21	46 29	231.6	7.03	12.3, 12.3	1904.40	2468	
9004	14 30 11	47 34	135.6	21.63	11.7, 12.1	1898.33	590	
			136.5	21.22	11.8, 12.3	1904.40	2468	
7103	14 57 14	47 40	155.8	36.37	7.1, 9.8	1902.44	1573	
			157.6	35.20	6.6, 9.6	1902.38	1591	
			156.6	*35.51*	*6.1, 8.6*	*1867.12*		
7158	15 7 27	47 14	288.8	18.19	9.8, 10.3	1902.46	1584	
			289.7	18.49	9.9, 10.3	1904.40	2467	
			291.1	*19.01*	*8.5, 8.5*	*1830.63*		
7176	15 9 34	47 12	132.2	18.98	11.7, 12.0	1902.45	1596	
			133.7	18.69	11.5, 12.6	1902.46	1584	
			128.7	18.43	11.1, 12.2	1904.41	2467	
			148.4	*14 ±*	*10, 11*	*1830 +*		
—	15 16 35	46 24	37.5	3.82	10.4, 10.8	1902.45	1596	
9005	15 22 32	46 5	217.8	15.43	12.0, 12.0	1904.46	2526	
7281	15 23 35	46 30	316.6	1.54	10.2, 10.5	1904.46	2526	dd
			332.3	*3.16*	*9.5, 9.9*	*1901.38*		
7287	15 24 50	46 33	258.0	2.00	11.2, 11.4	1904.46	2526	
			340.0	*2.88*	*7.5, 9*	*1900.71*		7^m5?
—	15 26 47	46 38	83.8	4.34	10.5, 10.8	1904.46	2526	
9006	15 48 32	46 32	177.8	7.46	12.2, 12.2	1902.50	1641	dd
			191.7	9.38	11.5, 11.9	1903.50	2096	
7508	16 2 37	47 56	284.3	22.01	10.5, 10.7	1903.51	2161	
			285.2	22.22	10.7, 10.9	1904.51	2511	
			284.4	*21.42*	*9.1, 9.2*	*1900.41*		
9007	16 6 4	46 49	320.1	12.35	12.6, 12.7	1904.51	2511	
9008	16 6 43	46 39	248.3	19.01	12.0, 12.7	1904.51	2511	
7543	16 7 36	48 4	202.3	17.65	8.1, 11.7	1897.48	354	
			201.9	16.69	8.2, 12.0	1904.51	2511	
			201.4	*17.77*	*7.2, 10.2*	*1851.73*		
9009	16 9 9	47 3	284.2	12.01	12.0, 12.5	1897.48	354	
			282.1	11.75	12.0, 12.6	1899.42	957	
			286.7	11.20	11.9, 12.4	1904.51	2511	
7686	16 31 2	47 29	253.1	4.29	9.1, 9.1	1901.53	1384	
			242.8	7.04	10.0, 9.8	1902.44	1571	
			249.7	4.54	9.0, 9.3	1903.48	2141	
			257.1	*5.46*	*8.3, 8.3*	*1830.43*		
7695	16 32 43	47 53	180.0	3.99	10.2, 11.2	1901.53	1384	
			180.9	4.31	9.9, 11.4	1903.48	2141	
			184.6	*5.05*	*8.6, 9.7*	*1830.83*		
—	16 40 11	47 46	84.5	21.23	11.5, 11.9	1901.53	1384	
			84.1	20.97	10.7, 11.6	1902.45	1593	
			84.6	20.84	11.4, 11.8	1902.47	1624	

[1]) A general catalogue of double stars. Carnegie Institution of Washington, 1906.

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Note: A translation of the preface to the table above is included in the body of this article.

Azeglio Bemporad and the "BEM" Double Stars

Astronomische Nachrichten, Volume 244, Issue 18, Nr. 5850, 02/1932. p.355 & 356

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	Burnham	α	δ	Angolo di posizio.	Distanza	Grandezze	Epoca	Lastra No.	Note
9010		17h 0m 5s	46°51′	252°.4	18″.63	11.7, 11.8	1899.56	992	
				251.0	18.65	11.2, 11.2	1901.56	1378	
	7873	17 2 18	47 6	91.4	7.46	9.4, 12.1	1899.56	992	
				92.2	6.82	9.8, 12.1	1902.46	1631	
				111.3	*6.91*	*7.4, 10.5*	*1848.44*		
	—	17 5 35	47 4	97.8	15.41	11.6, 12.3	1899.56	992	
				94.3	14.78	12.3, 12.8	1902.46	1631	
				96.8	14.77	12.1, 12.7	1902.52	1665	
	8009	17 21 0	47 22	10.8	9.04	9.0, 10.6	1901.52	1381	
				11.9	11.22	8.9, 10.0	1902.52	1684	
				11.5	9.06	8.7, 10.0	1903.48	2122	
				16.5	*8.82*	*7.8, 9.3*	*1829.46*		
9011		17 24 0	47 32	27.9	10.84	12.9, 12.9	1903.48	2122	

Napoli, R. Osservatorio astronomico di Capodimonte, 1931 Ott. 31.

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	Burnham	α	δ	Angolo di posizio.	Distanza	Grandezze	Epoca	Lastra No.	Note
	8040	17h25m 0s	46°30′	140°.2	2″.33	9.3, 10.6	1903.48	2122	
				133.7	*3.15*	*8.5, 10.0*	*1831.46*		
	8046	17 25 15	46 22	183.7	7.85	11.5, 12.1	1903.48	2122	
				183.8	*7.58*	*9.2, 9.7*	*1879.34*		
	8073	17 30 9	47 57	99.3	20.67	7.4, 12.3	1902.50	1714	
				98.3	20.56	7.6, 12.8	1903.48	2122	
				100.2	21.50	8.1, 12.6	1903.48	2138	
				100.0	*21.07*	*7.9, 10.3*	*1901.39*		
9012		17 48 54	47 20	130.8	4.08	12.4, 12.5	1901.50	1571	
				154.5	3.87	12.6, 12.7	1901.50	1372	dd
				139.9	4.20	12.7, 12.8	1902.54	2510	
	—	17 49 25	46 58	220.3	6.14	10.3, 12.1	1901.50	1371	
				233.0	6.63	9.8, 12.2	1901.50	1372	
				224.6	6.34	9.9, 12.4	1902.54	2510	

A. Bemporad.

Azeglio Bemporad and the "BEM" Double Stars

Astronomische Nachrichten, Volume 246, Issue 2, Nr. 5882, 1932, p.23 & 24

Misure di stelle doppie eseguite nel corso dei calcoli per il Catalogo Astrografico di Catania. Da *A. Bemporad.*

Con riferimento alla precedente comunicazione col medesimo titolo in AN **244**, Nr. 5850 ci limitiamo a riportare nell'elenco seguente le coordinate approssimate e gli elementi ricavati per No. 34 doppie rinvenute nei volumi in corso di stampa del Catalogo Astrografico (da +48° a +52°).

Burnham	α	δ	Angolo di posizio.	Distanza	Grandezze	Epoca	Lastra No.	Note
6068	12h 6m 41s	51° 23.6′	206.2°	11.75″	8.2m, 10.7m	1900.31	1169	
			208.3	11.32	8.2, 11.0	1904.38	2480	md
			206.2	11.32	8.5, 10.6	1905.33	2605	
			206.3	10.81	7.7, 9.5	1831.90		Σ2
6140	12 16 24	51 31.9	140.7	25.27	10.7, 11.0	1900.31	1169	
			138.1	25.62	11.1, 11.2	1904.38	2483	
			144.7	18 ±	9, 10	1830 +		H
6268	12 41 24	50 22.2	208.3	6.22	10.0, 10.4	1899.32	923	
			209.8	5.01	9.7, 10.1	1904.28	2383	
			211.1	5.52	9.8, 10.5	1904.30	2431	
			208.3	5.52	8.5, 9.0	1832.05		Σ3
6383	13 1 8	51 31.4	272.0	13.18	9.9, 10.2	1899.26	918	
			272.8	13.45	10.0, 10.3	1904.28	2439	
			272.6	13.32	9.7, 9.9	1906.40	2637	
			272.4	13.12	8.5, 9.0	1831.50		Σ2
6401	13 3 39	49 38.7	177.5	9.08	11.0, 11.6	1904.34	2441	
			178.6	9.06	11.1, 11.7	1904.39	2425	
			179.4	8 ±	10 , 11	1830 +		H
6446	13 12 23	51 5.9	139.3	2.65	9.8, 10.1	1903.22	2114	md
			141.9	1.79	9.6, 9.8	1904.28	2439	
			133.0	2.26	7.7, 8.5	1846.83		OΣ3
6495	13 23 32	48 16.9	346.7	14.89	10.0, 10.4	1898.39	612	
			347.1	14.53	10.2, 10.3	1902.38	1590	
			344.7	15.67	10.3, 10.5	1904.36	2415	
			346.5	14.98	8.2, 9.5	1831.50		Σ2
6527	13 28 45	49 39.3	309.8	6.31	9.3, 9.4	1904.36	2415	md
			312.5	5.36	9.4, 9.7	1905.31	2597	
			311.4	4.21	8.0, 8.2	1832.14		Σ3
6554	13 31 35	50 10.1	193.5	2.66	9.4, 10.1	1902.22	2112	md
			201.5	2.20	9.9, 10.2	1905.33	2602	
			9.2	3.17	8.9, 9.1	1902.30		Es4
6570	13 33 40	48 45.3	3.4	13.79	11.0, 11.4	1902.30	1534	
			5.4	13.83	11.1, 11.3	1904.36	2415	
			6.6	8 ±	11 = 11	1830 +		H
6573	13 33 42	51 13.4	110.7	2.73	8.6, 7.9	1902.22	2112	
			121.0	1.79	6.4, 7.9	1831.80		Σ4
6589	13 36 25	51 1.5	136.1	17.04	7.0, 11.4	1902.22	2112	
			137.3	17.73	7.1, 11.4	1904.28	2447	
			137.0	17.93	6.9, 11.7	1904.41	2478	
			134.2	17.93	6.7, 10	1879.26		β1
6738	14 4 58	48 58.8	170.3	13.47	10.4, 11.2	1902.35	1552	
			174.9	12.71	10.4, 11.4	1904.36	2413	
			175.0	12.93	10.3, 11.2	1904.40	2426	
			173.5	13.19	9.0, 10.0	1831.76		Σ3
6754	14h 7m 22s	50° 43.2′	258.6°	11.33″	9.6m, 10.4m	1905.33	2600	1)
			259.6	11.43	10.2, 10.5	1924.41	4004	
			256.2	11.03	8.5, 9.0	1831.54		Σ2
—	14 27 33	48 34.1	316.5	6.52	11.2, 11.4	1898.33	590	
			317.9	6.56	11.2, 11.4	1904.43	2532	
—	14 33 56	48 9.1	7.7	4.82	10.4, 12.1	1898.33	590	
			4.7	2.72	10.5, 12.0	1904.43	2532	
9013	14 37 17	49 53.3	323.4	5.15	11.1, 11.7	1897.33	319	
			322.1	6.23	11.5, 12.0	1905.44	2617	
7063	14 51 30	51 2.7	138.8	25.94	10.2, 10.8	1904.28	2474	
			138.9	25.43	10.0, 10.5	1907.46	2694	
			139.0	25.03	9.1, 9.4	1900.43		Es2
7299	15 26 12	48 3.4	127.2	10.66	6.6, 11.7	1899.43	975	
			128.5	10.74	6.5, 12.5	1879.28		β2
7499	16 1 11	49 13.8	254.0	8.22	10.6, 10.8	1903.47	2125	
			256.5	8.09	10.9, 11.1	1903.51	2111	
			254.8	8.19	9.3, 9.4	1900.38		Es3
7508	16 2 39	47 55.6	284.6	22.03	10.7, 10.9	1903.51	2111	2)
			284.4	21.42	9.1, 9.2	1900.41		Es2
9014	16 25 45	48 32.2	102.0	12.31	11.3, 12.2	1902.45	1595	
			102.7	12.25	11.1, 12.1	1903.48	2120	
			103.7	12.03	11.4, 12.0	1903.48	2141	
7714	16 35 49	49 3.6	91.6	23.29	7.2, 10.7	1902.46	1611	
			91.6	24.18	7.2, 11.0	1902.46	1632	
			91.8	24.65	6.8, 10.6	1903.48	2120	
			92.3	22.39	4.0, 10.7	1828.43		Σ3
7752	16 41 9	50 51.1	296.7	24.65	9.6, 12.0	1897.48	355	
			294.1	23.68	9.0, 11.0	1902.46	1632	
			294.5	23.22	9.7, 11.4	1902.56	1706	
			295.7	22.88	8 , 10	1900.46		Es2
28	17 36 15	49 25.9	350.8	2.50	11.8, 12.3	1902.51	1692	
			345.7	1.46	12.3, 12.4	1902.50	1715	
8139	17 39 37	49 2.9	117.6	3.57	9.8, 11.1	1902.50	1715	
			121.9	2.97	8.5, 10.0	1831.73		Σ4
9015	17 41 0	51 23.8	277.1	12.39	12.5, 12.6	1931.53	4054	
8167	17 42 30	51 57.7	308.9	9.57	—, —	1902.51	1693	
			308.1	9.29	—, —	1902.60	1752	
			307.1	8.57	10.9, 11.4	1931.53	4054	
			319.4	9.07	8.9, 9.2	1830.25		Σ4
8175	17 43 25	50 13.3	343.2	6.72	9.8, 11.4	1902.59	1784	
			346.3	5.30	9.4, 10.5	1931.53	4054	
			342.0	6.13	7.7, 9.7	1830.46		Σ3
—	17 44 20	50 49.0	113.8	8.44	13.1, 13.2	1931.53	4054	
—	17 46 49	50 13.0	356.4	2.76	11.4, 11.6	1902.59	1784	
			343.5	3.32	10.9, 11.1	1931.53	4054	
9016	17 47 39	50 41.6	196.0	4.92	12.5, 12.8	1931.53	4054	
—	17 47 40	51 4.8	341.3	8.51	10.9, 12.9	1931.53	4054	
8247	17 52 2	49 39.0	27.2	15.10	9.5, 12.3	1902.51	1701	
			25.9	15.05	9.8, 12.1	1902.59	1784	
			32.5	14.41	8.2, 11.2	1830.43		Σ3

1) Doppia fisica: Prec. μ_α −0.0372s μ_δ +0.111″
Seg. −0.0356 +0.100

2) Cfr. AN **240**, Nr. 5850.

Napoli, R. Osservatorio astronomico di Capodimonte, 1932 Juni 20.

A. Bemporad.

Azeglio Bemporad and the "BEM" Double Stars

Astronomische Nachrichten, Volume 248, Issue 2, Nr. 5930, 02/1933, p.29-32

29 5930 30

Misure di stelle doppie

eseguite nel corso dei calcoli per il Catalogo Astrografico di Catania. Da *A. Bemporad.*

Con riferimento alle precedenti comunicazioni col medesimo titolo in AN **244**. Nr. 5850, e AN **246**, Nr. 5882, comunichiamo le coordinate approssimate (1900.0) e gli elementi ricavati per Nr. 40 doppie rinvenute nei volumi in corso di stampa del Catalogo Astrografico (da +48° a +54°). Sono segnati in corsivo gli elementi desunti da *Burnham*.

Burnham	α	δ	Angolo di posiz.	Distanza	Grandezze	Epoca	Lastra No.	Note
5988	$11^h54^m40^s$	53° 37'.3	29°.8	0".89	9^m1, 9^m5	1899.32	928	dd
			10.9	*0.72*	*7.8, 8.8*	*1846.04*		OΣ 3
6025	12 0 29	52 29.3	92.2	8.17	8.6, 8.8	1901.33	1351	
			94.3	8.01	8.4, 8.6	1904.36	2417	
			93.4	7.60	8.0, 8.2	1904.38	2480	
			93.2	*7.63*	*7.0, 8.0*	*1832.35*		Σ 4
6026	12 0 30	53 25.9	307.3	2.06	8.9, 8.6	1899.32	928	
			311.7	3.68	9.5, 8.8	1904.36	2417	
			319.0	*3.31*	*9.2, 7.2*	*1850.13*		OΣ 4
6064	12 6 28	53 58.7	223.4	12.25	9.3, 9.1	1899.32	925	
			221.1	12.44	9.1, 8.9	1899.32	928	
			219.5	12.29	8.9, 8.8	1904.36	2417	
			223.9	*10.59*	*7.7, 7.5*	*1832.04*		Σ 3
—	12 26 5	54 24.7	183.9	8.80	11.9, 10.6	1907.38	2690	
BEM2	12 49 47	53 24.0	267.7	4.23	12.5, 11.9	1928.38	4029	
6451	13 14 17	54 51.6	332.1	25.26	10.9, 10.2	1904.41	2477	
			345.4	*25:*	*9+, 9*	*1830+*		H
—	13 15 26	54 55.2	289.4	7.13	11.9, 11.7	1904.41	2477	
9017	13 16 22	54 50.7	211.4	13.74	11.6, 11.4	»	»	
—	13 17 12	53 52.9	210.0	5.27	11.4, 10.5	1904.39	2409	
			213.6	6.06	11.5, 10.2	1904.40	2398	
			206.9	5.59	11.4, 10.2	1904.41	2477	
—	13 17 54	51 53.5	168.5	6.15	11.3, 11.7	1903.22	2114	
			172.8	6.39	11.3, 11.8	1904.26	2401	
			170.0	5.55	11.2, 11.7	1904.39	2420	
			170.3	6.18	11.4, 11.6	1904.39	2409	
BEM5	13 21 35	52 57.5	229.9	8.85	12.0, 11.9	1904.35	2401	dd
			220.5	10.12	11.7, 11.2	1904.39	2409	
BEM6	13 29 51	54 48.8	190.7	7.05	11.2, 10.6	1904.40	2398	
6797	14 11 50	50 54.3	152.5	5.62	7.8, 8.8	1905.23	2608	
			157.0	5.50	8.3, 9.0	1905.33	2600	
			161.5	5.65	8.3, 9.3	1924.41	4004	
			150.3	*5.30*	*7.7, 8.2*	*1831.11*		Σ 3
9018	14 15 33	52 1.1	30.8	15.92	10.7, 11.6	1904.39	2406	
			33.6	16.09	10.8, 11.6	1905.23	2608	
			32.1	16.16	10.5, 11.4	1905.40	2612	
6836	14 16 56 A e B	52 8.7	51.0	1.54	10.2, 10.9	1904.39	2406	dd
			59.2	1.44	10.4, 11.2	1905.40	2612	dd
			47.3	*1.71*	*9.0, 10.3*	*1902.18*		β 2
6836	14 16 36 A e C	52 8.7	170.4	41.31	10.2, 9.9	1904.39	2406	
			171.8	41.42	10.3, 9.6	1904.43	2533	
			170.7	41.05	10.4, 9.8	1905.40	2612	
			170.3	*40.84*	*9.0, 9.0*	*1902.18*		β 2
9019	14^h20^m	7° 52° 32'.2	16°.8	14".10	10^m7, 11^m5	1904.39	2406	
			14.3	14.13	10.9, 11.5	1904.43	2533	
9020	15 6 14	53 19.9	354.5	12.79	11.6, 11.5	1904.42	2464	
			355.4	13.05	11.8, 11.7	1904.48	2513	
			357.9	13.28	11.4, 11.3	1905.40	2610	
BEM18	15 15 39	52 20.8	15.1	8.65	10.7, 11.6	1904.49	2517	
			15.5	8.65	10.7, 11.6	1904.49	2519	
—	15 15 55	53 55.4	30.8	3.02	9.8, 10.5	1904.48	2513	dd
			24.2	2.72	10.0, 11.1	1904.49	2517	
—	15 16 56	53 6.6	237.5	9.53	11.3, 10.0	1903.50	2109	
			235.8	9.82	11.3, 10.0	1904.48	2513	
			233.5	9.25	11.4, 9.7	1904.49	2517	
—	15 35 42	52 53.8	207.5	5.84	11.6, 11.1	1902.46	1622	
			210.2	5.96	11.6, 11.2	1902.50	1647	
			220.8	6.34	11.4, 11.0	1904.45	2528	
			220.8	5.81	11.7, 11.0	1904.48	2514	[1]
—	15 42 57	54 0.9	131.1	4.85	11.5, 11.6	1902.50	1647	
			128.1	5.76	11.7, 12.0	1903.51	2110	dd
			126.0	5.45	11.7, 12.1	1904.48	2514	dd
—	15 44 22	53 55.8	82.2	3.81	9.6, 9.8	1903.51	2110	[2]
7428	15 48 33	53 12.4	264.7	6.70	9.4, 6.8	1903.51	2110	dd
			266.3	7.74	9.6, 7.0	1904.48	2514	dd
			258.3	7.25	10.2, 6.5	1904.49	2516	dd
			273.8	*6.53*	*8.5, 6.2*	*1830.72*		Σ 4
7429	15 49 22	52 51.8	251.1	9.50	9.9, 9.8	1902.46	1629	[3]
			251.4	10.02	9.6, 9.4	1903.51	2110	
			253.6	9.36	9.6, 9.5	1904.48	2514	
			254.3	9.71	9.5, 9.5	1904.40	2516	
			255.2	*9.30*	*8.9, 8.8*	*1900.37*		Es 2
—	15 52 47	53 10.6	330.8	3.93	11.6, 11.2	1902.38	1568	dd
			322.9	3.86	11.7, 11.2	1903.51	2110	
			327.6	5.02	11.3, 10.8	1904.40	2516	
—	16 15 59	51 34.3	287.0	11.98	11.4, 10.5	1903.50	2134	
			286.1	12.54	11.5, 10.6	1904.50	2523	
7595	16 17 7	51 48.5	232.6	3.47	11.4, 10.5	1902.46	1634	
			217.8	3.93	11.5, 10.4	1903.49	2134	
			228.7	3.24	11.0, 10.5	1904.50	2523	
			224.2	*4.16*	*12.5, 8.5*	*1904.31*		Hu 2
9021	16 23 45	51 0.9	32.7	17.85	11.0, 12.2	1897.51	379	
			36.9	18.57	11.0, 12.3	1902.49	1626	
			35.0	17.45	10.8, 12.5	1903.49	2134	
7702	16 33 49 (16 e 17 Drac.)	53 6.1	13.9	91.29	5.8, 5.6	1902.50	1645	
			13.8	91.15	5.8, 5.5	1904.45	2518	
			14.7	*90.42*	*5.0, 5.0*	*1833.39*		Σ 6
7703	16 33 52 (17 Drac.)	53 7.5	121.3	3.64	5.7, 6.6	1902.50	1645	
			122.1	3.93	5.5, 6.5	1904.45	2518	
			116.5	*3.74*	*5.0, 6.0*	*1831.91*		Σ 7
BEM22	16 39 51	52 46.6	104.5	7.80	11.5, 11.8	1897.50	374	
			105.0	7.52	11.6, 11.8	1902.50	1720	

[1] Dal confronto fra i primi due osservazioni e i seguenti appare un forte spostamento angolare che si concilierebbe coll'ipotesi di un moto di rivoluzione con periodo di circa 60 anni.

[2] Quattro osservazioni gentilmente comunicate dal sig. *W. Milburn* di Tow Law per incarico del Direttore Rev. *T. H. Espin* danno i valori medi 83°.8, 3".38.

[3] La precedente in qualche lastra appare diffusa. Spettro? Variabile?

31 5930 32

Burnham	α	δ	Angolo di posiz.	Distanza	Grandezze	Epoca	Lastra No.	Note
7796	16^h49^m 6^s	53° 57'.1	197°.1	7".57	12^m5, 9^m3	1902.47	1627	
			203.1	7.00	12.0, 9.4	1902.49	1619	
			197.2	*7.12*	*10.2, 8.6*	*1902.37*		β 2
9022	16 53 6	53 1.5	273.8	12.05	12.4, 12.2	1902.47	1627	
9023	17 29 12	52 26.1	64.2	13.61	11.8, 12.5	1902.47	1640	
			62.2	14.39	11.9, 12.3	1902.47	1623	
—	$17^h29^m42^s$	53° 53'.0	204°.8	12".88	12^m0, 11^m7	1902.47	1640	
			207.5	13.14	12.1, 11.8	1902.48	1618	
9024	17 46 47	49 6.2	241.3	12.81	12.7, 12.2	1902.50	1715	
			238.2	12.49	12.7, 12.4	1904.58	2510	
BEM29	17 46 47	48 24.3	148.6	2.84	10.7, 12.5	1902.50	1715	dd
			142.5	4.17	10.3, 12.8	1902.58	2510	

Napoli, Capodimonte, 1932 Dic. 18.

A. Bemporad.

Azeglio Bemporad and the "BEM" Double Stars

Contributi Astrofisici No. 42, 1938

R. OSSERVATORIO ASTROFISICO DI CATANIA

CONTRIBUTI ASTROFISICI N. 42

SCOPERTA OCCASIONALE DI UNA STELLA QUINTUPLA

Nota del prof. AZEGLIO BEMPORAD

ROMA

ANNO MCMXXXVIII - XVI

Azeglio Bemporad and the "BEM" Double Stars

Riassunto: Su due lastre esposte per soli 5 o 6 minuti è stata misurata una stella quintupla, l'unica riscontrata finora nel corso dei lavori del Catalogo Astrografico che datano da 40 anni e sono ormai prossimi al termine con 350.000 posizioni stampate.

Ognuno sa che le stelle doppie non sono un fenomeno molto frequente. Il grande catalogo di Aitken (1), che si spinge fin oltre la 14ª grandezza e si estende dal Polo Nord fino a 120° di distanza polare, non contiene che circa 17000 stelle doppie o multiple. Una statistica da me compilata su circa 10000 stelle contenute nel vol. III, parte 8ª del Catalogo Astrografico di Catania ha accertato l'esistenza di 129 stelle doppie, vale a dire appena l'1,3 % del numero delle stelle semplici, nella zona fra 21^h e 24^h A. R. fra i paralleli + 48° e + 50° di Decl. fino alla grandezza 12 +. Le stelle triple fra queste 10000 stelle si contano addirittura sulle dita (2). Assolutamente eccezionale è dunque il ritrovamento di una stella quintupla su lastre con soli 5 minuti di posa, come sono in generale quelle del Catalogo di Catania, e vale la pena di dar conto delle circostanze che hanno condotto alla scoperta.

Nel corso della revisione delle bozze del vol. II parte 8ª, e precisamente nella compilazione delle note sulle stelle doppie contenute nella lastra n. 752 (21^h 40^m, + 48°) mi è venuta sott'occhio una coppia di stelle *fuori quadrato* (3) costituenti una doppia piuttosto larga della quale, a causa appunto della posizione sfavorevole, non erano stati ancora determinati gli elementi. Guardando più attentamente ho notato presso la stella minore una traccia più debole che, mancando della seconda immagine (4), poteva venir ritenuta come dubbia o illusoria, anzichè come corrispondente ad una stella reale. Solo una seconda lastra poteva decidere in merito e questa fu la

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(1) « New general Catalogue of double stars... », Vol. I and II. Washington, 1932.

(2) Nel vol. IV, parte 8ª su 11265 stelle vennero riscontrate solo 7 stelle triple.

(3) Nel linguaggio corrente dei calcolatori dell'Osservatorio di Catania si chiamano stelle fuori quadrato quelle esterne al perimetro del reticolato di riferimento, tali cioè che una delle coordinate x, y misuri più di 65 mm. E' ovvio che queste stelle si presentano sempre con immagine allungata e spesso deformata dalle varie aberrazioni dell'obiettivo. Lo scrivente ritiene utile tuttavia estendere misure e calcoli anche alle immagini comprese nella fascia di 3 mm. intorno al perimetro, in quanto possono confermare o smentire circostanze emergenti da stelle contenute in posizione favorevole in altre lastre. L'utilità di questa estensione delle misure non poteva venir meglio dimostrata che con la scoperta di questa quintupla.

(4) Per distinguere le immagini stellari da quelle causate da difetti di sviluppo si è divisato di eseguire su ciascuna lastra una seconda posa di 2 minuti e mezzo a distanza conveniente (20") dall'immagine principale. Quando una stella è al limite di visibilità, la seconda posa di solito diviene impercettibile.

Azeglio Bemporad and the "BEM" Double Stars

L. 1810, dove la doppia in questione compariva vicina al centro. A prima vista venne confermata l'esistenza della tripla, ma un esame più accurato nei paraggi di questa rivelò l'esistenza di altre due stelle satelliti, subito confermata dalla predetta L. 752 non che da altre lastre più recenti non ancora sottoposte a misura. I risultati abbastanza concordanti delle misure subito eseguite sulle due lastre in questione vengono qui riepilogati. Questa è la prima quintupla che sia mai stata osservata nel corso dei calcoli per il Catalogo Astrografico di Catania iniziati circa 40 anni addietro e comprendenti ormai 350000 posizioni stellari stampate.

La lastra N. 752 ($21^h 40^m$, $+48^0$) fotografata il 29 agosto 1898, con 6 minuti di posa, ha dato i seguenti risultati:

Stella	x	y	D	Gr	α (1900)	δ
a . .	— 66′.2785	— 46′.9095	8	11.6	$21^h 33^m 29^s.922$	47°12′28″.89
b . .	— 66′.1682	— 46′.9533	1	12.7	$21^h 33^m 30^s.575$	47°12′26″.41
c . .	— 66′.1387	— 47′.1360	16	10.3	$21^h 33^m 30^s.772$	47°12′15″.49
d . .	— 66′.0778	— 46′.6905	1	12.7	$21^h 33^m 31^s.074$	47°12′42″.23
e . .	— 65′.7645	— 47′.3639	1	12.7	$21^h 33^m 33^s.002$	47°12′ 3″.32

Coppia	ab	cd	ce	ca
Distanza	7″.10	26″.92	26″.27	15″.96
Angolo di posizione . . .	110°.4	6°.6	120°.1	327°.1

La lastra N. 1810 ($21^h 35^m$, $+47^0$) fotografata il 10 settembre 1902, con 5 minuti di posa, ha dato corrispondentemente:

Stella	x	y	D	Gr	α (1900)	δ
a . .	— 15′.4045	+ 12′.6128	12	11.3	$21^h 33^m 30^s.114$	47°12′29″.28
b . .	— 15′.2896	+ 12′.5604	1	12.2	$21^h 33^m 30^s.791$	47°12′26″.16
c . .	— 15′.2698	+ 12′.3858	17	10.3	$21^h 33^m 30^s.911$	47°12′15″.69
d . .	— 15′.2026	+ 12′.8086	1	12.2	$21^h 33^m 31^s.298$	47°12′41″.05
e . .	— 14′.9079	+ 12′.1600	1	12.2	$21^h 33^m 33^s.044$	47°12′ 1″.96

Coppia	ab	cd	ce	ca
Distanza	7″.57	25″.67	25″.72	15″.83
Angolo di posizione . . .	114°.3	8°.8	122°.3	329°.1

Una ripetizione della L. 1810 con 10^m di posa è già predisposta per ottenere migliori elementi di queste coppie, dato che da stelle fuori quadrato e al limite di visibialità non è certo possibile ottenere risultati sicuri.

Azeglio Bemporad and the "BEM" Double Stars

The following is a translation of the plates shown on pages 359-361.

The Occasion of the Discovery of a Quintuple Star

Summary: On two plates exposed for only 5 or 6 minutes was measured a quintuple star, the only detected so far in the course of the Astrographic Catalog work dating for 40 years which is now coming to an end with 350,000 printed positions.

Everyone knows that double stars are not a very frequent phenomenon; the largest catalog of Aitken (1), which goes far beyond magnitude 14 and extends from the North Pole up to 12° polar distance, only contains about 17,000 double or multiple stars. A statistic compiled by me on about 10,000 stars contained in vol. III, part 8 of Astrographic Catalog of Catania has established the existence of 129 double stars, ie only 1.3% of the number of single stars in area of 21h to 24h RA between parallel +48d and +50° Dec up to magnitude 12+. The number of triple stars among the10,000 stars can be counted on the fingers (2). Absolutely outstanding is finding a quintuple star on plates with just 5 minutes of exposure which was generally used for the Catania Catalog and it is worth giving an account of the circumstances that led to the discovery.

In the review of the drafts of vol. II Part 8, namely the compilation of the notes for double stars contained on Plate No. 752 (21h 40m, + 48°) my eye fell on a pair of stars on the edge of the grid (3) constituting a rather large double which, precisely because of the unfavorable position, elements had not yet been determined. On closer inspection I noticed that for a minor star its corresponding image in the second exposure was missing (4), so it could be considered as doubtful or illusory, instead of corresponding to a real star.

Only a second plate (Plate 1810) could clarify the situation, where the double in question appeared near the center. At first glance it confirmed the existence of the triple, but upon closer examination in the neighborhood revealed the existence of two other satellite stars, also present in the aforementioned Plate 752 and by two more recent plates still to be measured. The fairly consistent results of the measures from the two plates are summarized here. This is the first quintuple that has been observed in the course of the calculations for the Astrographic Catalog of Catania begun about 10 years ago which now contains the positions of 350,000 stars.

Plate No. 752 (21h 40m, + 48°) photographed on August 29, 1898, with 6 minutes exposure, gave the following results:

See top table on page 361.

Plate No. 1810 (21h 35m, + 47°) photographed on September 10, 1902, with five minutes of exposure, gives correspondingly:

See bottom table on page 361.

A repeat of Plate 1810 with 10m exposure was made so as to get the best data for these pairs, since it is not possible to get reliable results when the stars are deformed and at the limit of visibility.

(1) "New General Catalog of Double Stars", Vol I & II, Washington, 1932.

(2) In vol. IV, Part 8 of 11,265 stars only 7 triple stars were found.

(3) It is obvious that the stars there are always elongated and often deformed by the various lens aberrations. The writer believes, however, it is useful to extend measures and calculations to the range of 3 mm around the perimeter, as they can confirm the circumstances of stars contained in more favorable positions on adjacent plates. The utility of this extension of measures could not be better demonstrated than with the discovery of this quintuple.

(4) To distinguish stellar images the from those caused by defects during development it was decided to perform on each Plate a second exposure of two and a half minutes with the image offset from the original exposure at a convenient distance (20"). When a star was at the limit of visibility, the second exposure was usually nearly imperceptible.

Jonckheere Double Star Photometry – Part V: Cancer

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Abstract: If any double star discoverer is in urgent need of photometry then it is Jonckheere. There are over 3000 Jonckheere objects listed in the WDS catalog and a good part of them have magnitudes which are obviously far too bright. This report covers the Jonckheere objects in the constellation Cancer. Only one image per object was taken as despite the risk of random effects even a single measurement is better than the currently usually given estimation, although the J-objects in this constellation seem with some exceptions better covered with observations as usual for Jonckheere doubles.

Introduction

The degree of contamination of the WDS catalog with wrong magnitude data is rather high – this might very well be a side effect of magnitudes considered being not as important as the basic double star parameters separation and position angle. Measurements of magnitudes without these basic parameters are not even counted as observations in the WDS catalog. As follow up to the report on J-objects so far, I selected this time all J-objects in Cancer to be imaged for measurements with a remote telescope located in Spain. To counter the single image random effects especially for the astrometry results, I checked catalogs like SDSS, URAT1 and GAIA DR1 with recent position data. The single image random effects seem less significant for the measured magnitudes as a magnitude error of ~0.1 or even a bit larger seems negligible in comparison with magnitude errors in the range of up to 2 magnitudes for Jonckheere objects.

Results of photometry and catalog checking

For each of the selected J-objects, one single image was taken with iTelescope iT18 with V-filter and 3s exposure time and plate solved with Astrometrica, using the URAT1 catalog with reference stars in the Vmag range of 8.5 to 14.5 and giving not only RA/Dec coordinates but also photometry results for all reference stars used including an average dVmag error. The J-objects were then located in the center of the image and astrometry/photometry was then done by the rather comfortable Astrometrica procedure with point and click at the components delivering RA/Dec coordinates and Vmag measurements based on all reference stars used for plate solving. As the companion of one double star was too faint to be resolved in the iT18 image, I took for this object additional images with iT24 for a stack.

The results are given in table 1 below with the following structure:

- The header line gives the WDS catalog data for each object per 08/2016 with RA/Dec in the HH:MM:SS/DD:MM:SS format with Date giving the year of the last observation
- The following rows give the data for the object in existing catalogs as far as available with
  - ◊ RA/Dec in decimal degrees with the catalog reference given in the Source/Notes column
  - ◊ Estimated visual M1 and M2 for 2MASS objects calculated from J- and K-band magnitudes if available
  - ◊ Visual M1 and M2 for URAT1 objects if available
  - ◊ Used Aperture and observation method code is given in the Ap and Me columns. As GAIA uses a rectangular aperture the value given in the Ap column is the calculated diameter for a corresponding circular surface
  - ◊ Date gives the Bessel observation epoch

    - ◊ If 2MASS (or in some cases SDSS9) and GAIA DR1 positions are available then also proper motion data is calculated (using the formulas provided by Buchheim – 2008 to determine proper motion vector direction and proper motion vector length) and checked for potential common proper motion with the CPM rating procedure according to Knapp and Nanson 2016
- The last row gives then the measurements based on the iT18 images
    - ◊ RA/Dec in decimal degrees from plate solving
    - ◊ Sep gives separation in arcseconds in the data lines calculated as SQRT(((RA2-RA1)*cos(Dec1))^2+(Dec2-Dec1)^2) in radians
    - ◊ PA gives position angle in degrees in the data lines calculated as arctan((RA2-RA1)*cos(Dec1))/(Dec2-Dec1)) in radians depending on quadrant
    - ◊ Visual magnitudes M1 and M2 based on the plate solving results
    - ◊ Measurement error estimations calculated on base of the average plate solving errors are given in a separate table in the appendix.

Summary

Table 1 shows with few exceptions significant differences for the magnitudes compared with the WDS data even if the J-objects in Cancer seem rather well researched in comparison with other northern constellations. A small part of the objects qualify as CPM pairs based on calculations with the now available GAIA DR1 data.

Acknowledgements

The following tools and resources have been used for this research:

- 2MASS catalog
- 2MASS images
- AAVSO APASS
- AAVSO VPhot
- Aladin Sky Atlas v9.0
- Astrometrica v4.10.0.427
- AstroPlanner v2.2
- iTelescope:
- iT18: 318mm CDK with 2541mm focal length. CCD: SBIG-STXL-6303E. Resolution 0.73 arcsec/pixel. V-filter. Located in Nerpio, Spain. Elevation 1650m
- iT24: 610mm CDK with 3962mm focal length. Resolution 0.625 arcsec/pixel. V-filter. No transformation coefficients available. Located in Auberry, California. Elevation 1405m
- GAIA DR1 catalog
- MaxIm DL6 v6.08
- POSS images
- SDSS DR9 and DR7 catalogs
- SDSS images
- SIMBAD
- UCAC4 catalog
- URAT1 catalog
- VizieR
- Washington Double Star Catalog

References

Buchheim, Robert, 2008, "CCD Double-Star Measurements at Altimira Observatory in 2007", *Journal of Double Star Observations*, **4**, 27-31.

Knapp, Wilfried; Nanson, John, 2016, "A New Concept for Counter-Checking of Assumed CPM Pairs", *JDSO*, **12**, 31-51.

Jonckheere Double Star Photometry – Part V: Cancer

Table 1. J objects in Cancer

J#	RA	Dec	Sep "	PA °	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM Rat	Source/Notes
46	07:55:39.13	+12:40:08.4	2.5	287.0	9.90	10.70	0	-15							2002		WDS07557+1240 values per 08/2016
	118.91308497	12.6690270	2.57	285.8									0.96	Hg	2015		GAIA DR1
	118.91306250	12.6690306	2.31	280.5	10.43	11.15							0.31	C	2016.088		iT18 1x3s/URAT1. Overlapping star disks, image quality not very good
																	Despite the clear elongation in the 2MASS images there is no 2MASS catalog object for B, the same goes for URAT1
J#	**RA**	**Dec**	**Sep"**	**PA°**	**M1**	**M2**	**pmRA1**	**pmDec1**	**e_pm1**	**pmRA2**	**pmDec2**	**e_pm2**	**Ap**	**Me**	**Date**	**CPM Rat**	**Source/Notes**
73	08:25:57.62	+07:49:08.6	4.1	217.0	8.75	12.00	-20	6							2000		WDS08260+0749 values per 08/2016
	126.49006100	7.8190020	3.90	216.9	8.78	8.84							1.30	E2	2000.181		2MASS. M1 and M2 estimated from J- and K-band
	126.48997611	7.8190449	4.07	217.6			-20.43	10.41	14.80	-30.02	3.34	11.94	0.96	Hg	2015	CCCB	GAIA DR1. PM data calculated from position comparison with 2MASS - obviously no CPM
	126.48993333	7.8190278	3.80	216.8	8.68	10.69							0.31	C	2016.090		iT18 1x3s/URAT1
J#	**RA**	**Dec**	**Sep"**	**PA°**	**M1**	**M2**	**pmRA1**	**pmDec1**	**e_pm1**	**pmRA2**	**pmDec2**	**e_pm2**	**Ap**	**Me**	**Date**	**CPM Rat**	**Source/Notes**
76	09:00:18.96	+09:17:18.2	4.4	263.0	10.98	13.40	-44	-12		-52	-16				2000		WDS09003+0917 values per 08/2016
	135.07899500	9.2884050	4.40	262.7	10.79	12.28							1.30	E2	2000.478		2MASS. M1 and M2 estimated from J- and K-band
	135.07872056	9.2883553	4.39	262.8			-65.51	-12.01	6.19	-67.83	-11.78	6.51	0.96	Hg	2015	AABA	GAIA DR1. PM data calculated from position comparison with 2MASS - solid CPM candidate
	135.07872500	9.2883472	4.44	263.5	10.92	12.46							0.31	C	2016.088		iT18 1x3s. SNR B<20
J#	**RA**	**Dec**	**Sep"**	**PA°**	**M1**	**M2**	**pmRA1**	**pmDec1**	**e_pm1**	**pmRA2**	**pmDec2**	**e_pm2**	**Ap**	**Me**	**Date**	**CPM Rat**	**Source/Notes**
77	09:05:04.69	+10:29:23.3	0.9	136.0	9.92	10.22	-21	-22		-21	-22				2013		WDS09051+1029 values per 08/2016
	136.26948333	10.4896861			9.32								0.31	C	2016.254		iT18 1x3s. No resolution. Combined magnitude confirms current WDS mag values 9.92 and 10.22 but as Vmags (WDS code "B" in error?)
																	No resolution in any available image, not even an elongation. WDS PM values suggest CPM - but POSS I to II images do not show significant proper motion

Table 1 continues on next page.

Table 1 (continued). J objects in Cancer

J#	RA	Dec	Sep"	PA°	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM Rat	Source/Notes
375 AB	08:08:54.70	+12:12:29.5	9.7	154.0	11.30	11.30	-16	-14		-9	-69				2014		WDS08089+1213 values per 08/2016
	122.22817200	12.2076710	8.96	152.3	11.46	11.91							1.30	E2	2000.908		2MASS. M1 and M2 estimated from J- and K-band
	122.22811916	12.2076252	9.62	153.7			-13.19	-11.71	6.54	-6.18	-61.35	6.54	0.96	Hg	2015	CCCB	GAIA DR1. PM data calculated from position comparison with 2MASS - obviously no CPM
	122.22812083	12.2076139	9.60	153.6	11.52	11.80							0.31	C	2016.088		iT18 1x3s
J#	RA	Dec	Sep"	PA°	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM Rat	Source/Notes
375 AC	08:08:54.70	+12:12:29.5	14.9	352.0	11.01	13.26	-16	-14		1	7				2014		WDS08089+1213 values per 08/2016
	122.22817200	12.2076710	14.64	350.9	11.46	12.97							1.30	E2	2000.908		2MASS. M1 and M2 estimated from J- and K-band
	122.22811916	12.2076252	14.79	352.0			-13.19	-11.71	6.54	4.57	1.55	6.54	0.96	Hg	2015	CCCC	GAIA DR1. PM data calculated from position comparison with 2MASS - obviously no CPM
	122.22812083	12.2076139	14.95	352.0	11.52	12.99							0.31	C	2016.088		iT18 1x3s
J#	RA	Dec	Sep"	PA°	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM Rat	Source/Notes
376	08:09:16.48	+12:03:31.4	2.1	284.0	9.20	9.60	6	-4							2008		WDS08092+1202 values per 08/2016
	122.31867800	12.0587710	2.19	280.2		16.05							2.50	Es	2005.189		SDSS DR9. Vmags estimated from (gmag+rmag)/2
	122.31866267	12.0587168	2.15	283.8			-5.50	-19.88	6.42	0.86	-7.35	6.42	0.96	Hg	2015	CCCB	GAIA DR1. PM data calculated from position comparison with SDSS DR9 - obviously no CPM
	122.31865417	12.0587417	1.99	279.0	11.20	11.69							0.31	C	2016.088		iT18 1x3s. Touching star disks
J#	RA	Dec	Sep"	PA°	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM Rat	Source/Notes
377	08:14:10.49	+06:59:43.1	1.8	355.0	12.20	12.90									2012		WDS08142+0658 values per 08/2016
	123.54369200	6.9952380	1.76	356.6									2.50	Es	2003.076		SDSS DR9
	123.54372083	6.9952139	1.69	350.4	11.88	13.53							0.31	C	2016.088		iT18 1x3s. Overlapping star disks
																	No objects for B in 2MASS, URAT1 and GAIA DR1. No SDSS9 object for A and B
J#	RA	Dec	Sep"	PA°	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM Rat	Source/Notes
380	08:22:36.77	+07:48:39.0	3.5	197.0	10.82	11.06	16	73							2000		WDS08226+0748 values per 08/2016
	125.65320600	7.8107830	3.43	197.3	10.42	11.03							1.30	E2	1998.782		2MASS. M1 and M2 estimated from J- and K-band
	125.65318333	7.8106528	3.25	198.4	10.43	10.76							0.31	C	2016.090		iT18 1x3s. Touching star disks
																	No objects for B in URAT1 and GAIA DR1

Table 1 continues on next page.

Jonckheere Double Star Photometry – Part V: Cancer

Table 1 (continued). J objects in Cancer

J#	RA	Dec	Sep "	PA °	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM Rat	Source/Notes
381	08:31:22.08	+13:30:50.8	2.9	308.0	10.65	13.30	-4	-6							2005		WDS08314+1331 values per 08/2016
	127.84187900	13.5140490	2.92	317.5		15.61							2.50	Es	2005.096		SDSS DR9. Vmag M2 estimated from (gmag+rmag)/2
	127.84197083	13.5141417	2.54	308.7	10.55	12.27							0.31	C	2016.088		iT18 1x3s. Touching star disks. SNR B <20
																	No objects for B in 2MASS, URAT1 and GAIA DR1
J#	**RA**	**Dec**	**Sep"**	**PA°**	**M1**	**M2**	**pmRA1**	**pmDec1**	**e_pm1**	**pmRA2**	**pmDec2**	**e_pm2**	**Ap**	**Me**	**Date**	**CPM Rat**	**Source/Notes**
382	08:42:18.57	+08:56:57.2	4.2	44.0	9.30	10.60	-9	-19							2012		WDS08423+0857 values per 08/2016
	130.57742400	8.9492340	4.24	44.4	9.31								1.30	E2	2000.183		2MASS. M1 estimated from J- and K-band
	130.57738080	8.9491785	4.34	43.7			-10.37	-13.50	8.24	-8.35	-6.02	9.18	0.96	Hg	2015	CCCB	GAIA DR1. PM data calculated from position comparison with 2MASS - obviously no CPM
	130.57734583	8.9491639	4.27	43.1	9.55	11.42							0.31	C	2016.090		iT18 1x3s
J#	**RA**	**Dec**	**Sep"**	**PA°**	**M1**	**M2**	**pmRA1**	**pmDec1**	**e_pm1**	**pmRA2**	**pmDec2**	**e_pm2**	**Ap**	**Me**	**Date**	**CPM Rat**	**Source/Notes**
415	09:14:03.87	+09:07:59.8	4.2	59.0	9.50	9.60	-49	-26		7	10				2015		WDS09141+0906 values per 08/2016. WDS mags and PM data obviously wrong. Seems despite the rather small proper motion vector length a quite solid CPM candidate. The difference in PM vector length might suggest an orbit. The position error is in comparison with the PM vector length rather large, but the relationship separation to PM is only about 150 years
	138.51613100	9.1332360	4.13	57.4	12.26	12.25							1.30	E2	2000.143		2MASS. M1 and M2 estimated from J- and K-band
	138.51613800	9.1331990	4.21	57.2									2.50	Es	2002.953		SDSS DR9
	138.51603334	9.1331630	4.17	57.3			-23.36	-17.70	8.10	- 21.15	-16.02	8.10	0.96	Hg	2015	ABCB	GAIA DR1. PM data calculated from position comparison with 2MASS
	138.51595833	9.1332333	4.15	57.7	12.05	12.29							0.31	C	2016.254		iT18 1x3s. SNR A and B <20

Table 1 continues on next page.

Jonckheere Double Star Photometry – Part V: Cancer

Table 1 (continued). J objects in Cancer

J#	RA	Dec	Sep"	PA°	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM Rat	Source/Notes
732	08:02:11.93	+10:06:47.5	2.6	191.0	9.40	9.40	-5	-2							2008		WDS08023+1008 values per 08/2016
	120.54969717	10.1134345	2.58	191.8									0.96	Hg	2015		GAIA DR1
	120.54962083	10.1133861	2.82	189.1	12.18	12.76							0.31	C	2016.090		iT18 1x3s. SNR A <20 and B <10
																	No objects for B in 2MASS, SDSS and URAT1
J#	**RA**	**Dec**	**Sep"**	**PA°**	**M1**	**M2**	**pmRA1**	**pmDec1**	**e_pm1**	**pmRA2**	**pmDec2**	**e_pm2**	**Ap**	**Me**	**Date**	**CPM Rat**	**Source/Notes**
734	08:08:55.54	+07:49:41.1	1.9	237.0	10.80	11.56									2002		WDS08089+0750 values per 08/2016
	122.23128356	7.8280218	1.88	236.7									0.96	Hg	2015		GAIA DR1
	122.23079583	7.8280194	1.70	245.6	10.38	10.68							0.31	C	2016.088		iT18 1x3s. SNR B <20. Rather average large plate solving position error
																	No objects for B in 2MASS, SDSS and URAT1
J#	**RA**	**Dec**	**Sep"**	**PA°**	**M1**	**M2**	**pmRA1**	**pmDec1**	**e_pm1**	**pmRA2**	**pmDec2**	**e_pm2**	**Ap**	**Me**	**Date**	**CPM Rat**	**Source/Notes**
735	08:46:07.92	+07:48:20.2	2.8	340.0	10.15	10.18	-99	54		-99	53				2014		WDS08461+0748 values per 08/2016. WDS PM data suggests clearly CPM - this is not supported by the position comparison between 2MASS and GAIA DR 1. But as it seems the position for B in 2MASS might be completely off as is visually suggested in the 2MASS image with 2MASS catalog overlay - the position given here for B does certainly not correspond with the centroid of the star disk. Comparison of POSS I.O and POSS II.J images supports clearly CPM
	131.53305200	7.8053710	1.66	338.0	9.97	9.36							1.30	E2	2000.116		2MASS. M1 and M2 estimated from J- and K-band
	131.53271824	7.8055358	2.78	339.8			-79.98	39.87	10.26	-102.99	112.09	9.01	0.96	Hg	2015	CCCB	GAIA DR1. PM data calculated from position comparison with 2MASS - quite different in direction and speed, no CPM
	131.53265833	7.8055500	2.60	341.7	9.85	9.91							0.31	C	2016.090		iT18 1x3s. Touching star disks
J#	**RA**	**Dec**	**Sep"**	**PA°**	**M1**	**M2**	**pmRA1**	**pmDec1**	**e_pm1**	**pmRA2**	**pmDec2**	**e_pm2**	**Ap**	**Me**	**Date**	**CPM Rat**	**Source/Notes**
1002	08:07:24.95	+11:44:02.3	2.3	118.0	9.30	9.50	-15	-2		27	-6				2008		WDS08074+1145 values per 08/2016
	121.85399100	11.7339590	2.11	119.9									2.50	Es	2005.509		SDSS DR9
	121.85396928	11.7339333	2.28	118.3			-7.80	-9.42	7.24	11.12	-13.10	9.03	0.96	Hg	2015	CCCB	GAIA DR1. PM data calculated from position comparison with SDSS DR9 - obviously no CPM
	121.85393333	11.7339528	2.21	114.3	11.31	11.29							0.31	C	2016.088		iT18 1x3s. Touching star disks

Table 1 continues on next page.

Jonckheere Double Star Photometry – Part V: Cancer

Table 1 (continued). J objects in Cancer

J#	RA	Dec	Sep"	PA°	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM Rat	Source/Notes
1007	08:36:47.77	+09:48:18.6	5.0	237.0	10.20	11.20	2	-21		-4	-23				2003		WDS08367+0948 values per 08/2016
	129.19906200	9.8051800	5.00	238.0	9.31								1.30	E2	2000.902		2MASS. M1 estimated from J- and K-band
	129.19904018	9.8051039	5.02	236.9			-5.49	-19.43	7.02	-3.07	-26.10	7.02	0.96	Hg	2015	CCCB	GAIA DR1. PM data calculated from position comparison with 2MASS. Rather no CPM even if the motion of both stars seems rather similar
	129.19901667	9.8051000	5.04	238.8	9.61	11.21							0.31	C	2016.254		iT18 1x3s. SNR B<20
J#	**RA**	**Dec**	**Sep"**	**PA°**	**M1**	**M2**	**pmRA1**	**pmDec1**	**e_pm1**	**pmRA2**	**pmDec2**	**e_pm2**	**Ap**	**Me**	**Date**	**CPM Rat**	**Source/Notes**
1009	09:07:27.89	+11:36:24.2	4.5	73.0	11.02	12.01	-21	-34		44	-10				2015		WDS09075+1136 values per 08/2016
	136.86624500	11.6067180	4.54	73.6	11.03	11.98							1.30	E2	2000.140		2MASS. M1 and M2 estimated from J- and K-band
	136.86614553	11.6065690	4.56	73.1			-23.61	-36.09	7.67	-23.28	-32.84	7.67	0.96	Hg	2015	ABCB	GAIA DR1. PM data calculated from position comparison with 2MASS - not a perfect CPM candidate but looks promising even if the error size in relation of the PM vector length is rather limited. Small difference in PM vector length might be a potential hint for an orbit
	136.86611667	11.6065833	4.59	72.4	11.01	12.23							0.31	C	2016.088		iT18 1x3s. SNR B<20
J#	**RA**	**Dec**	**Sep"**	**PA°**	**M1**	**M2**	**pmRA1**	**pmDec1**	**e_pm1**	**pmRA2**	**pmDec2**	**e_pm2**	**Ap**	**Me**	**Date**	**CPM Rat**	**Source/Notes**
1110	08:42:06.27	+25:00:43.4	3.4	42.0	9.92	10.24	-47	-21		-25	3				2012		WDS08421+2501 values per 08/2016
	130.52625500	25.0121710	2.71	42.5	9.10								1.30	E2	1998.092		2MASS. M1 estimated from J- and K-band
	130.52615740	25.0120864	3.41	41.2									0.20	Eu	2000.580		UCAC4. Date is calculated mean epoch
	130.52594389	25.0120214	3.41	41.8			-60.03	-31.86	9.20	-33.99	0.12	6.69	0.96	Hg	2015	CCCA	GAIA DR1. PM data calculated from position comparison with 2MASS - obviously no CPM. But the 2MASS position data seems a bit off
							-46.03	-17.70	1.805	-42.15	-20.99	1.117	0.96	Hg	2015	CCAA	GAIA DR1. This is one of the so far rare cases with PM data for both components directly in the GAIA catalog. While these values give to some degree the impression of potential CPM they are not close enough for such a conclusion: Delta PM vector direction is more than 5° and difference in PM vector length is near 5%. We have also given the parallax with 5.91mas for A and 5.94mas for B with an error of 0.37 and 0.38mas indicating that the distance between these two stars might be less than 1 parsec but with the given error range probably much more
	130.52597917	25.0119778	3.41	44.2	9.72	10.11							0.31	C	2016.090		iT18 1x3s

Table 1 concludes on next page.

Jonckheere Double Star Photometry – Part V: Cancer

Table 1 (conclusion). J objects in Cancer

J#	RA	Dec	Sep"	PA°	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM Rat	Source/Notes
2051	07:59:52.11	+13:06:35.1	6.0	131.0	11.10	12.00	-14	3		27	-27				2013		WDS08000+1307 values per 08/2016
	119.96663300	13.1101310	5.88	130.2	13.05	14.21							1.30	E2	1997.836		2MASS. M1 and M2 estimated from J- and K-band
	119.96663500	13.1101397	5.90	130.3	12.83		0.44	1.97	5.35	1.24	0.27	5.27	0.20	Eu	2013.825	CCCC	URAT1. PM data calculated from position comparison with 2MASS - obviously no CPM
	119.96663045	13.1101383	5.91	130.2			-0.52	1.53	4.94	0.86	-0.10	4.94	0.96	Hg	2015	CCCC	GAIA DR1. PM data calculated from position comparison with 2MASS - obviously no CPM
	119.96654167	13.1101639	6.36	129.9	13.08	14.40							0.61	C	2016.859		iT24 5x3s
J#	RA	Dec	Sep"	PA°	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM Rat	Source/Notes
2063	08:45:35.34	+09:16:03.2	7.9	115.0	12.63	12.74	-3	-5		-5	-8				2000		WDS08456+0915 values per 08/2016. Note Code "B" for blue magnitudes
	131.39701300	9.2673590	7.84	114.4	11.01	12.12							1.30	E2	2000.116		2MASS. M1 and M2 estimated from J- and K-band
	131.39695145	9.2673410	7.72	115.1			-14.69	-4.34	5.70	-24.80	-6.61	5.70	0.96	Hg	2015	ACCB	GAIA DR1. PM data calculated from position comparison with 2MASS - PM values too small to be significant, but CPM possi-ble, potentially with orbit
	131.39691667	9.2673333	7.78	115.1	10.94	12.06							0.31	C	2016.254		iT18 1x3s
J#	RA	Dec	Sep"	PA°	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM Rat	Source/Notes
2067	09:09:45.10	+08:47:48.3	10.8	343.0	11.74	12.87	-1	-3		3	63				2015		WDS09100+0849 values per 08/2016
	137.43793700	8.7967680	9.91	340.2	12.17	13.41							1.30	E2	2000.140		2MASS. M1 and M2 estimated from J- and K-band
	137.43791476	8.7967958	10.73	342.3			-5.32	6.74	6.66	2.08	67.29	6.66	0.96	Hg	2015	CCCB	GAIA DR1. PM data calculated from position comparison with 2MASS - obviously no CPM
	137.43795833	8.7967472	10.97	342.2	12.25	13.22							0.31	C	2016.088		iT18 1x3s

Explanations Notes column:

- "iT28 1x3s" indicates the use of telescope iT18 images with 3s exposure time and use of URAT1 for plate solving
- "iT24 5x3s" indicates the use of stacked telescope iT24 images with 3s exposure time and use of URAT1 for plate solving
- "Touching star disks" indicates that the rims of the star disks are touching and that the measurement results might be a bit less precise than with clearly separated star disks
- "Touching/Overlapping star disks" indicates that the star disks overlap to the degree of an elongation and that the measurement results is probably less precise than with clearly separated star disks
- "SNR <20" indicates that the measurement result might be a bit less precise than desired due to a low SNR value but this is already included in the calculation of the magnitude error range estimation
- "SNR <10" indicates that the measurement result is probably a bit less precise than desired due to a very low SNR value but this is already included in the calculation of the magnitude error range estimation
- "Image quality questionable" or similar indicates rather large average errors for the reference stars used for plate solving for different reasons (one of them might be objects with fast proper motion not or wrong given in URAT1). But this is already included in the calculation of the error range estimation

Appendix A

Table 2 gives the plate solving errors for the used images and error information derived from the measurements reported in Table 1 and also the measured positions for both components.

Table 2: Error estimations for the in table 1 provided measurements for the given objects:

Name		RA	Dec	dRA	dDec	Err_Sep	Err_PA	Err_Mag	SNR	dVmag
J 46	A	07 55 39.135	12 40 08.51	0.09	0.15	0.175	4.336	0.063	54.54	0.06
	B	07 55 38.980	12 40 08.93					0.069	31.97	
J 73	A	08 25 57.584	07 49 08.50	0.07	0.11	0.130	1.967	0.071	124.06	0.07
	B	08 25 57.431	07 49 05.46					0.076	37.66	
J 76	A	09 00 18.894	09 17 18.05	0.05	0.08	0.094	1.217	0.093	43.80	0.09
	B	09 00 18.596	09 17 17.55					0.118	13.76	
J 77	A	09 05 04.676	10 29 22.87	0.08	0.10			0.051	108.89	0.05
	B									
J 375	A	08 08 54.749	12 12 27.41	0.06	0.10	0.117	0.696	0.096	30.88	0.09
	B	08 08 55.040	12 12 18.81					0.098	27.07	
J 375	A	08 08 54.749	12 12 27.41	0.06	0.10	0.117	0.447	0.096	30.88	0.09
	C	08 08 54.607	12 12 42.21					0.125	11.98	
J 376	A	08 09 16.477	12 03 31.47	0.09	0.10	0.135	3.868	0.116	29.69	0.11
	B	08 09 16.343	12 03 31.78					0.121	20.82	
J 377	A	08 14 10.493	06 59 42.77	0.09	0.09	0.127	4.297	0.091	24.53	0.08
	B	08 14 10.474	06 59 44.44					0.248	4.15	
J 380	A	08 22 36.764	07 48 38.35	0.07	0.12	0.139	2.451	0.102	53.71	0.10
	B	08 22 36.695	07 48 35.27					0.104	39.90	
J 381	A	08 31 22.073	13 30 50.91	0.05	0.08	0.094	2.125	0.093	44.56	0.09
	B	08 31 21.937	13 30 52.50					0.133	10.61	
J 382	A	08 42 18.563	08 56 56.99	0.08	0.13	0.153	2.046	0.082	66.05	0.08
	B	08 42 18.760	08 57 00.11					0.095	21.08	
J 415	A	09 14 03.830	09 07 59.64	0.23	0.19	0.298	4.109	0.129	15.41	0.11
	B	09 14 04.067	09 08 01.86					0.148	10.53	
J 732	A	08 02 11.909	10 06 48.19	0.07	0.09	0.114	2.319	0.108	17.46	0.09
	B	08 02 11.879	10 06 45.41					0.184	6.27	
J 734	A	08 08 55.391	07 49 40.87	0.37	0.28	0.464	15.296	0.079	28.53	0.07
	B	08 08 55.287	07 49 40.17					0.099	15.06	
J 735	A	08 46 07.838	07 48 19.98#	0.10	0.22	0.242	5.307	0.093	43.75	0.09
	B	08 46 07.783	07 48 22.45					0.094	42.01	
J 1002	A	08 07 24.944	11 44 02.23	0.06	0.08	0.100	2.593	0.089	27.47	0.08
	B	08 07 25.081	11 44 01.32					0.087	30.62	
J 1007	A	08 36 47.764	09 48 18.36	0.13	0.14	0.191	2.169	0.094	37.28	0.09
	B	08 36 47.472	09 48 15.75					0.114	15.15	
J 1009	A	09 07 27.868	11 36 23.70	0.06	0.09	0.108	1.349	0.105	34.36	0.10
	B	09 07 28.166	11 36 25.09					0.129	12.87	
J 1110	A	08 42 06.235	25 00 43.12	0.05	0.09	0.103	1.727	0.072	59.63	0.07
	B	08 42 06.410	25 00 45.57					0.074	45.08	
J 2051	A	07 59 51.970	13 06 36.59	0.11	0.10	0.149	1.339	0.064	47.95	0.06
	B	07 59 52.304	13 06 32.51					0.076	22.67	
J 2063	A	08 45 35.260	09 16 02.40	0.10	0.10	0.141	1.041	0.113	40.60	0.11
	B	08 45 35.736	09 15 59.10					0.120	21.79	
J 2067	A	09 09 45.110	08 47 48.29	0.06	0.11	0.125	0.654	0.122	19.76	0.11
	B	09 09 44.884	08 47 58.74					0.143	11.43	

- dRA and dDec = average RA and Dec plate solving errors in arcseconds
- Err_Sep = separation error estimation in arcseconds calculated as SQRT(dRA^2+dDec^2)
- Err_PA = position angle error estimation in degrees calculated as arctan (Err_Sep/Sep) assuming the worst case that Err_Sep points perpendicular to the separation vector
- dVmag as average mag plate solving error (Vmag for images with made V-filter and Imag for images made with I-filter)
- Err_Mag = magnitude error estimation calculated as SQRT(dVmag^2+(2.5*LOG10(1+1/SNR))^2)
- SNR as signal to noise ratio for the given object

Appendix B

CPM rating scheme according to Knapp/Nanson 2016 with extensions:

Four rating factors are used: Proper motion vector direction, proper motion vector length, size of position error in relation to proper motion vector length and relationship separation to average proper motion speed:

- Proper motion vector direction rating: "A" for within the error range identical direction, "B" for similar direction within the double error range and "C" for outside
- Proper motion vector length rating: "A" for within the error range identical length, "B" for similar length within the double error range and C for outside
- Error size rating: "A" for error size of less than 5% of the proper motion vector length, "B" for less than 10% and "C" for a larger error size
- Rating for relation separation to average proper motion speed: "A" for less than 100 years, "B" for 100 to 1000 years and "C" for above.

To compensate for (depending on the selected objects and available catalogs) excessively large position errors resulting an "A" rating despite rather high deviations, absolute upper limits are applied regardless calculated error size:

- Proper motion vector direction: Max. 2.86° difference for an "A" and 5.72° for a "B"
- Proper motion vector length: Max. 5% difference for an "A" and 10% for a "B"

Modification for cases of very small position errors (when for example using SDSS9 instead pf 2MASS) with the consequence that the requirements to get an A or even B CPM rating get unreasonablely hard:

- The from the position error resulting error estimation for proper motion vector direction and length is in this case calculated as root mean square from both position errors (instead of so far only the larger 2MASS one)
- If the PM vector direction difference is larger than this calculated "allowed" error but still less than 0.5° then an "A" is given, a "B" is given for larger than 0.5 but less than 1 degree, and a "C" is given if above
- If the PM vector length difference is larger than this calculated "allowed" error but still less than 0.5% then an "A" is given, a "B" is given for larger than 0.5 but less than 1 percent, and a "C" is given if above.

Report on the Observation of Binaries in 2013: Humacao University Observatory

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Abstract: This is a report on observations of position angle and separation of binary stars of the year 2013 from the Humacao University Observatory. The stars analyzed totaled 62; they were imaged at the NURO 31 inch telescope in Flagstaff, Arizona in June 2013. The images were analyzed at the Humacao Observatory of the University of Puerto Rico.

Introduction

The objective of this paper is to continue reporting on measurements of position angle and separation of binary stars gathered from CCD images obtained at the National Undergraduate Research Observatory (NURO) telescope. The Humacao Campus of the University of Puerto Rico is a member of NURO, a consortium of primarily undergraduate institutions (www.nuro.nau.edu) with access to a 31 inch telescope owned by Lowell Observatory. This telescope, located at the Anderson Mesa facilities of the Lowell Observatory (located roughly 20 miles east of Flagstaff, Arizona at an altitude of 7200 feet) is equipped with a 2K X 2K CCD camera with 15 micron pixels. The camera is cooled to -110 C.

We present here our observations for the year 2013. A total of 62 images were considered fit for analysis. They were gathered at the prime focus of the NURO telescope during an observing run in June 16, 17 and 18 of 2013. We usually gather data in September or October but, for the first time in many years, we were rained and clouded out in our September visit. So we limit our report to the June data.

Procedure

Students pursuing undergraduate research projects at the Humacao Campus Observatory of the University of Puerto Rico analyzed the CCD images following a procedure detailed in a previous paper (Muller et.al, 2010). The 62 binaries are detailed here in Table I following standard JDSO ordering.

Acknowledgements

We made extensive use of the Washington Double Star Catalog of the U.S. Naval Observatory. We also looked into the Sixth Catalog of Orbits for information pertaining to binaries. We would like to acknowledge support for this project from the Puerto Rico Space Grant Consortium and the L.S. Alliance for Minority Participation of the University of Puerto Rico. We also want to thank Ed Anderson of NURO for his efforts on behalf of our students.

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Report on the Observation of Binaries in 2013: Humacao University Observatory

Table I.

Name	RA	DEC	Magnitudes		ρ	θ	Date 2013+
GRV 849	120253.16	+234550.8	12.03	12.35	28.1	232.32	0.457
STI 738	120317.64	+592405.8	12.24	13.1	6.59	40.82	0.457
STF1594AD	120328.56	+412415.5	10.09	14.4	27.21	74.32	0.457
BAL1450	120311.85	+004348.8	11.70	12.46	22.84	210.99	0.457
POU3120	120405.70	+231140.6	11.09	13.1	14.26	199.32	0.457
BU 458	120417.11	-210221.0	7.87	9.97	30.87	234.82	0.457
HJ 1206	120243.45	+042435.4	11.4	11.5	16.93	225.99	0.457
KZA 26	120507.86	+432246.7	13.0	13.6	16.88	110.82	0.457
HJ 4496	120612.76	-185327.9	10.05	10.98	12.50	30.65	0.457
COU2707	123004.89	+222216.5	11.77	14.1	14.20	346.15	0.457
HJ 519	123026.33	+360744.7	10.32	10.35	18.10	192.57	0.457
ES 726AC	123049.06	+535129.7	10.48	13.6	20.19	179.82	0.457
STF1650	123132.99	+243713.1	9.54	10.47	16.60	182.32	0.457
LDS4224	123213.27	+314719.6	10.4	13.5	11.05	311.62	0.457
HJ 211	123221,12	-015333.3	11.86	11.77	11.6	28132	0.457
HJ 2641	130855.13	+075958	12.1	12.8	12.9	249.32	0.460
HJ 542	141221.20	364612.6	12.9	12.5	12.20	57.32	0.460
STF1821AB	141329.00	+514723.8	4.53	6.62	12.15	259.32	0.460
SWI 1	140233.18	+462023.9	10.05	10.26	4.91	22.82	0.460
KZA 80	152042.06	+313315.1	12.13	12.82	23.6	54.82	0.460
KZA 87	152448.68	+293428.4	12	12.5	10.83	357.32	0.460
STF1999AB	160425.96	-112657.6	7.52	8.05	11.98	101.48	0.463
ARA 433	160635.80	-181911.6	11.6	14.1	9.94	58.92	0.463
ALI 370	160726.70	+354827.8	12.0	13.0	13.13	150.07	0.463
POU 3214	160748.84	+230529.9	11.1	13.3	12.58	86.32	0.463
STF2010AB	160804.55	+170249.2	5.10	6.21	28.31	15.82	0.463
BAL 564	161109.67	-020613.7	11.53	11.8	12.58	283.82	0.463
POU3216	161323.41	+242948.1	13.7	14.9	14.18	297.32	0.463
STF2032AB	161440.85	+335131.0	5.62	6.49	4.58	239.32	0.463
ES 627	161835.71	+511951.5	9.88	10.98	12.26	292.07	0.463
BAL2421	164056.30	+033806.0	8.51	11.1	9.21	230.32	0.463

Table 1 concludes on next page.

Report on the Observation of Binaries in 2013: Humacao University Observatory

Table 1.

Name	RA	DEC	Magnitudes		ρ	θ	Date 2013+
KZA 120	165322.06	+460130.9	10.5	10.5	10.55	82.62	0.463
BAL2429	165451.18	+031840.8	11.77	12.8	12.0	56.32	0.463
ES 1255	170100.54	+461626.8	8.19	11.7	7.30	49.32	0.463
HJ 2804AB	170433.42	+385927.3	11.00	13.3	7.23	238.07	0.463
WFC 186	170605.40	+432857.4	10.81	12.11	18.55	18.07	0.463
STF2123	170657.50	+064803.0	9.82	9.98	18.07	218.62	0.463
STF2127	170704.42	+310535.1	8.70	12.30	14.65	286.82	0.463
SLE 9	170706.29	+202921.7	10.49	12.30	20.3	177.07	0.463
ARA1121	170706.09	-201443.6	11.8	12.4	8.13	215.15	0.463
BEM 26	170836.72	+502245.2	11.06	13.34	14.78	199.32	0.463
STF2250AB	175918.09	-065121.2	8.79	9.24	8.26	346.82	0.463
STI2369	180729.23	+551431.1	12.3	12.6	14.78	191.32	0.463
SLE 85	180733.14	+031353.7	11.2	12.5	11.17	182.32	0.463
BAL1952	180734.41	+022407.8	11.52	12.8	13.06	155.32	0.463
STF2280AB	180749.56	+260604.4	5.81	5.84	13.93	181.32	0.463
SLE 138	180752.70	+304157.2	11.5	12.3	11.01	328.32	0.463
POU3338	175954.77	+233053.1	9.70	13.5	9.16	321.62	0.463
ES 183	180801.13	+364204.1	9.36	12.7	9.01	168.32	0.463
POU3351	180808.78	+232712.4	12.05	13.9	9.19	157.62	0.463
ARA 453	180852.23	-182655.1	10.69	12.5	9.0	57.82	0.463
SLE 111	180853.96	+272456.6	10.8	12.5	14.4	316.98	0.463
BEM 31	180941.21	+532931.5	9.90	12.3	12.63	311.57	0.463
STF2293	180953.83	+482405.7	8.08	10.34	13.73	85.82	0.463
BAL2483	181441.54	+034205.5	12.00	12.7	12.93	197.32	0.463
SLE 145	181458.39	+030343.6	11.2	11.9	11.92	30.62	0.463
ES 646	181509.43	+520924.8	8.72	14.1	9.48	204.32	0.463
POU3380	181722.66	+245636.2	12.4	13.3	12.84	74.82	0.463
HJ 1349	184848.77	+331912.1	8.29	10.7	29.41	97.32	0.463
STF2459	190722.01	+255823.9	9.12	10.07	14.21	234.92	0.463
AG 375	191413.48	+262628.4	9.89	10.92	18.43	302.82	0.463
SLE 959AB	201150.08	+372606.8	10.69	12.5	11.81	163.98	0.463

Measurements of Neglected Double Stars: December 2016 Report

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Abstract: This article presents measurements of 36 neglected double stars and one double star. The stars were selected from the Washington Double Star Catalog published by the United States Naval Observatory. The photographs were taken by remote telescopes. The measurements were done by the author.

Methodology

Photographs were taken using telescopes operated by the SLOOH observatories, which are part of the Institute of Astrophysics. One of the observatories is located in the Canary Islands near the west coast of Africa. That telescope is located at an elevation of 2,300 meters on the island of Tenerife. The instrument has a focal length of 3,910mm, an aperture of 356mm, and is a Celestron unit of Schmidt-Cassegrain design. The other observatory is located near Santiago, Chile. That telescope is the same model as the unit located in the Canary Islands. The methods used to calibrate the instruments of the SLOOH observatories are unknown to this author.

The camera used most frequently was a CCD SBIG 10XME, but some photographs were taken using a CCD SBIG 2000XM.

The photographs were analyzed by the author using the programs CCD Soft v5 and SKY 6. The two programs are products of Software Bisque.

After accumulating the photographs, averages were calculated for the position angles and separations. All of the star patterns were compared with the data from ALADIN (part of the SIMBAD site), or with the SKY X program to insure correctness. After measuring each star and calculating the results, comparisons were made with the published data. The results are listed in the tables, which contain averages of measurements, or, in the case of a single measurement, the actual value. The statistical calculations were rounded to one decimal place in accord with significant figure rules.

Report

The following information was reported for each star: the WDS code with components, the discoverer code, the constellation, the position angle, the separation, the date of the last observation, and, under measures by the author, the results of other authors. The number of measurements, and the WDS values were taken from the WDS on the last observation date.

The column headings are: Washington Double Star identifier and components, DC = Discovery Code, PA = position angle, SD = standard deviation, SE = standard error of the mean, Sep = Separation, Mts = number of measurements, Con = Constellation, and the last observation date.

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WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
02145+5912 AB	**STI 1812**	***58.6***	***0.5***	***0.3***	***10.8***	***0.3***	***0.1***	**3**	**CAS**	**2016.7066**
WDS		41			8.0					1908
WDS		59			10.7			9		2012

Other identifiers: CCDM J02145+5912A, IDS 02074+5844A, 2MASS J02142896+5912231

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
04480+5307 AB	**STF 587**	***185.8***	***0.3***	***0.2***	***20.9***	***0.1***	***0.1***	**3**	**CAM**	**2016.7367**
JDSO (Bertoglio)		*186*			*21*					2010
Tycho-2		186			20.8					1991
WDS		185			19.6					1882
WDS		188			21.2			30		2013

Other identifiers: ADS 3442 A, BD+52 880, SAO24835, TYC 3733-656-1

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
05463+3152 AB	**SEI 384**	***176.2***	***0.7***	***0.4***	***14.0***	***0.2***	***0.1***	**4**	**AUR**	**2016.7751**
JDSO (Berkó)		354.4			13.9					2009
OAG		355.5			13.7					1982
WDS		171			15.3					1899
WDS		174			13.9			9		2007

Other identifiers: TYC 2405-337-1, CCDM J05463+3152B, 2MASS J05461620+3152206

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
06084+2048 AB	**AZC 48**	***27.8***	***1.4***	***0.7***	***25.2***	***0.2***	***0.1***	**4**	**ORI**	**2016.6190**
WDS		27.0			25.1					1997
WDS		27.0			25.2			2		2000

Other identifiers:: HD 252131

Measurements of Neglected Double Stars: December 2016 Report

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
06324+1312 AB	**AG 326**	***3.8***	***2.2***	***0.6***	***24.0***	***0.1***	***0.1***	**13**	**GEM**	**2015.1433**
JDSO (Schlimmer)		4			23.9					2009
Webb		4.1			23.4					1982
WDS		120			1.5					1871
WDS		4			23.5			4		1999

Other identifiers: AG+13 604, BD+13 1296, GSC00745-00517, SAO95802, TYC 745-517-1

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
07082-0151 AB	**J 2781**	***6.4***	***0.3***	***0.1***	***25.1***	***0.1***	***0.1***	**6**	**MON**	**2015.3158**
JDSO (Berkó)		9.1			25.8					2009
WDS		10			25.8					1893
WDS		9			25.9			8		2008

Other identifiers: CCDM J07082-0152A; GSC 04185-02431; IDS 07031-0142A

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
07144-1519 AB	**ROE 26**	***121.3***	***1.3***	***0.7***	***10.4***	***0.1***	***0.1***	**4**	**CMA**	**2016.8463**
JDSO (Nugent)		*120.5*			*8.7*					2016
WDS		119			8.0					1910
WDS		121			8.7			7		2016
07144-1519 AC	**ROE 26**	**50.6**	**0.7**	**0.3**	**52.4**	**0.3**	**0.1**	**4**	**CMA**	**2016.8463**
OAG		52			51.4					1982
WDS		50			41.3					1910
WDS		51			52.5			6		2016

Other identifiers:: BA-15 1715, CCDM J07144-1519A, TYC 5965-917-1

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
07426+0330 AB	**BAL 2303**	***118.0***	***0.7***	***0.4***	***7.9***	***0.1***	***0.1***	**3**	**CMI**	**2016.8463**
WDS		113			10.8					1910
WDS		118			8.0			6		2013

Other identifiers:: none

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
07493+0148 AB	**BAL 1820**	***178.7***	***0.3***	***0.2***	***13.1***	***0.1***	***0.1***	**4**	**CMI**	**2016.8463**
OAG		189.6			9.4					1983
WDS		205			13.1					1910
WDS		179			13.1			9		2015

Other identifiers:: none

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WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
07549+0039 AB	**BAL 1122**	***91.0***	***0.3***	***0.1***	***10.8***	***0.1***	***0.1***	**6**	**CMI**	**2016.8463**
JDSO (Nugent)		89.1			10.7					2016
WDS		90			10.9					1893
WDS		89			10.4			8		2015

Other identifiers: none

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
08009+0111 AB	**BAL 1419**	***327.6***	***1.1***	***0.5***	***15.2***	***0.4***	***0.2***	**4**	**CMI**	**2016.8463**
WDS		330			14.4					1909
WDS		328			14.9			8		2015

Other identifiers:: none

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
08026+1309 AB	**SLE 320**	***43.7***	***0.2***	***0.1***	***22.1***	***0.1***	***0.0***	**3**	**CNC**	**2016.0441**
WDS		44			22.7					1984
WDS		44			22.1			8		2016
08026+1309 AC	**SLE 320**	***221.6***	***0.1***	***0.1***	***52.3***	***0.1***	***0.0***	***3***	**CNC**	**2016.0441**
OAG (Minet)		220.9			52.2					1984
WDS		221			52.2					1984
WDS		222			52.3			7		2016
08026+1309 AD	**SLE 320**	***239.0***	***0.1***	***0.1***	***51.2***	***0.1***	***0.0***	***3***	***CNC***	***2016.0441***
OAG (Minet)		238.0			50.7					1984
WDS		238			50.3					1984
WDS		239			51.2			9		2016
08026+1309 CD	**SLE 320**	***324.3***	***0.1***	***0.0***	***15.7***	***0.1***	***0.0***	***3***	***CNC***	***2016.0441***
OAG (Minet)		323.9			15.2					1984
WDS		323			15.3					1984
WDS		324			15.7			10		2016

Other identifiers:: GSC 00793-00111, TYC 793-111-1

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
08213-1335 AB	**J 2876**	***158.2***	***1.0***	***0.6***	***5.1***	***0.1***	***0.0***	***3***	***PUP***	***2016.1645***
WDS		177			11.6					19.2
WDS		156			5.2			6		2007
08213-1335 AC	**J 2876**	***36.6***	***0.8***	***0.5***	***13.7***	***0.5***	***0.2***	***5***		***2016.1645***
WDS		32			14.6					1902
WDS		37			13.7			7		2007

Other identifiers:: none, not in SIMBAD, not in Aladin

Measurements of Neglected Double Stars: December 2016 Report

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
08273+0139 AB	**BAL 1425**	***148.6***	***0.1***	***0.0***	***15.3***	***0.1***	***0.0***	**4**	**HYA**	**2016.1262**
WDS		162			12.1					1910
WDS		150			15.2			7		2000

Other identifiers:: not in SIMBAD

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
08434+0340 AB	**BAL 2821**	***83.0***	***0.4***	***0.2***	***10.0***	***0.1***	***0.0***	**4**	**HYA**	**2016.1262**
OAG (Minet)		86.1			9					1982
WDS		86			8.2					1910
WDS		82			10.1			6		2008

Other identifiers: TYC 215-2231-1

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
08459-0643 AB	**HJ 796**	***123.3***	***1.8***	***0.8***	***22.5***	***0.2***	***0.1***	**5**	**HYA**	**2016.1262**
WDS		140			12.0					1827
WDS		124			21.5			11		2011

Other identifiers:: BD-06 2718, CCDM J08459-0643A; SAO136252, TYC 4876-1124-1

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
08462+1915 AB	**STF 1269**	***308.7***	***0.2***	***0.1***	***11.4***	***0.1***	***0.0***	**3**	**CNC**	**2016.0441**
OAG (Comellas)		*308.0*			*11.0*					1980
WDS		308			11.5					1827
WDS		309			11.4			17		2016

Other identifiers:: BD-+19 2100; GSC 01396-01217; SAO 98108; TYC 1396-1217-1

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
08505+0333 AB	**BAL 2351**	***110.0***	***1.1***	***0.5***	***14.2***	***0.2***	***0.1***	**4**	**HYA**	**2016.1645**
WDS		101			10.9					1899
WDS		108			13.9			8		2010

Other identifiers:: BD+04 2054; GSC 00216-01133; SAO 117186; TYC 216-1133-1

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
09216-0243 AB	**FIL 21**	***2.5***	***0.4***	***0.2***	***11.0***	***0.1***	***0.1***	**4**	**HYA**	**2016.1645**
JDSO (Buchheim)		2.2			11.2					2008
WDS		0			13.2					1897
WDS		2			11.1			9		2010

Other identifiers:: RAVE J092130.4-024146; TYC 4884-442-1

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WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
10084-1945 AC	**BU 911**	***54.2***	***0.7***	***0.3***	***83.4***	***1.2***	***0.6***	**4**	**HYA**	**2016.1481**
OAG		*55*			*79.5*					1980
WDS		83			47.3					1880
WDS		55			78.4			18		1999

Other identifiers: BD-19 2926; HD 87998; HIP 49668; SAO 155757; TYC 6067-598-1

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
13267-2418 AB	**BGH 6**	***268.1***	***0.1***	***0.0***	***319.0***	***0.8***	***0.4***	**4**	**HYA**	**2016.5232**
WDS		268.0			319.4					1933
WDS		268.0			319.4			14		2015

Other identifiers:: CCDM J13267-2418A; HD 116858; IDS 13211-2346A; SAO 181657; TYC 6713-183-1

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
13433-2458 AB	**HJ 2671**	***66.3***	***0.3***	***0.2***	***27.8***	***0.1***	***0.1***	**3**	**HYA**	**2016.5232**
JDSO (Nugent)		66.8			27.4					2014
OAG		71			29.0					1973
Tycho 2		67.1			27.4					1991
WDS		76			25.0					1831
WDS		67			27.4			16		2013

Other identifiers:: BDS 6595A; HD 119375; IDS 13378-2428A; SAO 181899; TYC 6719-378-1

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
19170+0144 AB	**BAL 1516**	***271.8***	***0.2***	***0.3***	***10.7***	***0.1***	***0.1***	**3**	**AQL**	**2016.6820**
OAG		271.6			9.2					1983
WDS AB		269			12.0					1909
WDS AB		272			11.2			10		2011

Other identifiers:: TYC 464-592-1

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
19303+0419 AB	**BAL 2943**	***288.1***	***0.5***	***0.3***	***11.8***	***0.2***	***0.1***	**3**	**AQL**	**2016.6847**
OAG		286			12					1980
WDS		288			10.3					1910
WDS		286			11.7			8		2010

Other identifiers:: BD+04 4128; HD 183617; IDS 19254+0407B; PPM 167993

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WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
19377-0958 AB	**LV 21**	***284.1***	***0.1***	***0.1***	***84.1***	***0.2***	***0.1***	**4**	**AQL**	**2016.7066**
JDSO (Curelaru)		285.4			86.5					2011
OAG (Tobal)		284.1			84					1984
WDS		287			83.9					1900
WDS		285			86.5			9		2010

Other identifiers: BD-10 5137; CCDM J19377-0958A; SAO 162829; TYC 5727-2380-1

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
19534+3934 AB	**MLB 946**	***221.3***	***1.2***	***0.6***	***5.1***	***0.1***	***0.1***	**4**	**CYG**	**2015.8989**
Webb (Soon)		216			5.4					2006
WDS		221			4.9					1934
WDS		219			5.6			5		2014

Other identifiers:: BD+39 3945; HD 226382; HIP 97875; SAO 69035; TYC 3141-1667-1 1

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
20055+5800 AB	**A 866**	***182.1***	***0.1***	***0.1***	***44.3***	***0.7***	***0.3***	**5**	**CYG**	**2016.5396**
WDS		180.0			31.1					1904
WDS		172			44.9			7		2015

Other identifiers: ADS 13385 AB; GEN#+1.00239319J

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
20105+3635 AB	**SEI 948**	***87.7***	***1.5***	***0.7***	***21.7***	***0.1***	***0.1***	**5**	**CYG**	**2016.5424**
OAG (Tobal)		*87.8*			*21.9*					1993
WDS		89.0			21.5					1896
WDS		87.0			21.5			7		2010

Other identfiers: GSC 02683-00666; IDS 20068+3617A; LF3a +36 34

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
20127+3645 AB	**SEI 1006**	***305.5***	***0.8***	***0.4***	***17.1***	***0.3***	***0.1***	**4**	**CYG**	**2016.5369**
JDSO (Micello)		306.0			17.0					2001
OAG (Tobal)		304.3			17.1					1993
WDS		307.0			17.1					1896
WDS		307.0			17.1			6		2010

Other identifiers: CCDM J20127+3645A; IDS 20090+3627A

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WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
20160+2929 AB	**MLB 478**	***13.1***	***0.4***	***0.2***	***6.3***	***0.2***	***0.1***	**4**	**CYG**	**2016.5478**
Webb (Soon)		12.9			7					2006
WDS		0			6.3					1894
WDS		13			7.0			6		2006

Other identifiers: HD 333973

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
20324+3859 AB	**SEI 1157**	***65.5***	***0.2***	***0.1***	***7.6***	***0.2***	***0.1***	**3**	**HYA**	**2015.9893**
WDS		66			7.4					1895
WDS		65			7.6			4		2002

Other identifiers:: TYC 3153-471-1

WDS number/Comp	D.C.	P.A.	SD	SM	SEP	SD	SM	Mts	Con	Date
23280+4301 AB	**CHE 481**	***280.7***	***0.3***	***0.1***	***15.6***	***0.3***	***0.1***	**7**	**AND**	**2016.6628**
WDS		287			15.0					1911
WDS		281			15.4			8		2015

Other identifiers:: BD+42 4679; GSC 03238-00459; PPM 64265; TYC 3238-459-1

Notes:

02145+5912 This star was formerly identified as WDS02144+5945 and SMA 31.

04480+5307 In the JDSO, Bartoglio (2010) reported PA = 224.2 and Se = 16.1. In the OAG, Comellas (1973) reported PA = 175 and Se = 21. In the OAG, Schnabel (1977) reported PA = 176 and Se = 20.3. In the OAG, Comellas (1980) reported PA = 175 and Se = 21.

05463+3152 In the JDSO, Berkó (2009) reported PA = 354.4 and Se = 13.9. In the OAG, Tobal (1982) reported PA = 355.5 and Se 13.7. Given that the Separation values match, perhaps their measurements were from B to A.

07082-0151 AB While my value for the position angle is significantly different from the WDS value(6.4 versus 9), I included my measurements for four reasons: 1) the data were consistent with a standard deviation of 0.3; 2) the measurements were taken over a period of 3 months; 3) six measurements were made using VIZIER, and the average value of 6.2 was close to my value of 6.4. [Please see Richard Harshaw's article on the use of VIZIER for this function (JDSO January 2013).]; 4) the separation was close to published values, and was as consistent as was the position angle.

13267-2418 The coordinates given in SIMBAD (RA = 13 26 39.5 and DE = 24 17 36) result in the same star. Entering the WDS coordinates in SIMBAD will result in a different star. Using VIZIER for four measuremnents, the average PA value was 268.2, and the average Separation value was 317.3

20055+5800 The position angle differs from the WDS value by +5.86%. These 5 values are very close, and were taken over a period of 14 months.

Reclassification of WDS 18224+4545 from a Binary to Optical Double Star

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Abstract: In 1998, based exclusively on visual observations, Wulff Heintz calculated an orbital path, with a period of 234 years and a semi-major axis of 0.55″, and determined that WDS 18224+4545 (A700) was a gravitationally bound binary star system. The research presented here disputes this and presents an optical double star system solution with a linear trajectory. Using data from the first speckle interferometry observation for A700, collected on October 22, 2013, with the 2.1-meter telescope at Kitt Peak National Observatory (KPNO), new separation and position angles were determined to be 0.623″ and 127.872°, respectively. These results diverge radically from Heintz's predicted orbit, and when correlated with past observational data, they follow a linear trend that returns a fit with an R^2 value of 0.977. New calculations predict a minimum separation of 0.076″ in the year 1953.

Introduction

This paper is the product of a summer Cuesta College Astronomy Research Seminar (ASTR 299) designed to introduce student teams to the processes of scientific research and subsequent publishing. Our team's specific goal was to obtain a data point to add to the orbit of a star system published in the Washington Double Star (WDS) catalog (Mason et al. 2012) with the hope that an accurate speckle interferometry observation would contribute to the accuracy of that system's published orbit. The importance of obtaining accurate orbits was best highlighted by the late Wulff Heintz, then a Professor Emeritus of Astronomy at Swarthmore College, in his seminal book *Binary Stars:* "Stellar masses are basic quantities for the theory of stellar structures and evolution, and they are obtained from binary-star orbits where they depend on the cube of observed parameters; this fact illustrates the significance of orbits as well as the accuracy requirements" (Heintz 1978).

Figure 1. Team picture - From left to right: Russell M. Genet, Jordan Steed, Ian R. Parent, Michelle Williams, Daniel Orman, Ellery Conover, S. Taylor Vaughn, Nels Siverson, Jessica C. Gardella, and Jonathan Ogden.

The student team (Figure 1) chose double star WDS 18224+4545 (A700) as a research subject for four specific reasons. First, on the night of October 22, 2013, double star A700 was observed on the 2.1-meter telescope equipped with a speckle interferometry camera at Kitt Peak National Observatory (KPNO) during an observing run of multiple stars believed to be binary. Second, the lack of any previous speckle interferometry observations meant that A700 was ripe for potential new discoveries. Third, A700 also only had ten published observations, with nine out of the ten being visual observations, plus one by Tycho-2 (Høg 2000). Finally, the Tycho-2 observation appeared to lie outside of the calculated orbit, lending reason to believe the system's orbit might need to be updated. This discrepancy could have come about because Wulff Heintz first determined the orbit solely from visual observations (he did not have access to the Tycho-2 plotted location at that time). Alternatively, the Tycho-2 observation could have been in error. Either way, the student team thought that an additional speckle interferometry observation might help decide between these two alternatives. Unsurprisingly, A700's orbit is classified in the Sixth Catalog of Orbits of Visual Binary Stars (ORB6) as a grade five, or indeterminate, which is the lowest quality orbit in the catalog.

These facts about A700 made it clear while conducting research that there appears to be a potential issue concerning many orbits of binary star systems in the WDS, and more specifically in the ORB6. For varying and often uncontrollable reasons, many of the cataloged stars lack enough highly accurate observations to form a precise orbit. Such was the case with A700. A 2012 paper in the Astronomical Journal, titled *Speckle Interferometry at SOAR in 2010 and 2011: Measures, Orbits, and Rectilinear Fits,* pointed out that, "of the 113,366 pairs in the Washington Double Star Catalog (WDS) (Mason et al. 2001), only 2,158 (or 1.9%) have orbital determinations of any quality. Of these, only 310 have orbits graded as either 'definitive' or 'good' in the Sixth Catalog of Orbits of Visual Binary Stars (Hartkopf et al. 2001), while 60% of cataloged orbits (excluding astrometric solutions) are considered either 'preliminary' and 'indeterminate'" (Hartkopf et al. 2012). These statistics further highlight the importance of conducting this kind of research into binary and optical star systems.

The discovery and first visual observation of A700 was in 1904 by Robert G. Aitken. Many of the subsequent observations of A700 were made by astronomers George A. Van Biesbroeck (1961), Paul Couteau (1972), and Wulff D. Heintz (1978).

Past Observations and Observers

Robert G. Aitken

In an editorial (Clark 2006), it was written that, "[Robert] G. Aitken was the grand old man of double star astronomy and still observed doubles visually long after others had turned to photography." R.G. Aiken was on the Board of Directors of the Astronomical Society of the Pacific for decades and penned the influential book *The Binary Stars*, originally published in 1918. He is ranked sixth on the list of the total number of double star observations. Over his entire career, Aitken discovered 3,087 new double stars and performed measurements of 26,560 pairs. Aitken was born in 1864 and passed away in 1951. In Figure 2, R.G. Aitken is in a pose he often held in his life looking up to the stars.

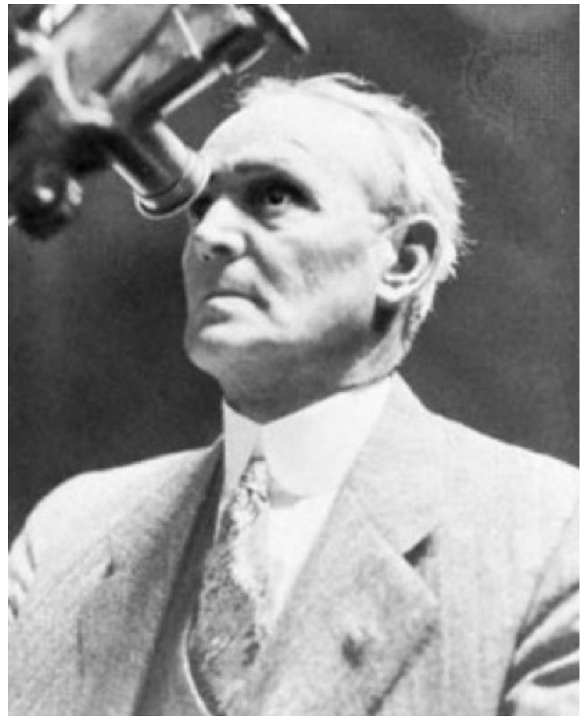

Figure 2. *Robert Grant Aitken in his later life doing what he did best—observing the stars with a filar micrometer on the great 36-inch refractor at Lick Observatory.*

R.G Aitken made the first recorded observation of double star A700 using a filar micrometer on the historic 36-inch–refractor at Lick Observatory on Mount Hamilton (Aitken 1904). He subsequently observed A700 in 1917 and 1928 (Aitken 1937).

Wulff D. Heintz

Wulff-Dieter Heintz wrote the seminal book on double star research, aptly named *Double Stars*, which is often attributed as the "field standard" by many experts in astronomy. Born in 1930 in Germany, he moved to the US where he was Professor of Astronomy at Swarthmore College in Pennsylvania during the latter half of his professional life. His productive career made him into one of the most respected scientists in double star research. He calculated the orbits of over 900 binary stars. Figure 3 shows Heintz along with his preferred instrument for observation. Heintz passed away in 2006.

Reclassification of WDS 18224+4545 from a Binary to Optical Double Star

Figure 3. *Wulff Heintz posing with filar micrometer attached to the refractor at Swathmore Observatorty*

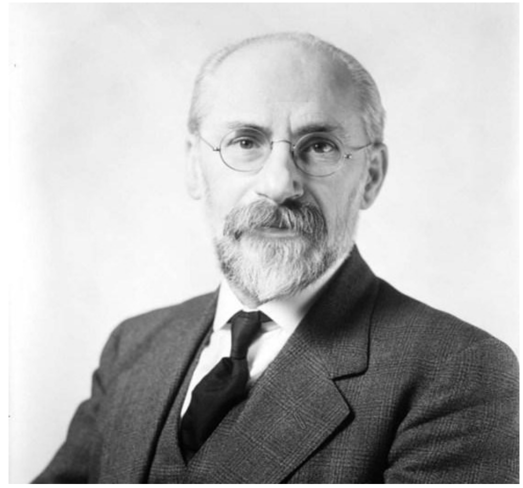

Figure 4. *George A. Van Biesbroeck.*

Heintz observed A700 in 1977 (Heintz 1978) and 1983 (Heintz 1985) and made his last visual observation in 1996 (Heintz 1998). He made these observations on the 61 cm refractor at Swarthmore Observatory. He has long been regarded as one of the best at using a filar micrometer for stellar observations. Nonetheless, the margin of error for this method, compared to more modern techniques, such as speckle interferometry, must be acknowledged. It was his last observation, straying into what looked like the beginnings of an orbital pattern, which may have led him to interpret the trajectory of A700 as binary. Still, a well-known double star expert suggested to our team that, "Given the number of orbits he [Heintz] did it's not surprising to see an error made by the 'Swarthmore Orbit Machine.' Still, I'd be willing to bet his percent wrong is lower than most!"

George A. Van Biesbroeck

George A. Van Biesbroeck (Figure 4) was an observational astronomer of double stars, comets, and asteroids. He was known for discovering the faintest star of its time. He was born in Belgium in 1880. After fleeing Europe at the end of WWI and becoming a US citizen, he began his career in astronomy. He went on to earn a degree in theoretical astronomy and pursued many challenging astronomical research projects, even in some of the most impoverished unstable regions of the world. He was a supervisor of the construction of the McDonald Observatory at the University of Texas.

He observed A700 in 1951, 1954, and 1960, using a filar micrometer on the 82 inch reflector at the McDonald Observatory (Biesbroeck 1965). Unfortunately, the 1951 and 1954 observations were both unresolved because, most likely, the secondary star passed near primary at this point in time. Then in 1961, he published his own Star Catalogue (Biesbroeck 1961) consisting of many small faint stars, including Red Dwarfs, for which he is most well-known. Even after a lifetime of success, he continued astronomy research to within a few months of his death in 1974.

Observation and Calibration

The observational data used for A700 was obtained on October 22, 2013, with the 2.1-meter telescope at KPNO and a speckle interferometry camera. The telescope had an effective focal length of 16,200 mm. With an 8x magnification Barlow lens before the speckle camera (Figure 5), the increased overall effective focal length was 129,600 mm with F/ratio of 61.7. This setup translates into a calibrated plate scale of 0.01166″/pixel (Genet 2015).

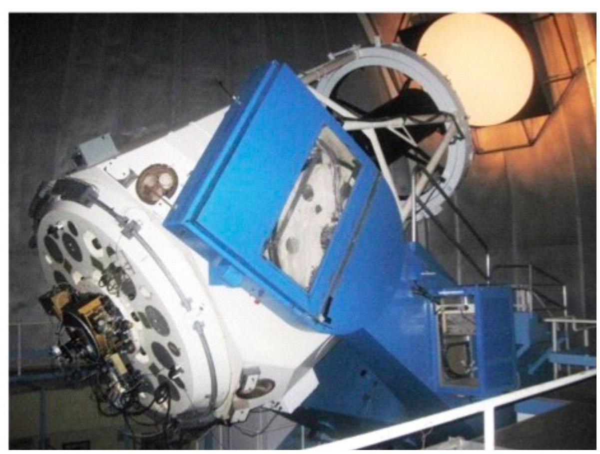

Figure 5. *2.1-meter telescope with speckle camera as used for the observations.*

Reclassification of WDS 18224+4545 from a Binary to Optical Double Star

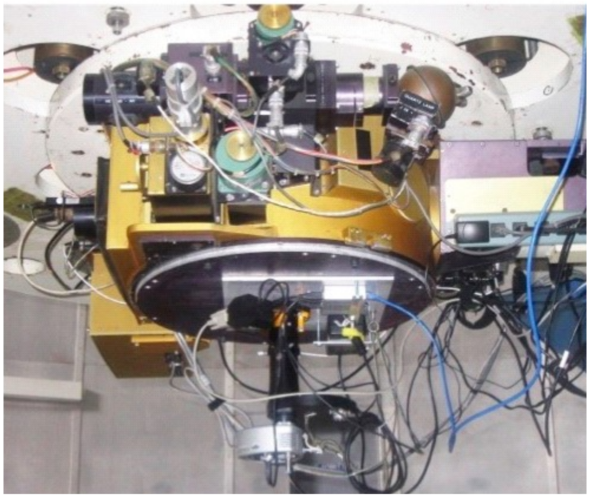

Figure 6. Speckle camera installed on the 2.1-meter telescope at KPNO.

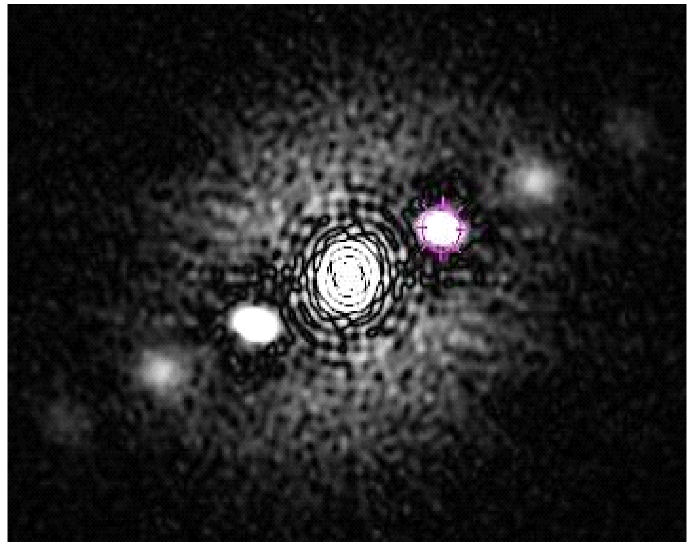

Figure 7. Autocorrelogram of A700 with the "Captain's wheel" marking the secondary star.

Frames were taken with an Andor Luca-R electron multiplying charge coupled device (EMCCD) camera. To minimize atmospheric dispersion, observations were made using a Sloan 'i' filter. The observations yielded a FITS data cube of 512 x 512 pixels x 1000 frames, with each frame having an exposure time of 10 milliseconds. The camera was attached to the acquisition-guider unit at the Cassegrain focus of the telescope (Figure 6). The camera's angle was additionally calibrated to -11.049° (Genet 2013).

Results

The 1000 images of A700 from the speckle observation were consolidated during the observation into a FITS data cube. The FITS cube was processed in PS3 reduction software to produce an autocorrelogram (Figure 7) and determine a new separation of 0.623″ and a new position angle of 127.872°. A FITS cube of deconvolution star HIP93713 was used in the processing to reduce atmospheric and telescope-induced distortions.

Discussion

Comparison to Past Observations

To identify any trends and/or deviations, A700 was analyzed using past observational data obtained from the WDS Catalog along with the new data point from the KPNO observation (Table 1). A deviation was identified when comparing the KPNO and the Tycho-2 data points to the Heintz orbital plot prediction, as both of these plot points fell outside the predicted orbital path (Figure 8). It was evident that, with the addition of the KPNO observation, the trend in the data does not support the established orbit as calculated by Heintz.

To investigate these deviations further, the data points for the KPNO and Tycho-2 observations were first analyzed individually against Heintz's orbital predictions, and then correlated with the full data set. For the night of the KPNO observation, the orbital elements, derived by Heintz, were used to determine a predicted separation and position angle of 0.118″ and 152.49°, respectively. However, the results from the KPNO speckle interferometry observation determined a separation and position angle of 0.623″ and 127.876°, respectively, and greatly deviated from the Heintz orbital prediction. In comparison to the published orbit,

Table 1.

Year	Rho (ρ)	Theta (θ)	Ap. (m)	Reference
1904.58	0.49	322	0.9	A_1904b
1917.13	0.44	328.4	0.9	A_1932a
1928.8	0.29	319.8	0.9	A_1937b
1960.55	0.15	105.3	2.1	VBs1965
1970.47	0.21	116.7	0.7	Cou1972e
1973.62	0.29	114.6	0.7	Wor1978
1977.57	0.25	112.7	0.6	Hei1978b
1983.52	0.33	116.5	0.6	Hei1985a
1991.61	0.47	121.1	0.3	TYC2002
1996.65	0.32	128.3	0.6	Hei1998
2013.81	0.623	127.872	2.1	Parent et al.

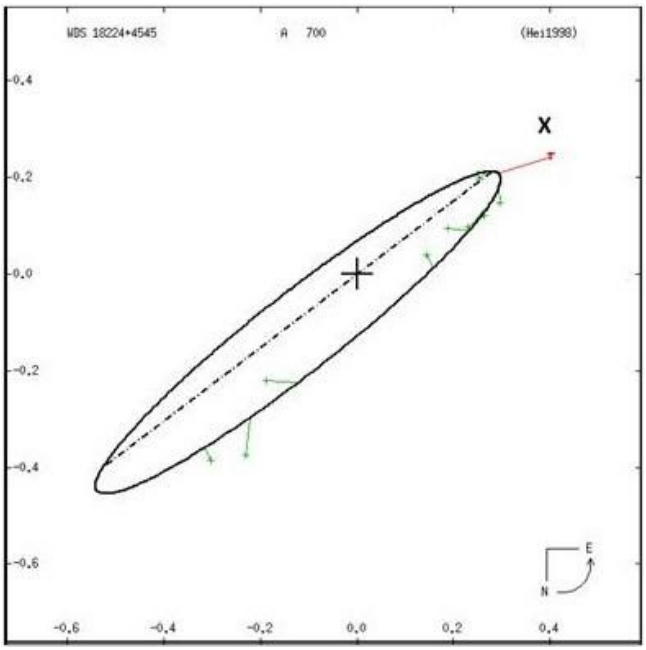

Figure 8. WDS Catalog orbital plot with X marking the KPNO speckle interferometry point deviating from the orbit. The other outlier to the data set, when compared to the orbital plot, is the Tycho-2 observation from 1991.

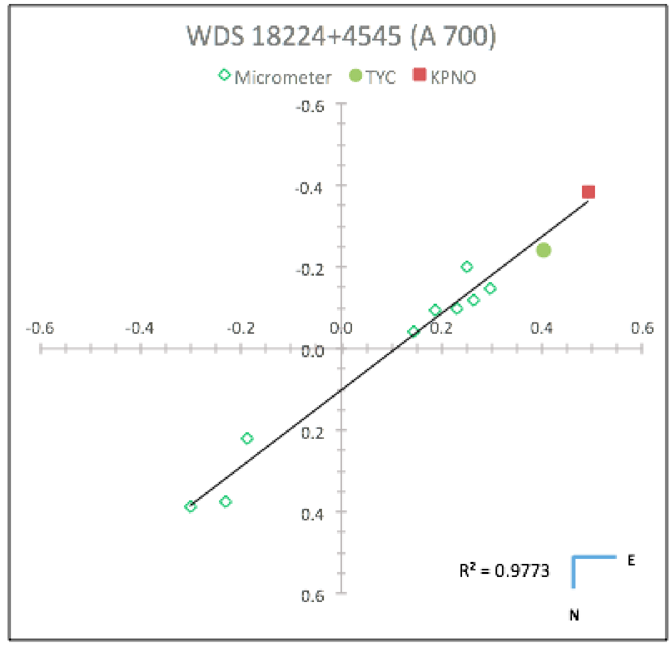

Figure 9. X vs Y graph shows a linear trend, in arcseconds, that represents the motion of the companion star, derived from the separation (ρ) and position angle (θ) of each observation, relative to the primary at point (0,0). Plot points are distinguished by the method of observation.

our results missed the predicted plot point by a separation difference of 0.505″, which in comparison, is nearly the length of the semi-major axis, and an angular difference of roughly 24.61° (Figure 8).

Analyzing the Tycho-2 observation, a separation of 0.359″ and position angle of 125.36° were predicted by the Heintz orbit for the night of the Tycho-2 observation and instead, a separation of 0.47″ and position angle of 121.1° were found from the KPNO observation. This yields a difference of 0.11″ and 4.26°. While the difference in position angle is not highly significant, the difference in separation is approximately ten times greater than the difference in separation for the other observations versus their corresponding predicted positions along the orbital path, excluding the KPNO observation. This lends to the argument that the Tycho-2 observation deviates from the predicted orbital path.

When calculating the orbit for A700, Heintz did not have the results from the Tycho-2 or the KPNO observations, and only had access to the data from the nine visual observations that were made between 1904 and 1996. Thus, either the KPNO and Tycho-2 results deviated due to inaccuracies in the observational methods used, or they are valid data points that challenge the integrity of Heintz's calculated orbit. According to the book *Small Telescope Astronomical Research Handbook* (Genet et al. 2015), speckle interferometry can be used to measure the separation of double stars within a fraction of an arcsecond and is one of the most accurate methods for observing double stars. Similarly, the Tycho-2 observation was taken from a satellite in orbit which removes any error due to atmospheric turbulence. The high precision and accuracy of these two observational methods lends credence to the integrity of the KPNO and the Tycho-2 data points. Conversely, using a micrometer is one of the oldest historical methods for observing double star systems, but it is also one of the least accurate of the three methods by modern standards.

To identify any trends, the entire data set of separations and position angles were adjusted for precession to the epoch of 2000 and plotted in an X vs Y graph, a separation vs time graph, and a position angle vs time graph. After plotting the

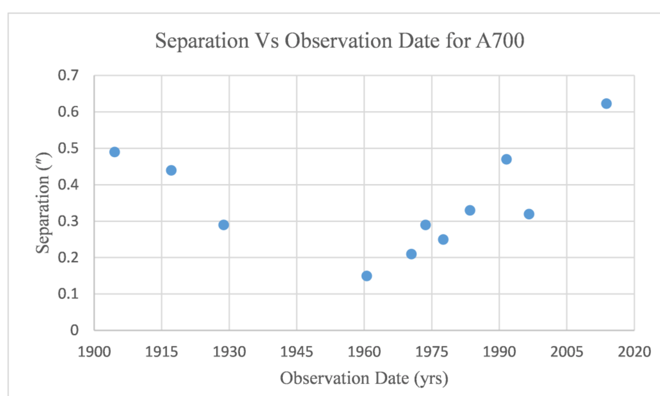

Figure 10. Plot of separation versus time graph shows a linear trend. As the companion star approaches T_0 the separation approaches a minimum. After passing through this minimum, the separation increases at a roughly constant rate.

Reclassification of WDS 18224+4545 from a Binary to Optical Double Star

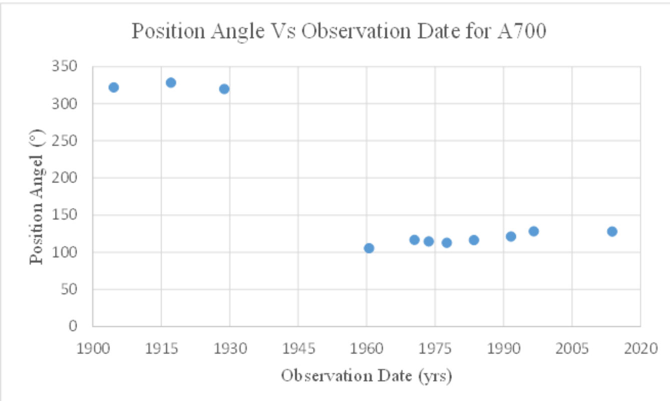

Figure 11. *Change in position angle versus time. What appears is the convergence of the data at an upper limit starting after the companion star reached T_0 that will continue as it gains distance from the primary at a constant linear trajectory.*

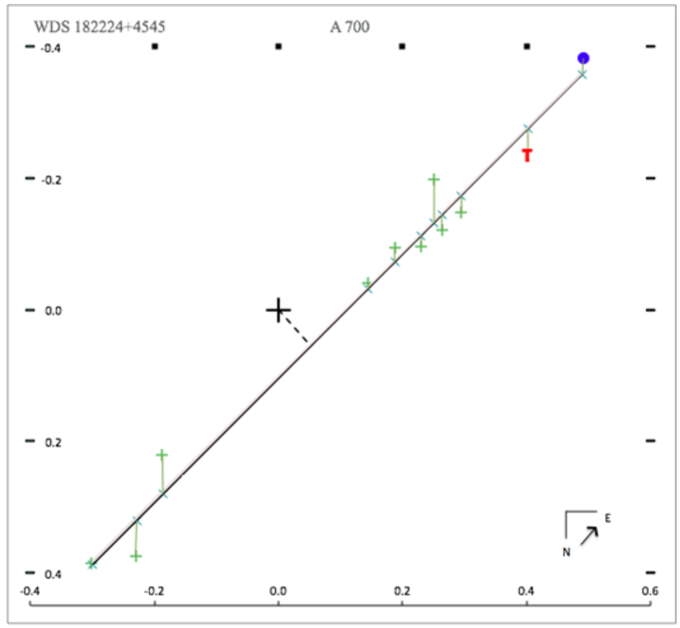

Figure 12. *Rectilinear plot, in arcseconds. The black line represents the linear path of the secondary relative to the primary as time evolves. Measurements are connected to their predicted location with a line indicating a weighted calculation.*

data in an X vs Y graph, a tight linear trend emerged that returned a linear fit with an R^2 value of 0.9773 (Figure 9). This is significant because the R^2 value is a statistical measure of how close the data is to the fitted regression line. The closer this is to the value of one, the better the data fits the model. Having such a high R^2 value yielded a strong argument that the linear trajectory describes the relative motion of the secondary to the primary better than the previously predicted Keplerian orbit. If A700 was a binary star with the orbit that Heintz calculated, this data plot would show a short arc-like trend describing the orbital motion of the secondary relative to its primary. Instead, the linear trend in the data is evidence that A700 is not a gravitationally bound binary and may just be optical in nature (i.e. a mere chance alignment as seen from Earth) with a linear trajectory. After plotting the data in a separation versus time graph (Figure 10), a linear trend emerges that further supports the argument that A700 is an optical double star.

Similarly, plotting the data in a position angle versus year graph (Figure 11) also points to a contradiction in the orbital solution. If A700 was a binary, a sinusoidal trend, representing the orbital motion as the companion moves through quadrant to quadrant, would have been expected. Furthermore, had the KPNO results followed the established orbit, the corresponding data point in Figure 10 would have fallen south-west of the 1996 observation, tending toward the third quadrant. This would have supported a sinusoidal trend for Figure 11. Instead, the position angle vs time graph shows a trend converging to an upper limit that is representative of a linear path.

Looking at the observational data as the companion star passes T_0, theta appears to be converging to a limit caused by the linear trajectory continuing its path in the fourth quadrant, with no indication that it will cease to do so. This can be detected starting with the 1960 observation all the way to the most recent KPNO observation. As time evolves, future observations should continue to support this trend.

New Rectilinear Elements and Linear Ephemerides

Having established that a linear trajectory best de-

Table 2. New Rectilinear Elements

WDS Designation	Discoverer Designation	X_0 (")	X_a ("/yr)	Y_0 (")	Y_a ("/yr)	T_0 (yr)	ρ_0	θ_0
18224+4545	HEI1998	0.052339	0.0075	0.055494	-0.00708	1953.321	0.076	43.36

Table 3. New Linear Ephemerides

WDS Designation	Discoverer Designation	2020		2025		2030		2035		2040	
		ρ_0	θ_0	ρ_0	θ_0	ρ_0	θ_0	ρ_0	θ_0	ρ_0	θ_0
18224+4545	HEI1998	0.692	127.03	0.743	127.46	0.495	127.85	0.846	128.18	0.897	128.48

scribes the relative motion of the secondary to the primary (Figure 12), the rectilinear elements (Table 2) and linear ephemerides (Table 3) were derived. In order to calculate a precise trajectory, a weighted least squares linear fit was applied to the data set. The weights for individual measures were determined using the technique outlined in the Sixth Catalog of Orbits of Visual Binary Stars. After taking these parameters into consideration for each observation, a weight of three was assigned to the KPNO and Tycho-2 observations, due to their increased accuracy, and a weight of three quarters was applied to the visual observations. A new trend line with a slope of -0.9442 and y-intercept of 0.1050 was determined. Both the rectilinear elements and the linear ephemerides were derived from this trend line as shown in Tables 2 and 3.

Conclusion

Using the new data point derived from reducing the speckle interferometry observation and correlating it with past observational data, this research suggests that the grade five orbital solution calculated by Heintz should be replaced with a linear solution, and that A700 should be reclassified from a binary star system to an optical double.

Acknowledgements

This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory. The researchers are indebted to Cuesta College for hosting the seminar. The researchers would like to especially thank Richard Harshaw, Joylon Johnson, and Bill Hartkopf for their advice. This research opportunity would not have been possible if it wasn't for the work and dedication put in by the observational team on the 2.1-meter telescope at Kitt Peak National Observatory. Last but not least, the researchers would like to thank Vera Wallen for her helpful suggestions.

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CCD Measurements of WDS 13510+6819 STTA127

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Abstract: WDS 13510+6819, a three-star star system, discoverer code STTA 127, is imaged using CCD cameras for astrometric measurements in comparison to historic data contained in the Washington Double Star Catalog. The historical data outlines measurements between the A-B and the B-C components and the 2016 measurements support the trend outlined in the WDS

Introduction

STTA 127 (WDS 13510+6819), Figure 1, is a triple star system in the constellation Draco. The last reported observations were 2015 for the AB component and 2010 for the BC component. Charged Coupled Device (CCD) imagery was used to add 2016 separation angle (Theta) and angular separation (Rho) of this Triple Star system. Referencing the Washington Double Star catalog (WDS), the criteria for selection was: stellar separations of 4 arc seconds or more, visual magnitude of 12 or brighter, and difference in WDS reported magnitude less than 3.

A group of remotely operated telescopes, the iTelescope network, was used to acquire the CCD images for these Theta and Rho measurements. These telescopes provide a large enough aperture to acquire high quality images of the fainter stars around STTA127. Table 1 identifies the two different telescopes used.

Imaging occurred on two different nights: T7 on March 30, 2016 and T11 on April 16, 2016, see Table 2. A variety of filters were chosen to enable satisfactory imagery for measurements on the faint C component

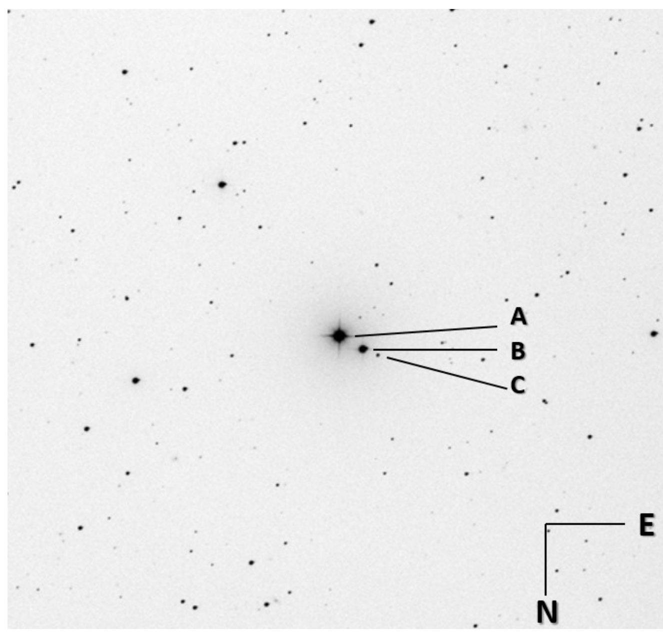

Figure 1. STTA127 with stars labeled

***Table 1**. Telescope Comparison*

Name	Location	Telescope	CCD Camera	Focal Length	Resolution	Field of View
T7	Nerpio, Spain	CDK 17”	SBIG STL11000M	f/6.8	0.63”/pixel	28x42 arcminutes
T11	New Mexico	CDK 20”	FLI Proline PL11002M	f/4.5	0.81”/pixel	36.2x54.3 arcminutes

Table 2. **Telescope Image Summary**

Name	Epoch	Number of Images	Filters	Exposure Length
T7	2016.2445	4	Luminance	180-seconds
	2016.2445	2	Luminance	120-seconds
	2016.2445	2	Hydrogen Alpha (Ha)	120-seconds
T11	2016.2910	2	Green	180-seconds
	2016.2910	2	Red	180-seconds
	2016.2910	2	Luminance	180-seconds

while ensuring there were not any oversaturation/blooming issues on the brighter stars of A and B.

Methods and Procedures

The historical observation data for STTA127 were requested and acquired from the United States Naval Observatory. CCD images were scheduled through the iTelescope's online interface and calibrated (Darks, Flats, Bias) by iTelescope prior to downloading. MaximDL and Pinpoint Astrometry were used to set the World Coordinate System (WCS) into the images FITS headers through star matching against the Fourth U.S. Naval Observatory CCD Astrograph Catalogue (UCAC4). This process was successful for the images acquired through the T11 telescope but failed to provide a solution for images acquired with T7. A WCS plate solution for the T7 images was successful when processed through Astrometry.net's website interface (http://www.astrometry.net).

Each WCS calibrated image was opened with Mira Pro x64. This software, using the WCS position in Right Ascension (RA) and Declination (Dec) for the image, measures distance separation in arc seconds (Rho), and relative position angles (Theta) through the point-and-click Distance & Angle function. To ensure the most accurate measurement, Mira automatically calculates the centroid of each star when performing the requested measurements, Figure 2. This process permits accurate measurements even for the faintest stars. The red square and "+" denotes the center of the FITS image.

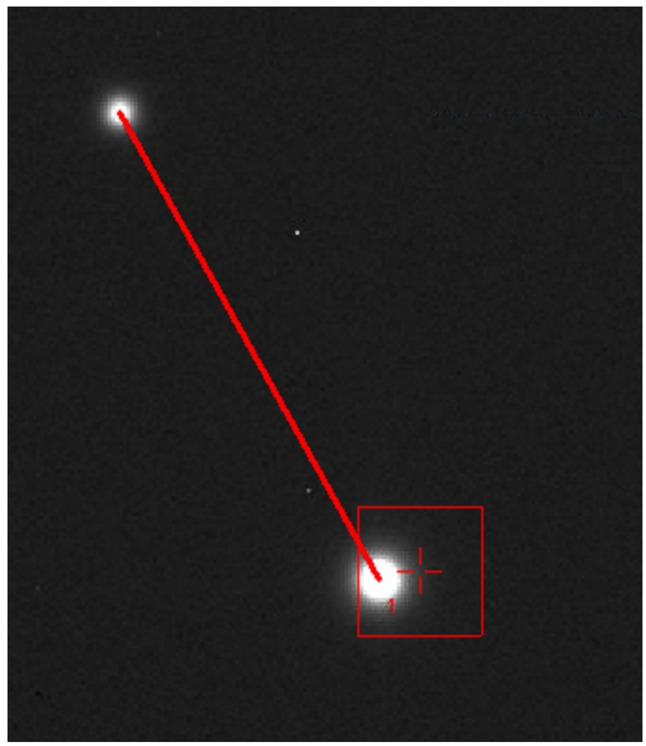

Figure 2. Example Position Angle and Separation measurement procedure with Mira Pro

The results from Mira were placed into an Excel spreadsheet to calculate the mean, standard deviation, and standard error of the mean for all components from the T7 and T11 images, Tables 3 and 4. The images

Table 3. *Theta, Rho, Mean Measurement, Standard Deviation, and Standard Deviation of the Mean for Telescope T7*

Telescope Used	Component	EPOCH	Measurement	Mean	Standard Deviation	Standard Deviation of the Mean
T7	AB	2016	Theta	61.6°	1.26°	0.157°
			Rho	87.2″	1.64″	0.205″
	BC	2016	Theta	70.2°	0.74°	0.093°
			Rho	54.2″	1.14″	0.142″

CCD Measurements of WDS 13510+6819 STTA127

Table 4. Theta, Rho, Mean Measurement, Standard Deviation, and Standard Deviation of the Mean for Telescope T11

Telescope Used	Component	EPOCH	Measurement	Mean	Standard Deviation	Standard Deviation of the Mean
T11	AB	2016	Theta	62.3°	0.27°	0.045°
			Rho	87.7″	0.98″	0.163″
	BC	2016	Theta	69.2°	0.76°	0.127°
			Rho	52.6″	0.55″	0.092″

were then compared to the measurements in the Washington Double Star catalog (WDS) to verify that the process fit the trends seen in the historical data.

Data for STTA127

The historical data, supplied by the US Naval Observatory, was compiled with the 2016 T7 and T11 measurements for the previously reported AB and BC components, Table 5. All data was plotted in Excel for a graphical depiction of the overall positioning for the previously reported AB and BC combinations, Figures 3 and 4. A trend line has been added as well.

Discussion of Results for STTA127

From the graphed data for the AB and BC pairs, there appears to be a trend in the position angle and separation of this pair that are supported by the 2016 CCD images and measurements with greater movement in Rho than in Theta. Prior to 1991, most measurements were completed with a Micrometer. After 1991, most were obtained through imagery. Given this diversity in measurement styles, most are in agreement and support the linear solution of STTA127 as noted in the WDS (Mason, 2015).

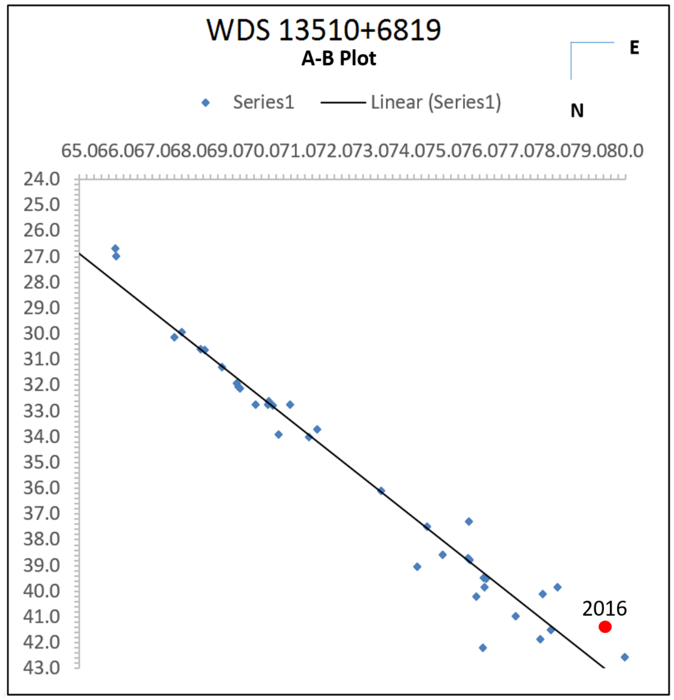

Figure 3. Graphical depiction of AB component for all historical measurements with 2016 measurement highlighted..

Table 5. Current and historical comparison for the AB and BC pairs.

Component	Number of Measurements	EPOCH	Theta	Rho
AB	35	1844 (First Recorded)	68°	71.2″
		2015 (Last Recorded)	63°	87.5″
	8	2016.2445 (T7)	61.6°	87.2″
	6	2016.2910 (T11)	62.3°	87.7″
BC	4	1912 (First Recorded)	65°	44.9″
		2003 (Last Recorded)	69°	51.9″
	8	2016.2445 (T7)	70.2°	54.2″
	6	2016.2910 (T11)	69.2°	52.6″

CCD Measurements of WDS 13510+6819 STTA127

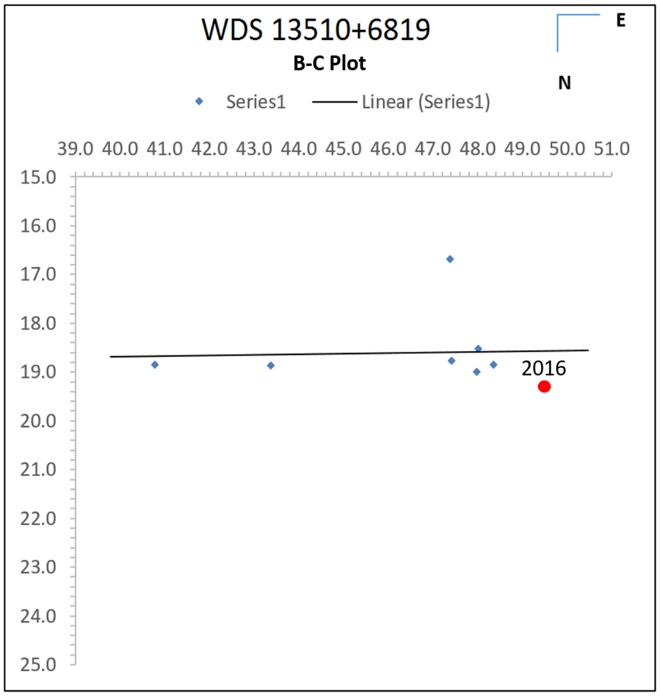

Figure 4. *Graphical depiction of the BC component for all historical measurements.*

Acknowledgements

We would like to thank the Boyce Research Initiatives and Education Foundation (B.R.I.E.F.) for their instructional support and financial donation that allowed us to use the iTelescope robotic telescope system and the Maxim DL Pro 6 and Mira Pro x64 software tools. This research made extensive use of the Washington Double Star catalog maintained by the U.S. Naval Observatory.

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Two New Stellar Pairs Discovered Using SDSS Imagery

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Abstract: Two previously uncatalogued stellar doubles were discovered by the author while searching the online DSS and SDSS images for variable stars. One of the candidates is a definite proper motion double.

In December 2016, I accidentally stumbled upon two previously uncatalogued double stars during a hunt for variable objects in DSS and SDSS. SIMBAD, Vizier, and The Washington Double Star catalog (WDS) had no mention of these objects. Brian Mason of the USNO confirmed both pairs as being two new double stars.

Candidate 1: UCAC3 171-146981

The first stellar pair was listed as a single star according to SIMBAD (UCAC3 171-146981), but when inspecting the DSS and SDSS images, it was clear that it was made up by two components of nearly identical brightness and color (see Figure 1). The SDSS9 (Adelman-McCarthy et al, 2012), USNO-B1.0 (Monet et al, 2003), PPMXL (Roeser et al, 2010), and 2MASS (Cutri et al, 2003) catalogs listed both components separately. The data extracted and derived from these catalogs was used to determine a B-V color index, Visual magnitude, and proper motion (see Table 1) for both components.

The 2MASS data was used to indirectly determine the B-V color indexes, using the J and K filters. The results summarized in Table 1 show that both components have a similar B-V index.

Individual optical magnitude measurements for each component were difficult to find, especially due to errors in the SDSS data. Using the previously calculated B-V color index and the USNO-B1.0 Blue magnitude measurements, I was able to deduce the visual magnitudes. But these values are approximate as the USNO-B1.0 filters are not purely monochromatic. Furthermore, the USNO-B1.0 Blue magnitude for one of the components was listed as unreliable, adding to the uncertainties. The proper motion was extracted from the PPMXL catalog. As the table shows, they are rather similar.

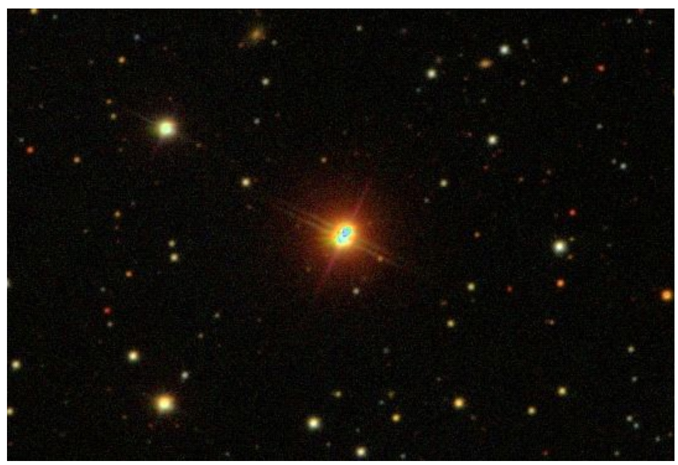

Figure 1: Discovery SDSS image showing the binary nature of UCAC3 171-146981 (centered in this image). The image was extracted from Skymap.org. Image taken B2005.4287.

The similarity in the B-V color index and the proper motion of both components is a good argument in favor for their binary nature. Even though the visual magnitude for one of the components is very uncertain, the “length” of the diffraction spikes in SDSS is definitely an indication that both objects are similar in apparent brightness. I tried to search for additional companions to this system using the PPMXL catalog, but none could be found within 2’. Separation is about 4".

Candidate 2: [SLS2012] PYC J16014+2116

The second candidate was listed by SIMBAD as a single star, [SLS2012] PYC J16014+2116. A close inspection of the SDSS image (Figure 2) shows however

Two New Stellar Pairs Discovered Using SDSS Imagery

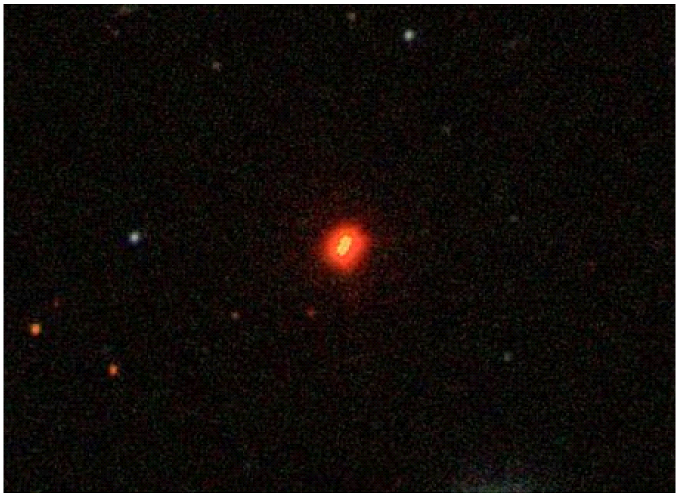

Figure 2: Discovery SDSS image showing the binary nature of [SLS2012] PYC J16014+2116 (centered in this image). The image was extracted from Skymap.org. Image taken B2004.2929.

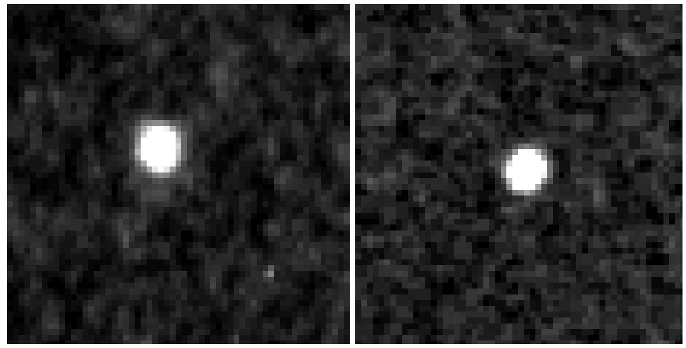

Figure 3: DSS1 and DSS2 Blue images of [SLS2012] PYC J16014+2116. In both images the object appears rather stellar. The small difference in elongation might be an artifact. Images are from the DSS Plate finder.

two apparently close (separation: 2") components of very similar brightness.

The SDSS9 catalog listed both components separately. A B-V color index for both components was thus derived based on this data (from the “g”, “r” and “u” SDSS filters). SDSS data was also used to calculate a visual magnitude for both components.

No catalog listed the proper motion for each component separately. However, the PPMXL catalog listed [SLS2012] PYC J16014+2116 having a proper motion of pmRA (mas/year)= -62.9; pmDEC(mas/year)=-89.5. Its proper motion was thus clearly detectable by comparing DSS1 and DSS2 images. The object appeared just as stellar in all these images, which could be an indication that both components have a rather similar proper motion (see Figure 3). The similarity of the B-V color index and possibly the proper motion are good arguments in favor for their binary nature.

Acknowledgments

I wish to thank Brian Mason of the USNO/NRL/Navy for his expertise and rapid response. I also want to thank amateur astronomer Laurent Ferrero (Marseille, France) for his opinion regarding UCAC3 171-146981, and Sebastian Otero (AAVSO) for having provided me with the tools allowing the magnitude conversions.

Table 1: Results for both candidates

Name	RA+DEC	PM(RA)	PM(DEC)	PA	Sep	B-V	Mags	Date
Candidate 1	163341+044336	-88.9,-83.0	+26.1,+26.8	336°	≈3.4"	1.11, 1.21	11.9,11.2(?)	2005.4287
Candidate 2	160127+211613	-62.9	-89.5	329°	≈1.6"	1.65, 1.64	16.2,16.0	2004.2929

Astrometric Measurement of Double-Star System 03074+1753 HJL 1020

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Abstract: The double star system HJL 1020 was observed using the iTelescope network. The angle and distance between the components were measured and reported. From telescope T3, we measured rho (ρ) of 105.75" ± 0.92" Standard Error of the Mean (SEM) and theta (θ) of 359.19° ± 0.4° (SEM). For telescope T18, we measured ρ of 105.28" ± 0.36" (SEM) and θ of 359.13° ± 0.21° (SEM). Combined with the historical measurements, our measurements suggest the distance between the A and B stars decreasing from 1896 to 2016. The plot of the data suggests an optical double due to a lack of Keplerian motion after 120 years.

Introduction

The purpose of this project was to select, observe, and measure a double star system from the Washington Double Star Catalog (WDS). The current separation and position angle between the two stars in the system HJL 1020 were measured and a new data point was added to the historical plot.

Selection of a binary star system from the Washington Double Star Catalog (Mason et al, 2015) followed specific criteria: a magnitude difference of 3 or more with the lowest magnitude being 11 or higher, a separation distance greater than 5.5 arc-seconds, a positive Declination and a Right Ascension of 01 to 08 hours. HJL 1020 matched these criteria.

HJL 1020 is in the constellation of Aries and its primary star is also known as 53Arietis. 53Arietis was once catalogued as a beta type Cepheid variable, but its variability was ruled out from an examination of seven years of photographic plates, a collection of new spectroscopic plates, and spectroscopic plates from 1956 (Sterken 1988). The B star is thought to be a part of a spectroscopic binary pair. This spectroscopic pair is thought to be orbiting the A star (Halbwachs, 2012).

The difference in magnitude between the primary and secondary star is 4.3, with the primary magnitude being 6.1 in the V band and the secondary magnitude being 10.42 in the V band as well, according to the SIMBAD Astronomical Database, which provides basic data, cross-identifications, bibliography and measurements for astronomical objects outside the solar system.

The first separation measurement of 109.3" was in 1896 and the last separation measurement of 104.2" was in 2014. There were 10 observations over 118 years. After receiving the historical data from the WDS catalog, the separation between the A star and B star over the 118 years was plotted and the data shows the distance between these stars decreasing.

The European Space Agency's Hipparcos Space Astrometry Mission gathered precision position data for 100,000 stars. We accessed the Hipparcos parallax data for HJL 1020 through the VizieR catalogue database (VizieR). According to the data for HJL 1020, the primary star has a parallax of 3.92 millarcsec with an error of 0.79 milliarcsec giving a midpoint distance of

Table 1. *Distance to star based on Hipparcos data*

3074+1753	Parallax		Parallax	Distance	Distance
Inputs	mas	Error	mas	parsec	light year
Star A	3.92	0.79	3.92	255	832
Star B	not recorded	N/A	N/A	N/A	N/A

831.6 light years (Table 1). This table shows the distance in parsecs and light years.

Materials and Methods

For centroid measurements with sub-pixel accuracy, telescopes with better than 1 to 2 arc-sec/pixel resolutions were sought. The telescope T18 (Figure 1) in Spain with a resolution of 0.73 arc-secs/pixel and the telescope T3 (Figure 2) in New Mexico with a resolution of 1.02 arc-secs/pixel were chosen. A Red filter with exposure lengths of 60 and 120 seconds and a Luminance filter for 60 and 90 seconds were chosen for the T18 telescope. T3 is a One-Shot Color system and exposures of 60, 90, and 120 seconds were used for a total of 10 measurements.

MaximDL was used to insert World Coordinate system (WCS) positions into the FITS headers by comparison to approximately 150 stars in the Fourth U.S. Naval Observatory CCD Astrograph Catalogue (UCAC4); and Mirametrics Mira Pro x64 software was used for measuring the stars Theta (angle) and Rho (distance). Microsoft Excel was used to calculate statistics and plot results along with the historical data.

Data

Figure 3 shows an example of an image of the XY pair that was used for measuring the Theta and Rho in HJL 1020. The historical data along with the newly measured data are shown in Table 2. This data was plotted in Figure 4 to get a better idea of the motion of the stars in relation to each other.

Table 3 reports the newly calculated position angles and separations along with the uncertainties in each for the sets of images of each telescope. We measured a mean position angle of 359.19° ± 0.133° and a mean

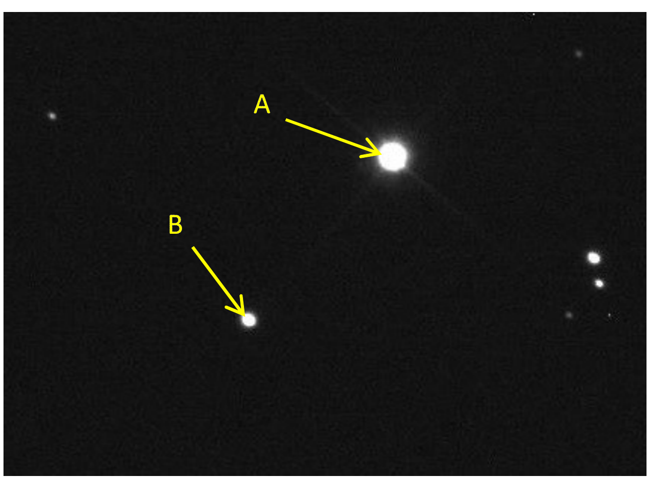

Figure 3. *Example image of HJL 1020 cropped to show the target pair from the T18 telescope*

Figure 1. *T18 in Spain .*
Optical Design: Corrected Dall-Kirkham Astrograph
Aperture: 318mm
Focal Length: 2541mm
F/Ratio: f/7.9
Mount: Paramount PME
Instrument Package
CCD: SBIG STXL-6303E
Non Anti-Blooming Gate (NABG)
Resolution: 0.73 arc-secs/pixel
Array: 3072 by 2048 (6.3 Mega pixels)
FOV: 37.41 x 24.94 arc-mins
Observatory: Nerpio, Spain

Figure 2. T3 in New Mexico
Optical Design: Apochromatic Refractor
Aperture: 150mm
Focal Length: 1095mm
F/Ratio: f/7.3
Mount: Paramount GTS
Instrument Package
CCD: SBIG ST-4000XCM One Shot Color CCD
Resolution: 1.45 arc-secs/pixel
Array: 2048 by 2048 (8.3 Mega pixels)
FOV: 49.6 x 49.6 arc-mins
Observatory: Mayhill, New Mexico

Table 2. *Historical data with new data from 2016*

Epoch	Position Angle	Separation
1896.94	357.5	109.29
1897.91	357.4	109.2
1929.33	357.7	108.31
1950	357	107
1959.42	357.6	107.11
1991.8	358.6	105.92
1999.75	358.9	105.57
2000.894	358.8	105.01
2010.558	359	105.29
2014.008	358.8	104.2
2016.813	359.15	105.42

angular separation of 105.75" ± 0.307" for T3. We measured a mean position angle of 359.13° ± 0.03° and a mean angular separation of 105.28" ± 0.05" for T18. The most recent historical data is reported as a comparison.

Discussion

The observed data shows a continuation of the historical trend which appears to suggest rectilinear motion of the B star relative to the A star. A determination cannot yet be made as to whether this is due to an orbit that is an elongated ellipse whose orbital motion is not yet apparent or to the fact that the two stars are unrelated and are changing their relative positions by reason of the difference in their proper motions.

Conclusion

We obtained astronomic measurements of position angle and separation in 2016.8 of the double star system HJL 1020 using the T3 and T18 telescopes of the iTelescope network. Our astrometric data shows the distance between the component stars is decreasing. The absence of obvious Keplerian motion after 120 years suggests an optical double. The question of whether or not this is a common proper motion pair or physical binary with a very long period and highly elliptical orbit could be answered if the distance to the secondary star was obtained.

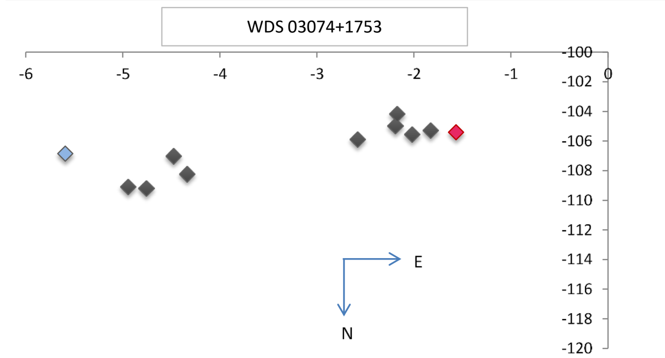

Figure 4. *XY plot of AB pair historical position with new position data shown with a pink diamond.*
First data point (1896) shown with a light blue diamond.

Acknowledgements

The authors wish to thank Grady and Pat Boyce of the Boyce research Initiatives and Education Foundation (BRIEF) for the opportunity to participate in this project and for sharing their expertise with us. Their guidance was invaluable as we went through this process. Our sincere thanks also go to Kent Smith for keeping us on track and providing much needed motivation and encouragement. We also wish to thank Mt. Everest Academy for access to the space needed to meet for this seminar and to successfully complete our

Table 3. *Summary of final data with standard deviations and standard error of the mean.*

WDS 03074+1753			
Telescope: (number of images used in each filter)		**θ (degrees)**	**ρ (arcseconds)**
T03: (3 Color)	Mean	359.19	105.75
	Standard deviation	0.4	0.92
	Std. error of mean	0.133	0.307
T18: (4 R), (3 luminance)	Mean	359.13	105.28
	Standard deviation	0.21	0.36
10 images total	Std. error of mean	0.03	0.05
2014.01 measurement (Last one previous to this investigation)		358.8	104.2

research project. Thanks also goes to Cuesta College for allowing young students to have this unique experience in research. And lastly, thanks to the reviewers of this work; Robert Buchheim, Richard Harshaw, and Russ Genet.

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CCD Astrometric Measurements of WDS 05247+3723

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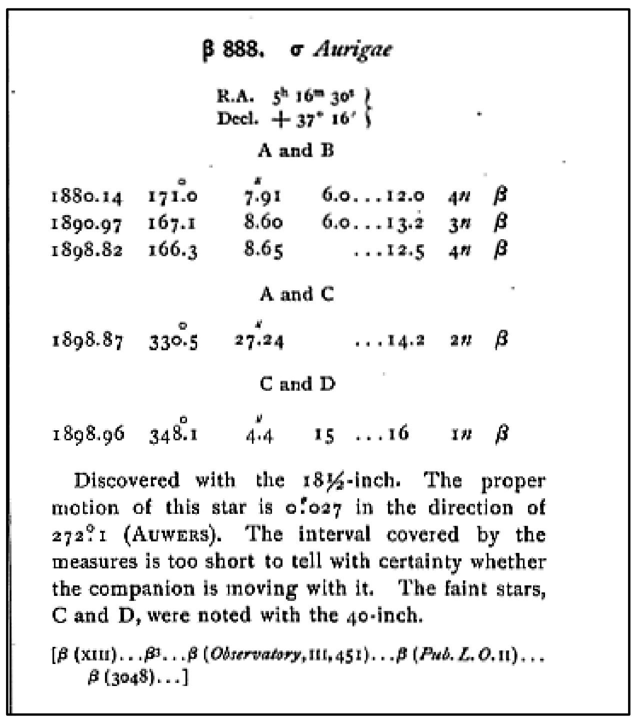
Abstract: Theta (θ) and rho (ρ) astrometric measurements were made of the double star system WDS 05247+3723 pairs AB, AC, and CD. These measurements compared favorably with the historic data from the Washington Double Star Catalog (WDS). We also measured the AD, BC, & BD pair relative astrometry.

Introduction

The goal of this project is to increase knowledge of WDS 05247+3723 by adding measurements and data to aid in a future determination as to whether WDS 05247+3723 is either an optical system or a gravitationally bound binary system.

The first recorded measurements of the AB pair were originally made by S. W. Burnham in 1880, with subsequent measurements made for the AC and CD pairs in 1898. He named this multi-star system "β 888 σ Aurigae" and published his findings of this system in various journals. Burnham, in 1880, Figure 1, recorded his findings on WDS 05247+3723 as: "Discovered with the 18 ½ inch. The proper motion of this star is 0.027 in the direction of 272.1 (AUWERS). The interval covered by the measure is too short to tell with certainty whether the companion is moving with it. The faint stars, C and D, were noted with the 40-inch" (Burnham, 1900).



β 888. σ *Aurigae*

R.A. 5h 16m 30s
Decl. +37° 16′

A and B

1880.14	171°.0	7″.91	6.0...12.0	4n	β
1890.97	167.1	8.60	6.0...13.2	3n	β
1898.82	166.3	8.65	...12.5	4n	β

A and C

1898.87	330°.5	27″.24	...14.2	2n	β

C and D

1898.96	348°.1	4″.4	15 ...16	1n	β

Discovered with the 18½-inch. The proper motion of this star is 0″.027 in the direction of 272°.1 (Auwers). The interval covered by the measures is too short to tell with certainty whether the companion is moving with it. The faint stars, C and D, were noted with the 40-inch.

[β (xiii)...β3...β (*Observatory*, iii, 451)...β (*Pub. L. O.* ii)... β (3048)...]

Figure 1. Screenshot of Publications of Yerkes Observatory, seen on the upper right as being named by Burnham as "β 888 σ Aurigae":

Equipment and Procedures

Two telescopes from the iTelescope network were used for data collection during this study: iTelescope 18 (T18), Figure 2, and iTelescope 21 (T21), Figure 3. The Telescope and CCD camera for T18 included a 0.32m Planewave CDK telescope, an SBIG STXL-6303 NABG CCD camera, Astrodon Series E LRGB filters, Astrodon 10nm hydrogen alpha, SII, OIII, and photometric V filters. T18 uses a Paramount ME Mount providing a system resolution is 0.73 arc-sec/pixel. The telescope and CCD camera for T21 included a 0.43m Planewave CDK telescope, a 0.66 focal reducer, an FLI -PL6303 NABG CCD camera, and a Paramount ME mount providing a system resolution of 0.96 arc-sec/pixel. The filter brand is not specified for T21. Thirty-six images were used in this study taken between 2016.80087-2016.86311.

Once the images were obtained from the iTelescope network, they were processed using MaxIm DL Pro 6

Figure 2: iTelescope 18 (T18), located in Nerpio, Spain

Figure 3: iTelescope 21 (T21), located in Mayhill, New Mexico

to encode World Coordinate System (WCS) into each image. Mira Pro x64 was used to measure angles, theta (denoted as θ), and distances, rho (denoted as ρ), between stars in the images of WDS 05247+3723 to obtain an accurate mean measurement. Using the distance and angle tool, measurements were made and then copy/pasted into a spreadsheet containing all measurements by order of pair (i.e, AB, AC, CD, etc.) to be used for further analysis.

Results and Discussion

AB

Measuring the AB pair proved to be a moderate challenge during the research phase due to the differential magnitude, approximately 7, between the components. In the first set of images using the Hydrogen Alpha filter, the B component, with a last reported Rho of 8" was not located as the size of the A star disk on the image exceeded the 8". This filter was selected since the A component has a reported 5.16 magnitude, while the B component has a reported 12 magnitude. The selection of the Ha filter, one with a lower bandpass, was an effort to reduce the brightness of the A component while allowing the B component to be seen.

The first attempt to image/measure AB was attempted with a 45 second exposure, as seen in Figure 4. The B component is not visible. Additional attempts yielded the same result.

Another effort to measure AB was attempted with a 180 second exposure through a luminance filter to allow more photons to be captured for the fainter B component. Figure 5 displays the result. This effort failed and oversaturated the A component resulting in blooming while the B component remained undetected.

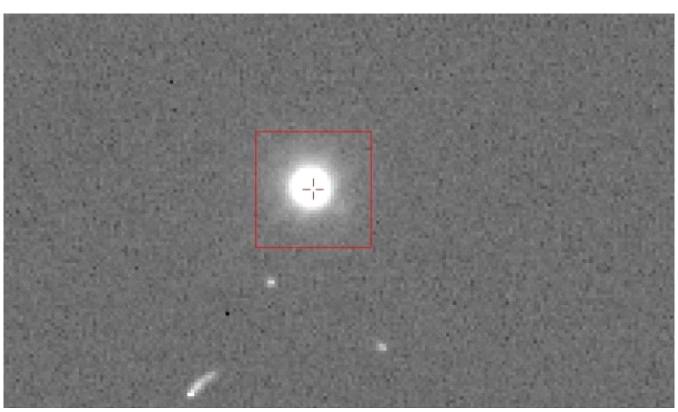


Figure 4. Initial image where the B component is obscured by the disk of A.

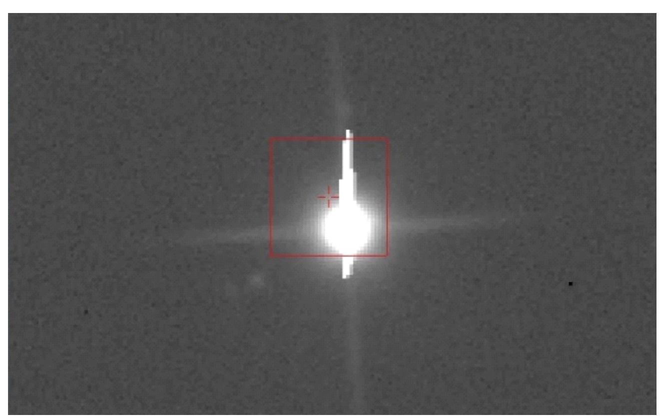


Figure 5. Image through a Luminance Filter.

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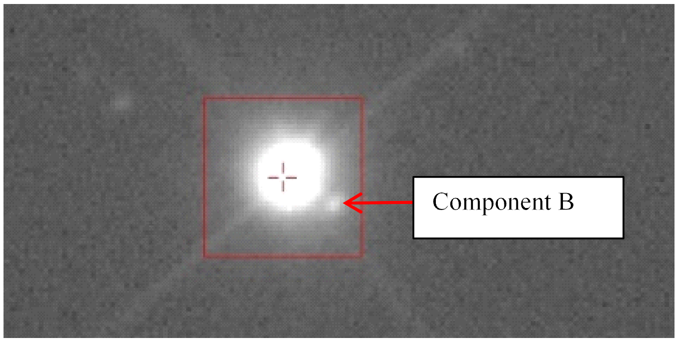

Figure 6. Image with B component visible after using B filter.

Using the internet resource, Stelle Doppie, the A component was listed with a spectral class of K3III. This spectral designation indicates that the A component is a cooler K class star that has left the main sequence of the Hertzsprung-Russell Diagram and evolved into a giant star. Applying Wien's Law, that a star's light curve (output) will peak at wavelengths inversely proportional to their temperature, we realized that since the K class star was emitting more light in the cooler red portion of the spectrum, the desired effect of filtering out some light with a red filter was counterintuitive. Therefore, in an application of the concept of Wien's Law, the third attempt used a blue filter where the A component would emit less light during the allotted exposure time. This application resulted in a clearly visible B component, seen in Figure 6 while reducing the size of the A disk on the image to 3.5".

The conclusion reached from this application was that spectral classes of the two components, if known, should be consulted for filter application in the case of closely spaced, high delta magnitude components. If not known, experimentation may be in order.

The method of displaying the data in these figures is noteworthy. The display data was "stretched" using Mirametrics Software function named "Vertical Transfer". Within the Vertical Transfer there are several settings available. The Min/Max setting was selected to apply a linear stretch using the minimum and maximum pixel values in the image. This creates an image that is brighter and has more contrast, producing the appearance of details that otherwise might have been missed. The gamma setting was also manipulated to adjust the degree of contrast of gray values. This also serves to brighten some details. It is worth noting that these changes affect the display of the image only leaving the subsequent centroid calculations, performed by the software, unaffected.

The sets of measurements taken from these images, along with other images from this epoch not shown in

Table 1. *Error statistics for AB.*

WDS 05247+3723 Astrometry (AB)				
Telescope	**Besselian Epoch**	**Measurement**	**θ (degrees)**	**ρ (arcseconds)**
T18: (4 images in Blue)	2016.83849	Mean	164.45	8.11
		Standard deviation	1.05	0.10
		Std. error of mean	0.42698	0.04267
	1922	Recorded Measurement	167.40	8.71

Table 2. *Historical measurement summary from WDS data.*

Date of Observation	Position angle (degrees)	Separation (arc seconds)
1880.14	171.0	7.91
1890.97	167.1	8.6.0
1898.82	166.3	8.65
1904.22	170.3	8.6.0
1908.83	166.0	8.55
1914.72	166.8	8.46
1922.073	167.4	8.71

this paper, were used in calculating averages. Looking at the results of our measurements in 2016, and comparing them with historical measurements, has led us to conclude that this is the closest the B component has been measured to come to A component since the first observation made in 1880, that first observation has the only closer measurement at 7.91″. The rest of the measurements from 1890 - 1922 display an arcsecond length ranging from 8.4 - 8.7 as seen in Table 2.

AC, CD, and AD

The AC, CD, and AD pairs were the most common measurements for the study. Since these pairs have the most numerous measurements, these averages are the most accurate of those documented by this research. The AC measurement results are displayed in Table 3, with the CD measurements in Table 4, and AD in Table 5.

The remainder of this research paper is measurements that haven't been documented previously, along with a description of the methods used to make these measurements. This section will provide even further data on this system than had already been published.

BC & BD

The BC and BD measurements, Table 6 and Table 7 respectively, were made with a process similar to the one described for the AB pair, taking the A component's KIII spectral type into account (Stella Doppie).

Conclusions

Imaging of binary stars with high delta magnitudes and close separations in arcseconds can be accomplished with a pragmatic approach that accounts for stellar spectral type and use of filters. In many cases, use of Ha and/or red filters is preferred as it may im-

(text continues on page 406)

Table 3. Measurements of the AC Components

WDS 05247+3723 Astrometry (AC)			
Telescope	**Besselian Epoch 2016.83849**	**θ (degrees)**	**ρ (arcseconds)**
T18: (Red - 2 images) (Luminance - 4 images) (Blue - 4 images) (Visual - 2 images) 12 images total	Mean	334.11	27.93
	Standard deviation	1.63	0.45
	Std. error of mean	0.383	0.106
	Besselian Epoch 2016.80087		
T21: (Red - 2 images) (Luminance - 2 images) (HA - 4 images) 8 images total	Mean	334.22	27.63
	Standard deviation	1.58	1.22
	Std. error of mean	0.43935	0.33796
	2014 measurement	335.68	26.789

*Table **4**. Measurements of the AD Components*

WDS 05247+3723 Astrometry (CD)			
Telescope	**Besselian Epoch 2016.83569**	**θ (degrees)**	**ρ (arcseconds)**
T18: (Red-2 images) (Luminance-4 images) (Visual-2 images) (Blue-4 images) 12 images total	Mean	345.05	7.35
	Standard deviation	1.98	0.23
	Std. error of mean	0.481	0.055
	Besselian Epoch 2016.80087		
T21: (Red-2 images) (Luminance-2 images) (Hydrogen Alpha-4 images) 8 images total	Mean	344.40	7.30
	Standard deviation	3.18	0.65
	Std. error of mean	0.851	0.173
	2002 measurement	346.70	7.066

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Table 5. Measurements for AD Pair.

WDS 05247+3723 Astrometry (AD)			
Telescope	**Epoch 2016.83849**	**θ (degrees)**	**ρ (arcseconds)**
T18: (Red-2 images) (Luminance-4 images) (Visual-2 images) (Blue-4 images) 12 images total	Mean	335.93	35.20
	Standard deviation	1.65	0.57
	Std. error of mean	0.389	0.134
	Besselian Epoch 2016.80087		
T21: (Red-2 images) (Luminance-2 images) (Hydrogen Alpha-4 images) 8 images total	Mean	334.85	35.86
	Standard deviation	3.63	1.14
	Std. error of mean	1.093	0.343

Table 6. Measurements for BC Pair.

WDS 05247+3723 Astrometry (BC)			
Telescope	Besselian Epoch 2016.83569	θ (degrees)	ρ (arcsec)
T18: (Luminance-1 image) (Visual-1 image) (Blue-2 images) 4 images total	Mean	335.69	35.78
	Standard deviation	0.56	0.28
	Std. error of mean	0.278	0.141

Table 7. Measurements for BD Pair.

WDS 05247+3723 Astrometry (BD)			
Telescope	**Besselian Epoch 2016.83849**	**θ (degrees)**	**ρ (arcseconds)**
T18: (Luminance-1 image) (Visual-1 image) (Blue-2 images) 4 images total	Mean	337.55	43.07
	Standard deviation	0.06	0.23
	Std. error of mean	0.032	0.116

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(Continued from page 404)

prove the signal to noise ratio. However, in certain spectral combinations, other filters may yield the desired results.

With some multiple stars that contain more than two components, measurements of each combination can assist in detecting stellar movement, especially in cases where parallax is not reported. Current CCD images can be combined with historical images such as the Palomar Sky Survey (I and II) and the 2Micron All-Sky Survey where needed. These additional measurements can be useful in a systemic analysis.

Acknowledgements

We thank the United States Naval Observatory for providing historical measurement data. We thank the Boyce Research Initiatives and Educational Foundation (B.R.I.E.F) for their mentorship as well as providing access to the iTelescope network.

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CCD Astrometric Measurements of WDS 00023-7238 HJ 5439

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Abstract: We obtained astrometric measurements of the double star system 00023-7238 (HJ 5439) using the iTelescope network and MaximDL v6 software. We measured a mean position angle of 79.2º ± 0.2º and an average separation distance of 9.53″ ± 0.04″; these measurements show a decrease of 0.4 º and 0.23” from the last measurement in epoch 1998.50. Historical and current data show no obvious signs of orbital motion, which suggests that HJ 5439 may be a visual double.

Introduction

Double stars are star systems which appear near to each other in the night sky. They can be either aligned by chance (an optical double star), or in other cases, gravitationally associated and orbiting each other (a binary star). If a double star is found to be a binary system via multiple observations, an orbit can be determined and from there the two stars can be "weighed" and thus the mass determined. The mass of a star is its single most important characteristic, allowing astronomers to approximate the life, luminosity, and the amount of material available for fusion.

Double star research offers a favorable entry for beginner researchers to do original work due to the relative simplicity in gathering the relevant data: separation and position angle.

A star system was selected that was visible during fall semester (August-December) to gain experience in planning astronomical observations. The Washington Double Star Catalog (WDS) was searched for candidates with a right ascension between 00 and 07 hours, a declination between -80º and 80º, a separation distance between 7" and 15", and a magnitude differential no more than 6. WDS 00023-7238 HJ 5439 (hereafter, referred to as HJ 5439) fit these parameters and had only 9 total previous observations. This was favorable because our data would be more valuable in providing new information about the star, such as determining whether HJ 5439, Figure 1, is a physical or visual double star. Filters were used when obtaining images to minimize atmospheric dispersion.

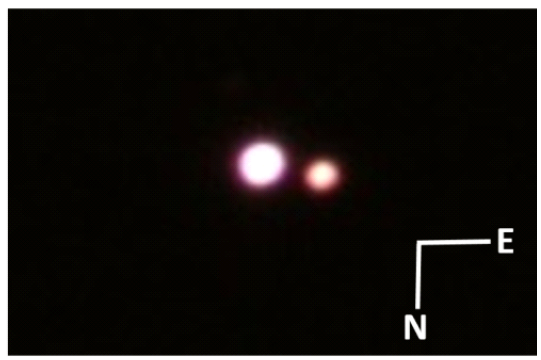

Figure 1. False color image of HJ 5439 by combining the frames from red, green, and blue filters. North is down, East is right and the size of the image is ~180″ by 120″.

Historical records state that HJ 5439 was first discovered in 1835 by Sir John Frederick William Herschel, the son of famed astronomer William Herschel (discoverer of Uranus). After discovery, HJ 5439 was observed again in 1892 by an astronomer from Yale University, P.K. Lu, and since has been observed roughly every twenty years until 1998, when the 2MASS catalog recorded its position for the most recent measurement prior to this paper (2MASS Catalog). Notably, it appears that there are no papers specifically written about HJ 5439 specifically by any of its observers. Table 1 lists all known historical measurements for

CCD Astrometric Measurements of WDS 00023-7238 HJ 5439

Table 1. *Historical measurements for HJ 5439. The Technique Codes for Table 1 can be seen below. Some measurements for the primary and secondary magnitudes were unavailable in the WDS database; and thus, are not reported here.*

Date Observed	Position Angle (°)	Separation Distance (")	Primary Magnitude	Secondary Magnitude	Technique Code
1835.17	86.7	4.5	9.5	13	Mb
1892.79	83.7	9.496	-	-	Pa
1917.91	80.1	9.67	9.3	11.5	Ma
1926.90	79.7	9.254	-	-	Pa
1955.80	78.1	10.118	-	-	Pa
1977.888	79.1	9.62	-	2.5	Mb
1984.657	79.0	10.3	-	-	Pa
1998.500	79.6	9.757	10.09	12.01	Eu
1998.60	79.5	9.80	9.147	10.847	E2

Table 1 Technique Codes
Pa = photographic, with astrograph
Ma = micrometer with refractor
Mb = micrometer with reflector
Eu = UCAC3 or UCAC4
E2 = 2MASS (Two Micron All-Sky Survey)

HJ 5439, recorded by the Washington Double Star database.

Equipment, Observations, and Data Analysis Procedures

Charged Coupled Device (CCD) images were taken using the T27 telescope, one of the many telescopes in the iTelescope network, located in New South Wales, Australia. T27, Figure 2, is also the largest telescope in the iTelescope network. Its primary mirror measures 27.5 inches (0.7 meters) in diameter. The T27 telescope has a focal length of 4531 mm and consists of a f/6.6 reflector along with CCD imaging for optimal imaging resolution. The CCD camera is 3056 by 3056 array (9 megapixels) imaging with a resolution of 0.53 "/pixel (iTelescope - T27).

A total of 29 images were acquired on epoch 2016.82424 with the T27 telescope when the target was 40º above the horizon. Two images were taken with a red filter and two more images were taken with a blue filter. All four of these images had an exposure time of 60 seconds. A hydrogen-alpha filter was used to take another two more images with an exposure time of 150 seconds. We also used no filter ("luminance") to take

Figure 2. The T27 telescope from the iTelescope network used for the astrometric measurements of HJ 5439.

an additional two images with an exposure time of 45 seconds. Lastly, 21 green images (19 unintentional images) were taken with an exposure time of 60 seconds. These specific exposure times were selected to ensure the prevention of oversaturation from the incoming rays of light, thus providing us with well-defined and highly resolved images.

All 29 of these images were preprocessed by the iTelescope data reduction pipeline to smooth out the distortions and adjust the resolutions. The images were then imported into MaximDL v6 software to attach the World Coordinate System (WCS) positions into the Flexible Image Transport System (FITS) headers by comparing the star field of our selected stars with respect to the Fourth U.S. Naval Observatory CCD Astrograph Catalogue (UCAC4). Throughout this process, MaximDL used 164 stars present around our star field to compute the precise coordinates of our binary stars within 0.14".

Mira Pro x64 was used to perform astrometric measurements to find the position angles (Theta) and separation (Rho) of HJ 5439 in each image; this process required Mira Pro to determine the A and B component stars, accurately mark the coordinates of these stars, and measure the centroids of A and B stars using Mirametrics' proprietary algorithm. The data was measured under the assumption that the centroid is the geometric center of the star, Figure 3.

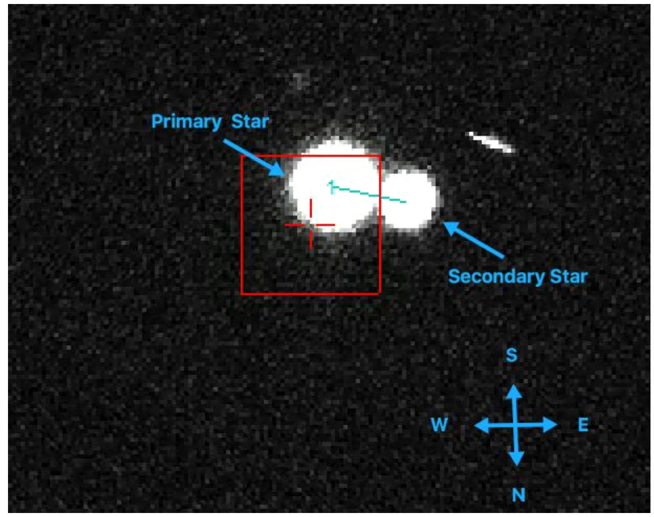

Figure 3. Mira Pro locating the centroids of the primary and secondary stars, dictated by the teal line, to perform astrometric measurements. The cross hairs centered on the red box are the coordinates of HJ 5439.

Mira Pro Results

The calculated values of the mean position angle and the mean separation distance of HJ 5439 for each filter used are outlined in Table 2. This table also includes the uncertainties associated with θ and ρ for individual filters and all 29 images combined. The listed uncertainties for θ and ρ are the standard error of the mean. These were determined by calculating the standard deviations of θ and ρ and dividing by the square root of the sample size, respectively. The mean position angle of all 29 images is 79.2º ± 0.2º while the calculated mean separation distance is 9.53" ± 0.04". These results indicate a discrepancy with the last measurement with reported uncertainties on 1998.50 (USNO), showing HJ 5439 as having a lower position angle with a

Table 2. Position angle and separation distance measurements and uncertainties for HJ 5439. We also include the measurements from 1998.50, which was the latest analysis prior to this paper of HJ 5439.

HJ 5434 of 2016.82424				
Type of Filter: (specific #'s of filters used)	**Mean Position Angle θ (°)**	**Standard Error of Mean θ**	**Mean Separation Distance ρ (")**	**Standard Error of Mean ρ**
H-Alpha: (2)	79.8	-	9.40	-
Luminance: (2)	80.0	-	9.63	-
Red: (2)	78.1	-	9.46	-
Blue: (2)	79.3	-	9.47	-
Green: (19)	79.2	-	9.55	-
All Images: (29)	79.2	0.2	9.53	0.04
1998.50 measurement (Last analysis prior to this paper)	79.6	0.1	9.76	0.02

shift of 0.3º. HJ 5439 shows a lower separation distance of 0.27" compared to epoch 1998.50.

Verifying Mira Pro

To test the validity of our results, we use an alternative astronomical imaging application, SAO DS9, to measure the position angle and the separation distance using the same methodology for two of our images. The separation distance differed by less than 0.5" and the position angle differed by about 2º, which is consistent with the uncertainties associated with the individual measurements.

Discussion

The position angle, Figure 4, displays a counter-clockwise trend from 1835 to 1955. Assuming all historical measurements are accurate, between 1835 and 1920 theta has shifted 7º relative to the primary star. Between 1920 and 2016 theta has remained static; this discrepancy in the change of theta between the two respective time frames defies Newton's 1st Law of Motion, suggesting that the 1835 measurement might be an error. The separation distance in Figure 5 has stayed constant around 10" except for the first measurement in 1835. Figure 6 shows that the secondary star demonstrates no obvious linear or arc-like motion with respect to the primary. For these reasons, we believe that our data, compared with the historical data, supports the idea that HJ 5439 is a non-physically associated double star system.

Conclusion

T27 from the iTelescope network was used to obtain 29 total images of 5 different filters of the double star system WDS 00023-7238 HJ 5439. We used astronomical imaging software to measure the position angle and the separation distance. Our measurements in epoch 2016.82424 were different from the most recent observation, measured in epoch 1998.50 yet consistent with many of the historical measurements. Our results, combined with the historical measurements, show no obvious orbital motion, suggesting that HJ 5439 may be a visual double star system.

Acknowledgments

The authors would like to thank the United States Naval Observatory for the historical data obtained with the iTelescope. This publication would not have been possible without the Boyce Research Initiatives and Education Foundation for sponsoring and organizing this project.

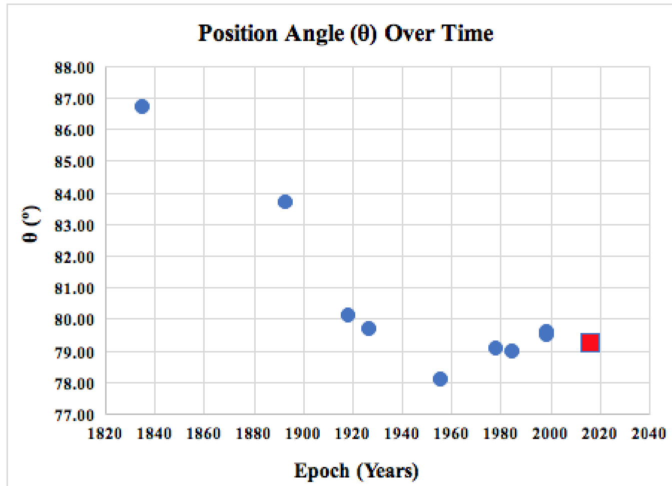

Figure 4. WDS 5439 position angle versus epoch. XY plot of the historical observations of HJ 5439's A & B component stars' relative positions. The blue dots indicate the position angles for each respective year. Our result (from Table 1) is marked as a red square. The error bars are too small to represent on this graph and the succeeding graphs, so they are omitted.

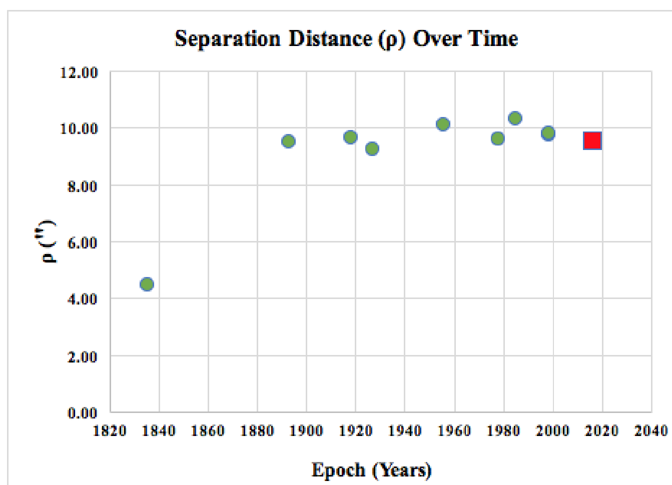

Figure 5. Separation distance versus epoch. XY plot of the historical observations of HJ 5439's A & B component stars' separation distances. The green dots indicate the separation distances for each respective year. Our result (from Table 1) is marked as a red square.

CCD Astrometric Measurements of WDS 00023-7238 HJ 5439

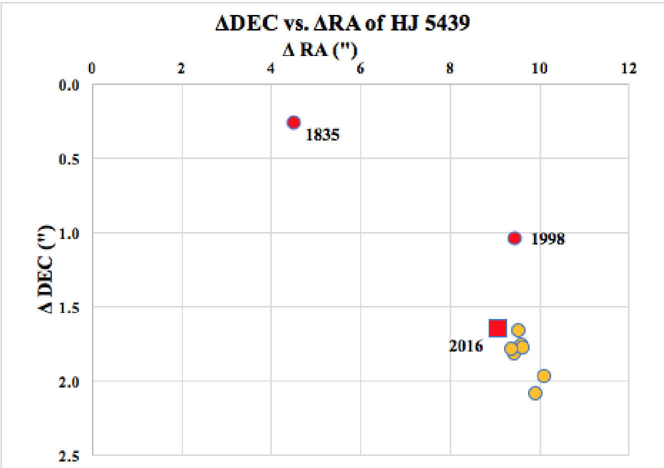

Figure 6. Relative declination versus relative declination plot of the historical observations of HJ 5439. This models an orbit with the primary component artificially fixed at the origin. The red points indicate the first and last historical measurements while our measurement is marked with a red square. The data presents no obvious indications of an arc or linear motion, suggesting that HJ 5439 is most likely a visual pair.

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Astrometric Measurement of WDS 03117+8128 STF 327 AB

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Abstract: We report CCD astrometric measurements of the double star system WDS 03117+8128 STF327AB using the iTelescope network. We found the relative position to be ρ = 20.26 ± 0.12 arc-sec and θ = 289.1 ± 0.39 degrees at epoch 2016.84. When combined with the historical data over the last 114 years the trend suggests the decreasing of the distance between the AB pair.

Introduction

We used the Washington Double Star Catalog (WDS) to identify a binary pair on which to conduct angle (Theta) and separation (Rho) measurements. The double star system was selected based on the following requirements:

- Observable from the Northern hemisphere in the autumn
- Angular separation greater than six arc seconds
- Magnitude difference of no more than 5

The catalog star WDS 03117+8128 (STF 327 AB) satisfied these criteria.

The A star in STF 327 is a spectroscopic binary (WDS Notes). The B star is not part of the spectroscopic pair. The primary has a spectral type of A7III-IV (Sordiglioni, G.). That means the star is a (A) white (IV) subgiant. The difference in magnitude between the A and B stars is 4.75 with the primary star having a magnitude of 5.914 in the visible and the secondary star having a magnitude of 10.7 in the visible, per SIMBAD data. The first position angle and separation measurements taken in 1902 were 282^o and 25 arc-seconds, respectively. The last measurements were 289^o and 21.2 arc-seconds, respectively, in 2003.

Equipment, Observations, and Data Reduction Procedures

CCD images were taken using the T7 and T18 telescopes, part of the iTelescope network. T7 is a Corrected Dall-Kirkham Astrograph with an aperture of 431mm, a focal length of 2929mm, and a F/Ratio of f/6.8. The CCD for the T7 is a SBIG STL-11000M (ABG) with a resolution of 0.63 arc-secs/pixel housing an array 4008 by 2672 (10.7 Mega pixels) with a FOV of 28.2 x 42.3 arc-mins located in Nerpio, Spain.

Additional images were taken using the T18 telescope, also located in Nerpio, Spain, using a Planewave 0.32-m f/8.0 reflector equipped with a 3072 by 2048 array imaging at a pixel scale of 1.69″. Both cameras can easily resolve separations above five arc-seconds.

A total of six images were acquired between epochs 2016.816 and 2016.854. Two images were taken with the T7 Telescope, each with red (1-90sec, 1-120sec). Four images were taken with the T18 Telescope, two images each with the red (1-90sec,1-120sec), hydrogen alpha (1-120sec, 1-180sec). An additional 11 images were excluded due to tracking quality of the observations.

The remaining 6 images were preprocessed (dark and flat correction) by the iTelescope data reduction pipeline. MaximDL v6 was used to insert World Coordinate System (WCS) positions into the FITS headers through comparison of the image star field against the Fourth U.S. Naval Observatory CCD Astrograph Catalogue (UCAC4).

During this process MaximDL typically used approximately 400 stars out of a database of 3000 stars for this star field. Mirametrics Mira Pro x64 was used to compute accurate position angles and separations of the component stars. The A and B stars were identified,

Table 1. Results of Mira Pro astrometric measurements of WDS 03117+8128.

WDS 03117+8128 STF 327AB			
Telescope: (number of images per filter)	**Epoch 2016.84**	**θ (degrees)**	**ρ (arcseconds)**
T07: (2 R) T18: (2 R), (2 H-alpha)	Mean	289.1	20.26
	Standard deviation	0.39	0.12
	Std. error of mean	0.065	0.02
2003.87 measurement (Last one previous to this investigation)		288.5	21.2

marked, and then measured using the algorithms of Mira Pro to find the centroids of each component. The telescopes and filters used for the 6 images measured gave consistent results so we calculated a master average of ρ and θ.

Results

Table 1 shows our calculated angular separation and position angle for STF327AB, Figure 1, and the uncertainty in each. We find a mean and position angle of 289.1º ± 0.06º and an angular separation of 20.26″ ± 0.02″, slightly but significantly larger than the 2003.87 measurement of 21.2″.

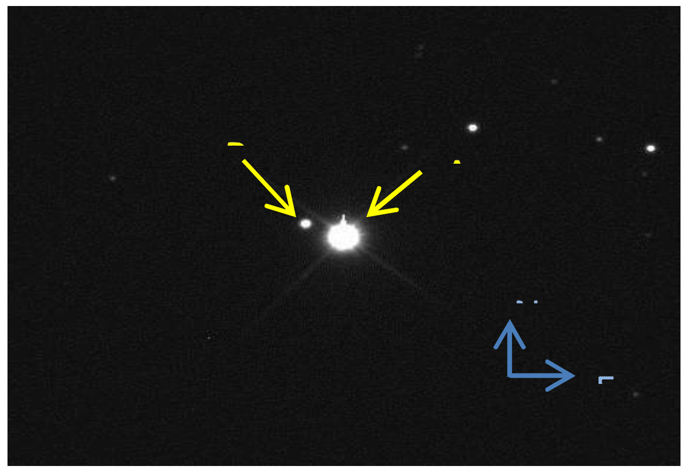

Figure 1. Image from T18 of WDS 03117+8128. Cropped to show target stars.

Discussion

Astrometry, derived from six images, are plotted together with historical data from the WDS (Figure 2). Further observations over the next several decades may reveal whether STF327AB angular separation will continue to increase or reach a maximum. Microsoft Excel was used to develop a scatter plot of the historical and our measured XY coordinate position of the AB pair based on the data in Table 2. The results are shown in Figure 2. The measurements from this activity are indicated by a red triangle.

Conclusions

We obtained astrometry of the double star system WDS 03117+8128 STF 327AB using the T7 and T18 telescopes of the iTelescope network. We have demonstrated that this system is fairly easy to observe with small-to-moderate sized telescopes. Astrometric observations of such systems as their relative path on the sky approaches maximum separation and curvature can improve their fitted orbits.

Acknowledgements

The authors thank the United States Naval Observatory for providing historical measurement data and iTelescope for the use of their service. Additionally, we thank the Boyce Research Initiatives and Education Foundation (BRIEF) for their generous financial donation that allowed us to use the iTelescope robotic tele-

Table 2. Historical and latest astrometric measurements of WDS 03117+8128.

03117+8128	Position Angle	Separation
Epoch	**(degrees)**	**(arc-seconds)**
1902.73	281.9	25.01
1904.84	281.6	24.64
1925.30	283.8	23.72
1935.63	284.1	23.71
2000.76	288.3	20.99
2003.87	288.5	21.20
2016.84	289.1	20.26

Astrometric Measurement of WDS 03117+8128 STF 327 AB

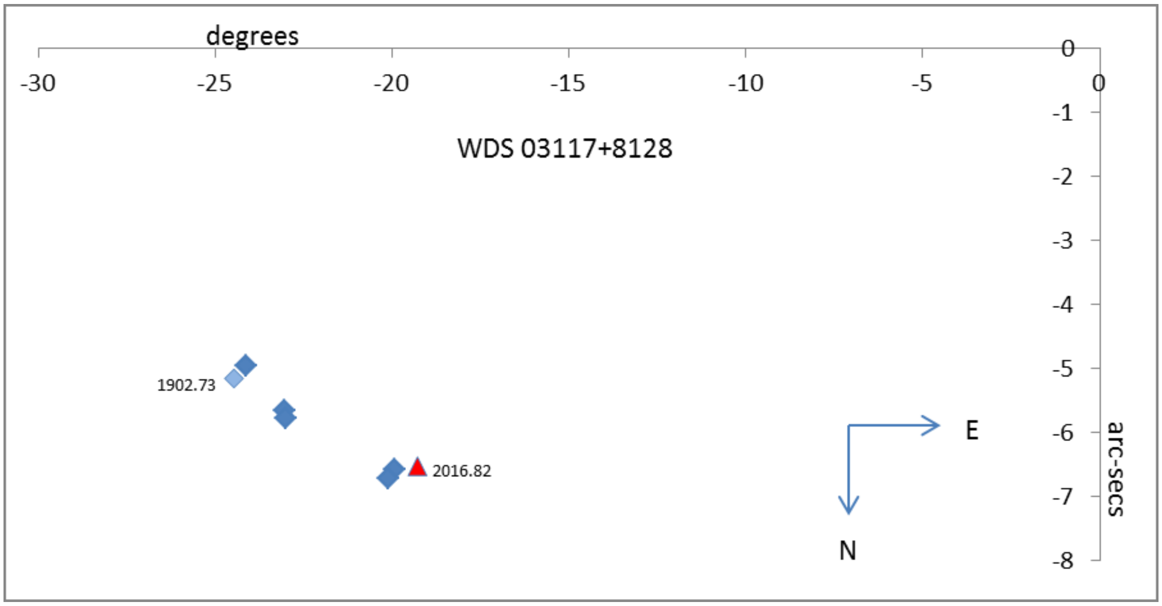

Figure 2. Distance between components A and B

scope system and remote server and software. The authors thank Russell Genet for providing guidance.

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CCD Astrometric Measurements of Double Stars BAL 746, BPM 342, KU 92, and STF 897

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Abstract: Double stars WDS 06589-0106 (BAL 746), WDS 06579+1430 (BPM 342), WDS 07006+0921 (KU 92), and WDS 06224+2640 (STF 897) were measured as part of a science fair project for the 2016 Greater San Diego Science and Engineering Fair. The goal was to measure the separation and position angles of stars by using a telescope with a charge-coupled device (CCD) on the iTelescope network. Five images were taken of each of the stars. These images were plate solved with Visual PinPoint and measured using Aladin Sky Atlas. Measurements for all five doubles compare well to the more recent values in the Washington Double Star Catalog.

Introduction

Double stars WDS 06589-0106 (BAL 746), WDS 06579+1430 (BPM 342), WDS 07006+0921 (KU 92), and WDS 06224+2640 (STF 897) were imaged with a charge-coupled device (CCD) in November and December of 2015 as part of a project for the 2016 Greater San Diego Science and Engineering Fair. These star systems were selected because they had separation angles greater than 10 arcseconds and the magnitudes of both components were between 8 and 10. STF 897 was specifically chosen as a test case to attempt to duplicate recent measurements (AlZaben, et al. 2016).

Equipment and Procedures

The iTelescope network was used to image the double star systems. iTelescope has telescopes of various focal lengths and apertures with charge-coupled device (CCD) cameras of various resolutions in four locations: seven in the U.S. (six in New Mexico and one in California), three in Spain, and nine in Australia. At least one set of telescopes is open at any time of the day, weather permitting. Spain had the most convenient times and best weather for imaging, so all images used in this project were taken using the T18 telescope in Spain. T18 is a PlaneWave Corrected Dall-Kirkham (CDK) 318mm aperture imaging platform and uses an STXL-6303E CCD camera from SBIG Imaging Systems with a resolution of 0.73 arcsecond/pixel and the field of view is 37.41 x 24.94 arcminutes.

A hydrogen-alpha (Hα) filter was used for all images. This filter shows light emitted by hydrogen, the most common element in stars. It is a "narrowband filter," meaning that it transmits a very specific, or narrow, wavelength of light. This filter was used in the hope that it would decrease the amount of ambient light from the moon, since many images were taken during a gibbous or full moon.

Visual PinPoint astrometric engine and the Fourth U.S. Naval Observatory CCD Astrograph Catalog (UCAC4) were used to plate solve the images. Aladin Desktop, an interactive sky atlas available from the Strasbourg Astronomical Data Center (CDS) was used to analyze the images and measure the position and separation angle of the doubles using its photometry "phot" and "Auto-distance measurer" tools.

Methods and Procedures

Imaging plans were scheduled with iTelescope.net. Weather often interfered with the scheduled imaging plans as the observations were done during the winter. Consequently, most images were taken in real time using the "Single Image" feature on iTelescope.com. The Single Image button immediately begins the imaging procedures when you confirm the settings, such as coordinates and filter, without having to reserve the system if the telescope is not in use. All doubles were imaged over two nights; consecutive nights for one double, and up to two weeks apart for two of the doubles.

Eventually, 5 FITS images were taken of each of the 4 double stars. This format allows extra data such as the coordinates of the stars and the arcsecond/pixel

CCD Astrometric Measurements of Double Stars BAL 746, BPM 342, KU 92, and STF 897

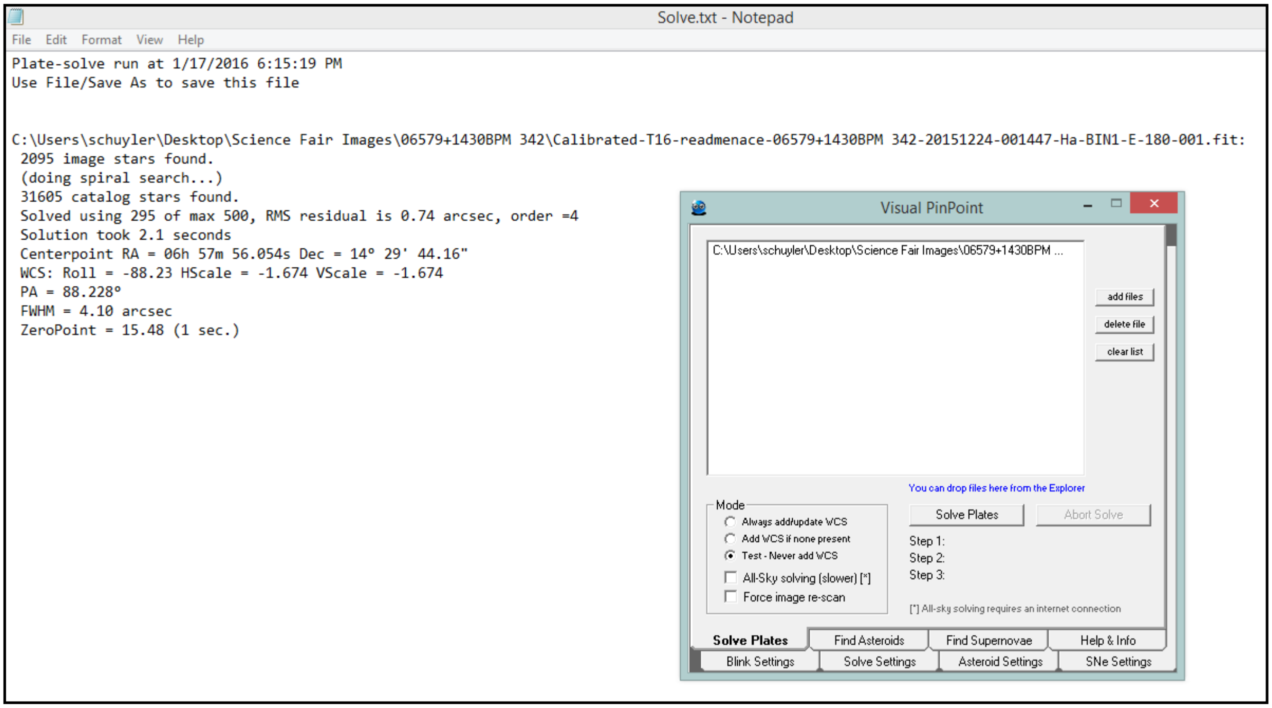

Figure 1. Visual PinPoint plate solving an image of BPM 342 using 295 stars.

scale to be added to the image file's header. To add this data, the images were plate solved using Visual PinPoint (Figure 1). To plate solve, Visual PinPoint required the UCAC4 star catalog so it could check to see if any stars in the image match stars in the catalog. When it determines where the image is in the sky, it adds coordinate information to the FITS header.

After the images were plate solved, they were imported into the free software Aladin Sky Atlas. Using Aladin's photometry "phot" tool, the separation between two objects can be calculated. In the "Tool" menu, the "Auto-distance measurer" option must be enabled and the "phot" tool button must be clicked. To measure the double, first the B component is clicked on, which finds its centroid. Next, the same is done with the A component. Finally, by clicking between the two components, Aladin will draw a line between them and calculate the position and separation angle of the two stars (Figure 2). This was repeated for each of the twenty images and the results were recorded in a Google Sheet spreadsheet. Statistics were calculated for all data, and Besselian epochs were calculated from the Julian dates of each image using the following formula: (Greaney 2012):

$$BesselianEpoch = B1900 + \frac{JulianDate - 2415020.31352}{365.242198781}$$

The epoch of each image was averaged and rounded to four decimal places to obtain an epoch for each mean measurement.

Results

Table 1 shows the mean of the measurements, the standard deviation (SD), and the standard error of the mean (SEM) for separation in arcseconds and position angles in degrees of the primary and secondary components of each double star system. Table 2 shows comparisons between these measurements and the most recent published measurements in the Washington Double Star Catalog (WDS).

Discussion

STF 897 was chosen as the first of the four stars to measure in this project because it was recently measured by a team of astronomers at the Army and Navy Academy in Carlsbad, California (AlZaben et al., 2015). After an early draft of their paper was read it was decided to attempt to duplicate their measurements first as a test. Instead of a separation of 18.3 arcseconds - the value listed in the WDS at the time - this project measured a separation of 17.99 arcseconds. AlZaben et al. measured a separation of 18.00 arcseconds, only .01 arcseconds off this project's measurements. The posi-

(Text continues on page 418)

CCD Astrometric Measurements of Double Stars BAL 746, BPM 342, KU 92, and STF 897

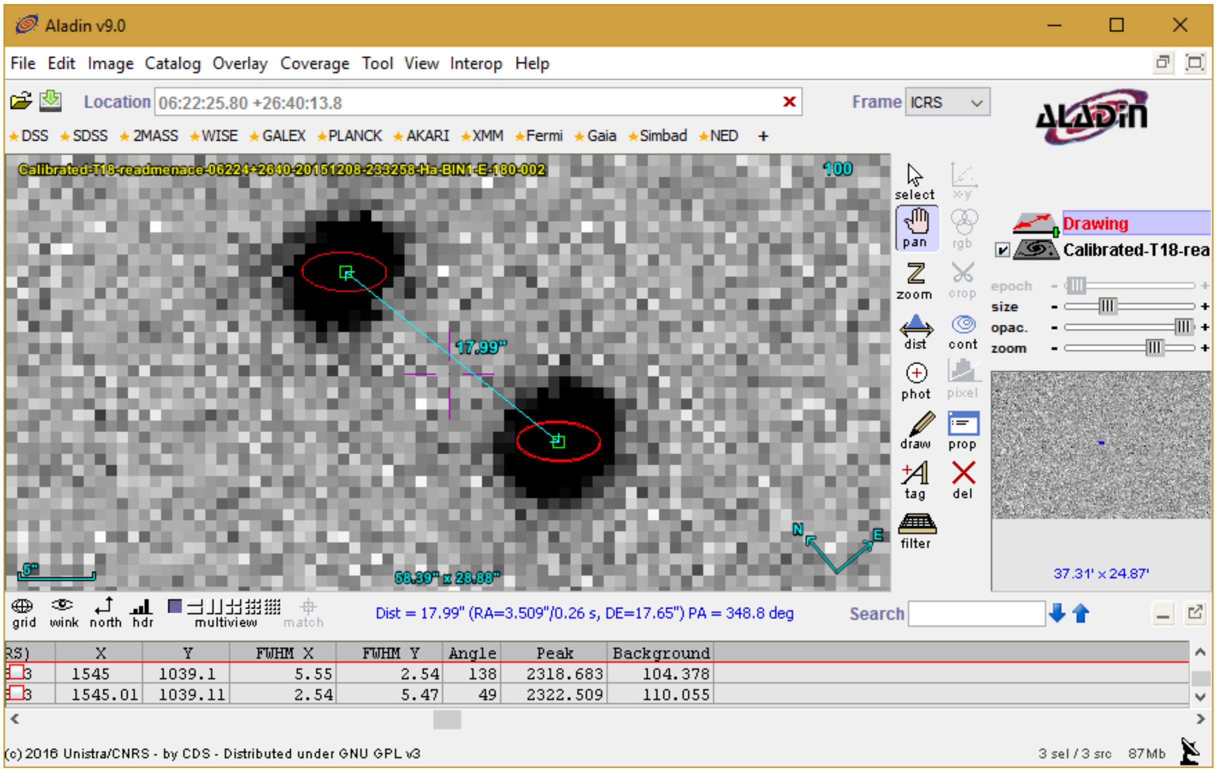

Figure 2. Measuring an image of STF 897 in Aladin Astrometry Software

Table 1. Measurements of the Pairs

Discoverer Code	WDS ID	Besselian Epoch	Total # of Exposures	Nights		Theta	Rho
STF 897	06224+2640	B2015.9306	5	2	Mean	348.58	17.99
					SD	0.28	0.037
					SEM	0.124	0.016
BPM 342	06579+1430	B2015.9724	5	2	Mean	223.26	26.83
					SD	0.05	0.074
					SEM	0.024	0.033
KU 92	07006+0921	B2015.9725	5	2	Mean	321.64	46.17
					SD	0.05	0.017
					SEM	0.024	0.008
BAL 746	06589-0106	B2015.9894	5	2	Mean	289.84	14.12
					SD	0.57	0.060
					SEM	0.256	0.027

Table 2. Comparison of Last and New Measurements

Discoverer Code	Last Historical WDS Measurements			New Measurements			Residuals	
	Date	Theta	Rho	Date	Theta	Rho	Theta	Rho
STF 897	2015.249	348.58	18.00	B2015.9306	348.58	17.99	0.00	-0.01
BPM 342	2001.01	223.4	26.802	B2015.9724	223.26	26.82	-0.14	0.016
KU 92	2004.967	321.1	46.41	B2015.9725	321.64	46.17	-0.46	-0.24
BAL 746	2010.5	290	14.06	B2015.9894	289.84	14.12	-0.16	0.06

CCD Astrometric Measurements of Double Stars BAL 746, BPM 342, KU 92, and STF 897

(Continued from page 416)

tion angles measured were the same - both projects measured 348.58° as opposed to the WDS's most recent listed value of 348°. Even though AlZaben et al. used a different combination of telescopes (iTelescope's T3, T18, and T11), different CCD cameras, and different software (Mira Pro x64) to perform measurements of STF 897, the results were almost identical, so the first attempt was considered a success. Eventually, AlZaben et al.'s measurement was recorded as the most recent measurement in the WDS.

All separation measurements were within ±0.25 arcseconds of the previous WDS value and all position angle measurements were within ±0.5 degrees of the listed value. STF 897 was most recently measured in 2015, BPM 342 in 2001, BAL 746 in 2010, and KU 92 in 2004. Hopefully these new measurements will help to determine their classifications as physical or optical doubles.

The standard deviation and standard error of the mean for the theta measurements of the stars STF 897 and BAL 746 were larger than expected. There was a single measurement for each star that strayed from the values of the other measurements, but not enough to be considered an outlier. Despite the fact that the theta result for STF 897 had a high SD and SEM, the mean of the measurements was identical to the most recent value in the WDS reported by AlZaben et al.

Acknowledgements

The author thanks Kent Smith for making iTelescope.net available for use, editorial help, and general guidance and encouragement with this paper. Thanks to Grady Boyce for feedback and encouragement. Thanks to Boyce Research Initiatives & Education Foundation (http://www.boyce-astro.org) and Pat Boyce for the introduction to double star astrometry. Thanks to Dr. Russell Genet, Richard Harshaw, and Dr. Vera Wallen for reviewing this paper. This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory. This research has made use of "Aladin sky atlas" and the SIMBAD database, both developed and operated at CDS, Strasbourg Observatory, France.

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Schuyler Smith (Figure 3) attends Mt. Everest Academy, a K-12 Independent Study school in San Diego, CA. At the time of writing this paper, she was in the 8th grade. This research was part of a science fair project that was awarded sweepstakes in the Junior Division of the 2016 Greater San Diego Science and Engineering Fair and 2nd Place in the Junior Division Physics & Astronomy category at the 2016 California State Science Fair. Ms. Smith is also a member of the San Diego Astronomy Association and volunteers at school star parties around San Diego.

Figure 3. Schuyler Smith measuring double stars through her Orion SkyQuest XT8.

Jonckheere Double Star Photometry – Part VI: Auriga

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Abstract: If any double star discoverer is in urgent need of photometry then it is Jonckheere. There are over 3000 Jonckheere objects listed in the WDS catalog and a good part of them has magnitudes which are obviously far too bright. This report covers the Jonckheere objects in the constellation Auriga. Only one image per object was taken as despite the risk of random effects even a single instance visual magnitude measurement is better than the currently usually given estimation although the J-objects in this constellation seem with some exceptions better covered with observations as usual for Jonckheere doubles.

Introduction

The degree of contamination of the WDS catalog with wrong magnitude data is rather high – this might very well be a side effect of magnitudes considered being not as important as the basic double star parameters separation and position angle. Measurements of magnitudes without these basic parameters are not even counted as observations in the WDS catalog. As follow up to the report on J-objects so far I selected this time all J-objects in Auriga to be imaged for measurements with a remote telescope located in New Mexico. To counter the single image random effects especially for the astrometry results of rather close pairs I checked also catalogs like especially GAIA DR1 for recent precise position data with a surprisingly high number of objects with missing GAIA DR1 data. The single image random effects seem less significant for the measured magnitudes as a magnitude error of ~0.1 or even a bit larger seems negligible in comparison with the Jonckheere objects often given magnitude errors in the range of up to 2 magnitudes. The G-band magnitudes given in the GAIA DR1 data lines covering the white light range of about 330 to 1050 nm (http://www.cosmos.esa.int/web/gaia/science-performance) are also a good indication for the visual magnitudes and there is even a relation available to convert Johnson V and Johnson-Cousins V-I_C to Gaia G:

$$G = V - 0.0257 - 0.0924(V - I_C) - 0.1623(V - I_C)^2 + 0.0090(V - I_C)^3$$

with an average fit error of 0.05 mag.

Results of Photometry and Catalog Checking

For each of the selected J-objects one single image was taken with iTelescope iT24 with V-filter and 3s exposure time, plate solved with Astrometrica using the URAT1 catalog with reference stars in the Vmag range of 8.5 to 14.5 giving not only RA/Dec coordinates but also photometry results for all reference stars used including an average dVmag error. The J-objects were then located in the center of the image and astrometry/photometry was then done by the rather comfortable Astrometrica procedure with point and click at the components delivering RA/Dec coordinates and Vmag measurements based on all reference stars used for plate solving. Weather was a bit difficult during the imaging sessions so I had to take additional images for several objects to get acceptable results.

The results are given in table 1 below with the following structure:

- The header line gives the WDS catalog data for each object per 08/2016 with RA/Dec in the HH:MM:SS/DD:MM:SS format and with Date giving the year of the last observation
- The following rows give the data for the object in existing catalogs (mostly GAIA DR1) as far as available with
  - ◊ RA/Dec in decimal degrees with the catalog reference given in the Source/Notes column
  - ◊ Sep gives separation in arcseconds in the data lines calculated (in radians) as

$$Sep = \sqrt{\left[(RA2 - RA1)\cos(Dec1)\right]^2 + (Dec2 - Dec1)^2}$$

- ◊ PA gives position angle in degrees in the data lines calculated as

$$PA = \arctan\left[\left(RA2 - RA1\right)\cos\left(\frac{Dec1}{Dec2 - Dec1}\right)\right]$$

  in radians depending on quadrant
- ◊ G-band M1 and M2
- ◊ If 2MASS and GAIA DR1 positions are available then also proper motion data is calculated according to the formulae used for Sep and PA (see above)
- ◊ Used Aperture and observation method code is given in the Ap and Me columns. As GAIA uses a rectangular aperture the value given in the Ap column is the calculated diameter for a corresponding circular surface
- ◊ CPM rating procedure according to Knapp and Nanson 2017 (see appendix for description)
- ◊ Date gives the Bessel observation epoch

- The last row per object gives then the measurements based on the iT24 images
  - ◊ RA/Dec in decimal degrees from plate solving
  - ◊ Sep gives separation in arcseconds in the data lines calculated (in radians) as

$$Sep = \sqrt{\left[\left(RA2 - RA1\right)\cos\left(Dec1\right)\right]^2 + \left(Dec2 - Dec1\right)^2}$$

  - ◊ PA gives position angle in degrees in the data lines calculated as

$$PA = \arctan\left[\left(RA2 - RA1\right)\cos\left(\frac{Dec1}{Dec2 - Dec1}\right)\right]$$

    in radians depending on quadrant
  - ◊ Visual magnitudes M1 and M2 based on the plate solving results
  - ◊ Measurement error estimations calculated on base of the average plate solving errors are given in a separate Table 2 in the appendix.

Summary

Table 1 shows with few exceptions significant differences for the magnitudes compared with the WDS data even if the J-objects in Auriga seem rather well researched in comparison with other northern constellations. Quite often also the WDS proper motion data seems quite off when compared with the values derived from comparing 2MASS to GAIA DR1 positions. Yet for a significant part of the objects calculation of proper motion values was not possible due to missing 2MASS data and for surprisingly many objects there is also no GAIA DR1 data for at least for one component available. That means that the GAIA DR1 coverage is less complete than expected. Only a small part of the objects with calculated PM numbers qualify as potential CPM pairs based on calculations with the now available GAIA DR1 data but the proper motion speed is in most cases too slow to be significant. This means that most Jonckheere objects in Aur are optical pairs. Finally two objects (J 943 and J988) seem to be either bogus or misidentified but on the other side one object with WDS code X for bogus (J 2414) is obviously real.

Acknowledgements

The following tools and resources have been used for this research:

- 2MASS catalog
- 2MASS images
- AAVSO APASS
- AAVSO VPhot
- Aladin Sky Atlas v9.0
- Astrometrica v4.10.0.427
- AstroPlanner v2.2
- iTelescope iT24: 610mm CDK with 3962mm focal length. Resolution 0.625 arcsec/pixel. V-filter. No transformation coefficients available. Located in Auberry, California. Elevation 1405m
- GAIA DR1 catalog
- MaxIm DL6 v6.08
- POSS images
- SDSS DR9 and DR7 catalogs
- SDSS images
- SIMBAD
- UCAC4 catalog
- URAT1 catalog
- VizieR
- Washington Double Star Catalog

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Jonckheere Double Star Photometry – Part VI: Auriga

Table 1. Jonckheere Objects in Auriga

J#	RA	Dec	Sep	PA	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM	Source/Notes
11	04:54:36.46	+43:44:24.8	1.6	20.0	10.20	10.20	1	5							2003		WDS 04546+4345
	73.65163333	43.7397917	1.49	20.9	11.27	11.36							0.61	C	2016.239		iT24 1x3s. Over-lapping star disks
																	Secondary neither in 2MASS nor GAIA DR1 available
12	05:00:15.19	+42:51:42.5	3.0	239.0	9.90	11.40	26	8							2002		WDS 05003+4252
	75.06331525	42.8617747	3.06	238.3	10.80	12.55							0.96	Hg	2015.000		GAIA DR1. M1 and M2 are G-band
	75.06332500	42.8617528	3.00	233.7	11.26	12.62							0.61	C	2016.239		iT24 1x3s. Touch-ing star disks
																	No 2MASS object for B
13	05:04:07.73	+43:40:23.8	2.0	168.0	9.60	9.60	11	-20							2008		WDS 05042+4341
	76.03214134	43.6737354	2.14	166.9	10.90	10.85							0.96	Hg	2015.000		GAIA DR1. M1 and M2 are G-band
	76.03214583	43.6737722	2.14	176.5	10.81	10.82							0.61	C	2016.116		iT24 1x3s. Touch-ing star disks. Image quality questionable. SNR A and B <20
																	No 2MASS object for B
17	06:05:10.92	+43:02:18.2	2.9	154.0	10.15	10.59	-13	5		0	-11				2002		06052+4303
	91.29547059	43.0383207	2.90	154.0	9.94	10.23	-4.33	-6.78	0.49	-4.44	-5.91	0.71	0.96	Hg	2015	BBBB	GAIA DR1. Gmag and PM data from GAIA DR1 catalog. Might be a CPM pair. Plx similar but most probably no gravi-tational relation. Border case for a physical
	91.29550833	43.0382361	2.52	156.1	9.80	10.01							0.61	C	2016.171		iT24 1x3s. Touch-ing star disks
																	No 2MASS object for B
31	04:57:29.66	+37:51:14.9	3.6	350.0	10.70	13.40	2	-10							2008		WDS04575+3751
	74.37358751	37.8541582	3.60	349.5	10.49	12.28	-1.84	0.48	5.68	-44.68	33.29	11.32	0.96	Hg	2015	CCCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position com-parison with 2MASS
	74.37358750	37.8541389	3.58	349.7	10.72	12.45							0.61	C	2016.239		iT24 1x3s. Touch-ing star disks
32	05:01:09.64	+38:13:38.2	2.6	291.0	10.23	13.50	17	-5							2000		WDS05012+3813
	75.29013333	38.2272583	2.29	289.7	10.06	11.88							0.61	C	2016.239		iT24 1x3s. Over-lapping star disks
																	Secondary neither in 2MASS nor GAIA DR1 available
J#	RA	Dec	Sep	PA	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM	Source/Notes
240	05:02:46.08	+35:07:55.3	1.3	211.0	10.70	10.90	1	11							2008		WDS05027+3507
	75.69208096	35.1322564	1.32	210.2	10.71	10.83							0.96	Hg	2015		GAIA DR1. M1 and M2 values are G-band
	75.69200833	35.1322194	1.23	216.2	10.80	11.29							0.61	C	2016.239		iT24 1x3s. Heavily overlapping star disks
																	Despite a hint of elongation in the 2MASS images there is no 2MASS cata-log object for B, the same goes for URAT1

Table 1 continues on next page.

Jonckheere Double Star Photometry – Part VI: Auriga

Table 1 (cointinued). Jonckheere Objects in Auriga

J#	RA	Dec	Sep	PA	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM	Source/Notes
591 AB	06:16:45.22	+38:52:29.7	4.5	200.0	11.20	12.40	-3	-9							2007		WDS06167+3852
	94.18843080	38.8749072	4.42	199.7	11.21		1.80	-2.32	7.24	-6.44	1.38	7.18	0.20	Eu	2013.575		URAT1. PM data calculated from position comparison with 2MASS
	94.18845388	38.8749158	4.49	199.7	11.52	12.86	5.89	-0.05	6.53	-3.13	-0.69	6.53	0.96	Hg	2015	CCCC	GAIA DR1. PM data calculated from position comparison with 2MASS
	94.18843750	38.8748889	4.36	198.3	11.59	13.01							0.61	C	2016.902		iT24 5x1s
GCB 18 AC	06:16:45.22	+38:52:29.7	5.5	321.0	11.20	12.80	-3	-9		38	-24				2007		WDS06167+3852
	94.18843080	38.8749072	5.47	321.6	11.21		1.80	-2.32	7.24	-2.25	3.94	7.17	0.20	Eu	2013.581		URAT1. PM data calculated from position comparison with 2MASS
	94.18845388	38.8749158	5.48	321.3	11.52	13.03	5.89	-0.05	6.53	0.28	5.07	6.53	0.96	Hg	2015	CCCC	GAIA DR1. PM data calculated from position comparison with 2MASS. WDS PM data for C probably wrong
	94.18843750	38.8748889	5.38	321.9	11.59	13.31							0.61	C	2016.902		iT24 5x1s
593	06:18:41.15	+37:52:23.6	4.4	195.0	11.22	12.20	-3	-9		-13	-46				2004		WDS06187+3752
	94.67151065	37.8731627	4.43	194.4	10.98	12.25	5.37	-24.06	5.60	2.52	-24.73	5.60	0.96	Hg	2015.000	CACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	94.67150417	37.8731389	4.42	194.1	11.14	12.47							0.61	C	2016.239		iT24 1x3s
650	04:51:21.02	+49:03:11.9	4.1	38.0	11.13	12.20	-4	-8							2002		WDS04513+4901
	72.83760387	49.0533203	4.14	38.0	10.83	12.07	-1.27	-2.07	5.60	-2.19	-3.59	5.60	0.96	Hg	2015.000	ACCC	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	72.83763333	49.0533250	4.12	38.7	10.99	12.23							0.61	C	2016.239		iT24 1x3s
651	05:01:41.20	+49:05:03.3	4.6	238.0	10.63	11.60	11	4							2002		WDS05017+4905
	75.42165942	49.0842541	4.63	238.3	10.57	11.68	0.73	1.54	5.97	-0.14	-4.56	5.97	0.96	Hg	2015.000	CCCC	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	75.42164583	49.0842667	4.60	238.2	10.63	11.82							0.61	C	2016.239		iT24 1x3s
652	05:20:43.39	+33:50:22.8	3.7	355.0	12.00	12.50	2	-26		0	-1				2008		WDS05207+3349
	80.18077667	33.8392027	3.75	355.5	12.03	12.50	-4.83	-9.00	6.69	-4.46	-9.71	6.69	0.96	Hg	2015.000	BACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	80.18076250	33.8391889	3.69	355.5	12.09	12.57							0.61	C	2016.239		iT24 1x3s
653	05:35:06.54	+35:18:20.6	5.7	172.0	11.37	12.90	0	-4		-8	-4				2001		WDS05351+3517
	83.77727208	35.3057459	5.77	172.0	11.24	12.56	-1.72	-7.69	5.45	-1.56	-7.65	5.45	0.96	Hg	2015	AACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS - a bit slow but potential CPM
	83.77727083	35.3057722	5.98	172.5	11.30	12.74							0.61	C	2016.902		iT24 5x2s
665	06:44:05.90	+38:22:33.0	7.4	69.0	10.22	10.40	-6	-10							2014		WDS06442+3822
	101.02458748	38.3757970	7.57	66.5	10.25	13.03	-3.96	-8.16	5.91	-2.80	-7.81	6.75	0.96	Hg	2015	CBCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	101.02452917	38.3757889	7.45	66.7	10.25	13.34							0.61	C	2016.902		iT24 5x2s
693	06:35:03.99	+29:09:55.6	1.6	279.0	10.15	10.75									2009		WDS06351+2909
	98.76678750	29.1653611	1.75	279.2	9.86	10.84							0.61	C	2016.239		iT24 1x3s. Heavily overlapping star disks
																	Secondary neither in 2MASS nor GAIA DR1 available
897	05:20:38.72	+44:52:41.9	3.3	236.0	10.60	12.60									2011		WDS05206+4452
	80.16137500	44.8783278	3.37	234.2	10.33	12.23							0.61	C	2016.239		iT24 1x3s
																	Secondary neither in 2MASS nor GAIA DR1 available

Table 1 continues on next page.

Jonckheere Double Star Photometry – Part VI: Auriga

Table 1 (continued). Jonckheere Objects in Auriga

J#	RA	Dec	Sep	PA	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM	Source/Notes
898	05:23:07.03	+33:58:14.3	3.7	153.0	10.00	10.50	-28	56							2003		WDS05231+3400
	80.77910934	33.9714456	3.94	150.1	12.18	12.63	-5.06	-10.09	5.45	4.81	-15.72	5.45	0.96	Hg	2015.000	CCCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	80.77910417	33.9714222	3.94	149.9	12.54	12.97							0.61	C	2016.239		iT24 1x3s
899	05:31:39.14	+32:24:43.9	1.8	335.0	9.70	10.30									2013		WDS05317+3225
	82.91330833	32.4118000	1.85	333.1	12.54	12.88							0.61	C	2016.239		iT24 1x3s. Overlapping star disks
																	Secondary neither in 2MASS nor GAIA DR1 available
901	05:38:32.89	+32:01:22.8	2.9	145.0	12.80	12.80	-15	28		30	-49				2009		WDS05385+3201
	84.63679712	32.0234021	3.17	146.3	12.78	12.74	-23.09	25.78	9.20	53.45	-63.50	6.69	0.96	Hg	2015	CCCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	84.63684167	32.0233889	3.12	150.4	13.01	13.01							0.61	C	2016.989		iT24 10x3s. Touching star disks
902	05:47:19.02	+32:21:50.5	3.1	236.0	11.70	11.90									2002		WDS05473+3222
	86.83007700	32.3644777	3.07	236.4	11.47	12.03							0.96	Hg	2015		GAIA DR1. M1 and M2 are G-band
	86.83010000	32.3644667	3.01	231.9	11.46	11.97							0.61	C	2016.171		iT24 1x3s. Image quality questionable. SNR B <20
																	Secondary in 2MASS not available
903	05:49:12.46	+33:22:42.6	2.9	124.0	10.36	15.20									1959		WDS05493+3323. Code X for bogus
	87.30176667	33.3782528			10.19								0.61	C	2016.171		iT24 1x3s. Image quality questionable. No resolution of B
																	Secondary in 2MASS not available nor in GAIA DR1
904	06:01:34.96	+39:36:29.3	4.0	197.0	12.80	13.10									2002		WDS06016+3938
	90.39558724	39.6078932	3.85	197.4	11.60	12.92							0.96	Hg	2015		GAIA DR1. M1 and M2 are G-band
	90.39551250	39.6079111	3.78	198.0	12.22	12.99							0.61	C	2016.171		iT24 1x3s. Image quality questionable. SNR B <20
																	Secondary in 2MASS not available
905	06:02:45.92	+39:39:06.1	4.6	44.0	11.60	12.40									2004		WDS06028+3939
	90.69135498	39.6516949	4.64	44.1	11.06	12.17	1.19	-9.35	5.69	2.23	-8.02	5.69	0.96	Hg	2015	CCCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	90.69136667	39.6517194	4.28	42.2	11.11	12.45							0.61	C	2016.171		iT24 1x3s. Image quality questionable. SNR B <20
906 AB	06:07:48.41	+38:36:58.4	4.9	293.0	11.87	12.70	-4	-11							2003		WDS06078+3837 catalog data
	91.95169152	38.6161986	4.98	296.4	11.45	12.52	9.45	-10.80	6.00	-25.75	30.94	6.00	0.96	Hg	2015	CCCC	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	91.95168750	38.6161472	4.90	297.2	11.42	12.46							0.61	C	2016.902		iT24 5x1s

Table 1 continues on next page.

Jonckheere Double Star Photometry – Part VI: Auriga

Table 1 (continued). Jonckheere Objects in Auriga

J#	RA	Dec	Sep	PA	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM	Source/Notes
WSI 32 AC	06:07:48.41	+38:36:58.4	2.8	282.0	11.87	13.50	-4	-11							2003		WDS06078+3837 catalog data
	91.95169152	38.6161986	2.79	282.8	11.45	12.63	-2.47	-11.26	0.429				0.96	Hg	2015		GAIA DR1. M1 and M2 are G-band. PM data from GAIA DR1
	91.95182500	38.6161306	2.66	281.0	11.56	12.20							0.61	C	2016.171		iT24 1x3s. Touching star disks. Image quality questionable. SNR C <10
																	No 2MASS object for C
907	06:07:47.97	+35:30:50.6	2.5	236.0	11.30	11.30									2001		WDS06078+3532
	91.94988235	35.5140679	2.52	235.5	11.71	11.98							0.96	Hg	2015		GAIA DR1. M1 and M2 are G-band
	91.94985417	35.5140583	2.27	234.4	11.68	11.83							0.61	C	2016.239		iT24 1x3s. Touching star disks
																	No 2MASS object for C
908	06:19:25.83	+40:59:05.3	1.2	95.0	10.93	11.06									2001		WDS06195+4100
	94.85760417	40.9846222			10.30								0.61	C	2016.171		iT24 1x3s. No resolution. Combined magnitude rather confirms WDS data
																	Secondary neither in 2MASS nor GAIA DR1 available
910 AB	06:28:27.54	+43:04:05.5	2.2	339.0	9.94	10.59	4	-30	4	-30					2011		WDS06285+4304
	97.11479479	43.0680555	1.75	330.1	9.64	10.20	6.20	-23.04					0.96	Hg	2015		GAIA DR1. M1 and M2 are G-band. No GAIA DR1 PM data for B - WDS values suggest CPM
	97.11488333	43.0679500	1.77	326.9	9.82	10.00							0.61	C	2016.239		iT24 1x3s. Overlapping star disks
																	No 2MASS object for B
910 AC	06:28:27.54	+43:04:05.5	46.0	33.0	9.94	10.62	5	-29		33	-15				2011		WDS06285+4304
	97.11479479	43.0680555	45.60	32.7	9.64	10.49	6.20	-23.04	0.25	34.07	-14.27	2.92	0.96	Hg	2015	CCBC	GAIA DR1. M1 and M2 are G-band. PM data from GAIA DR1 catalog
	97.11488333	43.0679500	45.54	32.2	9.82	10.76							0.61	C	2016.239		iT24 1x3s
935	05:02:26.29	+37:48:12.1	3.1	46.0	10.41	13.30									2011		WDS05025+3748
	75.60957254	37.8033096	3.24	46.1	10.41	12.62							0.96	Hg	2015		GAIA DR1. M1 and M2 are G-band
	75.60957500	37.8033194	3.11	45.1	10.46	12.36							0.61	C	2016.239		iT24 1x3s. Touching star disks
																	No 2MASS object for B
939	05:42:43.98	+30:54:19.7	5.0	45.0	10.00	13.00	-1	1		19	12				2001		WDS05438+3056
	85.68329260	30.9054951	4.85	45.0	11.78	13.57	5.41	-0.40	5.02	2.04	-1.41	5.02	0.96	Hg	2015	CCCC	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	85.68335833	30.9055111	5.00	47.9	12.10	14.49							0.61	C	2016.171		iT24 1x3s. B barely resolved. SNR B <10
940	05:43:27.24	+30:55:24.6	4.8	359.0	10.80	12.00	0	-21		0	30				2015		WDS05445+3057
	85.86349960	30.9234751	4.79	358.8	12.60	13.39	-1.72	-6.58	5.02	-2.13	-8.42	5.02	0.96	Hg	2015	ACCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	85.86350833	30.9235389	4.25	359.1	12.79	13.82							0.61	C	2016.171		iT24 1x3s. SNR A <20 und B <10
941 AB	05:45:25.31	+30:44:28.9	3.6	176.0	9.60	9.60	-14	63		1	-48				2003		WDS05453+3045
	86.35541343	30.7412264	3.68	174.8	11.86	11.63	-8.52	-26.33	5.45	-7.55	-25.74	5.45	0.96	Hg	2015	AACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS. Solid CPM candidate
	86.35542083	30.7411861	3.35	176.0	12.02	11.79							0.61	C	2016.171		iT24 1x3s

Table 1 continues on next page.

Jonckheere Double Star Photometry – Part VI: Auriga

Table 1 (continued). Jonckheere Objects in Auriga

J#	RA	Dec	Sep	PA	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM	Source/Notes
941 AC	86.35541343	30.7412264	3.57	80.4	11.86	15.33							0.96	Hg	2015		Data for a third component to be found only in GAIA DR1. M1 and M2 are G-band
942	05:49:57.53	+31:33:33.6	3.5	187.0	10.50	12.50	10	9							2015		WDS05496+3133
	87.48972270	31.5593532	3.91	199.6	11.88	15.27	2.04	-0.40	5.27	0.51	-11.21	14.49	0.96	Hg	2015	CCCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	87.48973333	31.5593528			12.48								0.61	C	2016.976		iT24 5x3s. A is 2mag fainter than WDS listed. No resolution of B, has to be fainter than 14.5mag
943	05:50:06.72	+31:34:31.4	2.7	209.0	10.88	12.20									1928		WDS05502+3135. Bogus or misidentification?
	87.52803022	31.5753936	5.28	254.3	9.92	16.01							0.96	Hg	2015		GAIA DR1. M1 and M2 are G-band. Data bad match with WDS values
	87.52801250	31.5754250			10.50								0.61	C	2016.171		iT24 1x3s. No resolution. Combined magnitude seemts to rather confirm WDS data but overall this observation record seems inconsistent
																	No object for B in 2MASS, SDSS, GAIA DR1
	87.48972270	31.5593532	3.91	199.6	11.88	15.27							0.96	Hg	2015		GAIA DR1. M1 and M2 are G-band. Alternative object nearby better match with first measurement according to WDS?
947	05:52:54.87	+31:45:42.9	5.3	323.0	10.00	11.00	11	-8		-8	-2				2001		WDS05529+3146
	88.22823750	31.7623994	3.00	322.0	11.76		-93.53	132.65	6.36	3.27	-3.66	6.16	0.20	Eu	2013.781	CCCB	URAT1. PM data calculated from position comparison with 2MASS. Bad match with WDS data but there is something completely odd with the URAT1 data for A (see PM values!)
	88.22865833	31.7618167	5.52	324.7	12.26	12.94							0.61	C	2016.171		iT24 1x3s
																	No GAIA DR1 object for B
949	05:53:21.23	+31:29:14.9	3.4	241.0	10.10	10.70	15	4							2003		WDS05534+3129
	88.33843516	31.4874696	3.41	241.5	9.91	10.62	13.54	6.71	5.74	-26.89	-30.22	6.70	0.96	Hg	2015	CCCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	88.33843333	31.4873528	3.21	244.2	9.88	10.52							0.61	C	2016.171		iT24 1x3s
950	05:54:11.17	+44:35:57.0	4.6	60.0	9.20	10.30	-9	-24		43	6				2002		WDS05542+4435
	88.54647906	44.5990677	4.67	60.4	10.98	12.43	-9.99	-20.34	5.25	-8.98	-23.77	5.25	0.96	Hg	2015	BCCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	88.54651667	44.5990250	4.60	59.2	11.13	12.74							0.61	C	2016.239		iT24 1x3s
951	05:53:40.27	+32:53:08.6	4.9	56.0	10.90	11.90	-11	-4		57	33				2004		WDS05537+3252. Last 2010 observation with 4.0" separation seems to be in error
	88.41787980	32.8857423	4.92	56.3	10.68	11.88	3.64	-5.54	5.74	3.62	-5.77	5.74	0.96	Hg	2015	AACC	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS - too small to be significant
	88.41786250	32.8857500	4.93	56.7	10.56	12.10							0.61	C	2016.171		iT24 1x3s

Table 1 continues on next page.

Jonckheere Double Star Photometry – Part VI: Auriga

Table 1 (continued). Jonckheere Objects in Auriga

J#	RA	Dec	Sep	PA	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM	Source/Notes
952	05:54:31.15	+33:32:29.6	3.7	232.0	11.70	11.80	58	33		10	-8				2002		WDS05545+3331
	88.63035151	33.5417594	3.76	232.0	11.45	11.71	8.43	-15.01	5.74	6.01	-11.63	5.74	0.96	Hg	2015	ACCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	88.63037917	33.5417250	3.70	233.3	11.65	11.93							0.61	C	2016.239		iT24 1x3s
953	05:55:55.05	+28:47:06.3	4.9	269.0	10.30	11.00	5	-2		-78	-39				2003		WDS05559+2847
	88.97934007	28.7851082	5.03	269.4	10.03	11.31	-4.06	-0.81	4.98	-0.49	-0.24	4.98	0.96	Hg	2015	CCCC	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	88.97933333	28.7851167	5.02	269.3	10.01	11.34							0.61	C	2016.239		iT24 1x3s
960	06:00:53.60	+30:53:28.5	6.2	196.0	10.58	13.80	5	-5		0	38				2015		WDS06009+3053
	90.22335990	30.8912597	5.77	198.4	10.55		0.44	-1.71	6.38	21.28	-10.88	6.38	0.20	Eu	2013.536	CCCC	URAT1. PM data calculated from position comparison with 2MASS
	90.22331250	30.8912111	5.57	194.9	10.57	13.59							0.61	C	2016.171		iT24 1x3s. SNR B <10. Some PM of B
																	No GAIA DR1 object for A
961	06:06:26.08	+28:49:12.7	4.0	149.0	11.50	12.40									2001		WDS06063+2849
	91.60836705	28.8204546	4.09	148.9	11.45	12.27	2.98	-12.82	5.43	4.81	-14.76	5.43	0.96	Hg	2015	BCCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	91.60833333	28.8204944	4.17	147.2	11.64	12.43							0.61	C	2016.989		iT24 5x3s. Touching star disks
962	06:06:44.90	+33:37:05.4	5.4	358.0	10.00	10.80	-6	-18		-9	0				2001		WDS06067+3337
	91.68689024	33.6174938	5.47	356.9	12.20	13.02	-5.74	-9.87	5.64	-5.92	-9.20	5.64	0.96	Hg	2015	AACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS - too small to be significant
	91.68685000	33.6174639	5.54	357.2	12.36	13.48							0.61	C	2016.171		iT24 1x3s. SNR B <20
963	06:06:59.09	+33:37:31.6	5.9	351.0	11.80	12.70	-2	-36		-1	-10				2001		WDS06069+3336
	91.74619006	33.6246270	6.25	350.7	11.62	12.53	1.41	-25.39	5.64	0.98	-6.34	5.64	0.96	Hg	2015	BCCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	91.74620000	33.6246167	6.28	350.5	11.83	12.77							0.61	C	2016.171		iT24 1x3s
965	06:09:14.20	+33:59:47.2	5.4	239.0	10.94	12.60	-9	-9		-21	-9				2001		WDS06092+3359
	92.30912071	33.9964458	5.37	238.5	11.00	12.73	-6.73	-5.42	5.75	-11.93	-3.47	5.75	0.96	Hg	2015	CCCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	92.30911250	33.9964000	5.10	235.3	11.25	13.22							0.61	C	2016.171		iT24 1x3s. SNR B <20
966	06:10:47.43	+34:59:44.8	6.7	35.0	10.91	13.10	2	-6		7	9				2005		WDS06108+3500
	92.69765383	34.9957932	6.65	35.3	10.22	12.59	-4.22	0.90	5.03	5.35	-3.49	7.54	0.96	Hg	2015	CCCC	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	92.69764583	34.9958194	6.57	34.8	10.55	12.93							0.61	C	2016.171		iT24 1x3s. SNR B <20
983 AB	06:35:11.08	+29:02:47.2	5.4	235.0	10.92	13.00	3	-5		-9	-5				2001		WDS06351+2902
	98.79619296	29.0464620	5.37	235.7	10.76	12.94	0.36	-2.33	5.00	-4.46	-3.00	5.00	0.96	Hg	2015	CCCC	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	98.79618750	29.0464583	5.35	236.2	10.86	13.04							0.61	C	2016.239		iT24 1x3s

Table 1 continues on next page.

Jonckheere Double Star Photometry – Part VI: Auriga

Table 1 (continued). Jonckheere Objects in Auriga

J#	RA	Dec	Sep	PA	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM	Source/Notes
983 AC	06:35:11.08	+29:02:47.2	9.2	19.0	10.92	14.00	3	-5		-6	14				2001		WDS06351+2902
	98.79619296	29.0464620	9.22	18.8	10.76	12.56	0.36	-2.33	5.00	-1.26	-1.47	5.00	0.96	Hg	2015	CCCC	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	98.79618750	29.0464583	9.20	18.9	10.86	12.97							0.61	C	2016.239		iT24 1x3s
988?	06:39:46.42	+30:27:34.2	4.7	173.0	10.87	11.90	6	-8							2006		WDS06397+3027. The given position seems to be a misidentification of J988 - see below
	99.94344583	30.4594750	3.26	214.0	10.56	13.84							0.61	C	2016		iT24 1x3s. Touching star disks
																	No object for B in 2MASS, URAT1 and GAIA DR1
988?	06:39:42.55	+30:27:39.7	4.7	173.0	10.87	11.90	6	-8							2006		WDS06397+3027. This nearby object seems a better match for the given WDS data
	99.92729720	30.4610243	4.63	172.4	12.02	12.41	-8.25	-2.84	5.72	-10.80	-2.42	5.72	0.96	Hg	2015	CCCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	99.92728750	30.4610194	4.62	172.3	12.26	12.70							0.61	C	2016.239		iT24 1x3s
1249	05:07:37.84	+43:43:13.4	2.2	18.0	10.00	10.00	-1	-3							2002		WDS05077+4342
	76.90752780	43.7200571	2.12	18.4	11.67	11.56							0.96	Hg	2015		GAIA DR1. M1 and M2 are G-band
	76.90754167	43.7200861	1.92	18.8	11.66	11.51							0.61	C	2016.239		iT24 1x3s. Touching star disks
																	No object for B in 2MASS
1250	05:14:50.21	+31:45:28.8	2.6	300.0	11.28	12.66	12	-5		-21	8				2001		WDS05148+3145
	78.70934452	31.7579893	2.58	299.0	11.19	11.73							0.96	Hg	2015		GAIA DR1. M1 and M2 are G-band
	78.70935833	31.7579361	2.61	296.6	11.21	11.75							0.61	C	2016.239		iT24 1x3s. Touching star disks
																	No object for B in 2MASS
1253	05:12:22.51	+42:48:08.2	3.0	256.0	12.00	12.20	9	-10							2005		WDS05124+4248
	78.09423499	42.8023100	2.99	256.3	11.77	11.99							0.96	Hg	2015		GAIA DR1. M1 and M2 are G-band
	78.09432083	42.8022833	3.04	256.5	12.00	12.17							0.61	C	2016.239		iT24 1x3s. Touching star disks
																	No object for B in 2MASS
1904	05:38:12.92	+30:04:47.3	9.3	318.0	12.40	13.80	1	-6		-22	-7				2001		WDS05386+2957
	84.55383830	30.0797592	9.30	317.3	12.38		-0.95	-16.93	5.48	-3.56	-15.26	5.47	0.20	Eu	2013.580	CBCB	URAT1. PM data calculated from position comparison with 2MASS
	84.55383750	30.0797583	9.22	317.4	12.51	14.09							0.61	C	2016.239		iT24 1x3s
2392	05:20:43.68	+39:46:48.5	7.1	124.0	11.40	12.30	-152	95		3	-4				2014		WDS05207+3946. PM data for A seems completely off
	80.18201163	39.7801111	7.09	125.0	10.97	11.57	4.97	-7.99	5.72	6.91	-6.77	5.72	0.96	Hg	2015	CACC	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	80.18201250	39.7801278	7.12	125.3	11.83	12.37							0.61	C	2016.979		iT24 5x3s
2393	05:22:11.87	+39:46:35.0	7.8	335.0	12.50	14.00	1	-4							2002		WDS05221+3945
	80.54948463	39.7763734	7.85	335.5	12.24	14.19	1.09	-1.20	6.43	1.78	2.10	6.43	0.96	Hg	2015	CCCC	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	80.54947083	39.7763750	7.91	334.8	12.35	14.59							0.61	C	2016.239		iT24 1x3s

Table 1 concludes on next page.

Jonckheere Double Star Photometry – Part VI: Auriga

Table 1 (conclusion). Jonckheere Objects in Auriga

J#	RA	Dec	Sep	PA	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM	Source/Notes
2414	05:25:33.54	+29:29:47.6	7.3	176.0	12.00	14.00	0	-3		15	1				2001		WDS05256+2929. Code X for bogus for unknown reason
	81.38975270	29.4965044	7.20	175.5	12.67	14.25	0.15	-15.35	5.97	1.15	-7.55	5.97	0.96	Hg	2015	CCCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	81.38977083	29.4964778	7.07	175.8	12.85	14.44							0.61	C	2016.239		iT24 1x3s
2415	05:25:37.18	+29:28:31.7	6.7	358.0	12.50	13.00	-2	-13		-6	112				2001		WDS05257+2928. PM values for B seem suspect
	81.40492135	29.4754449	6.76	358.5	13.42	13.68	-2.13	-7.64	5.97	3.15	-4.59	5.97	0.96	Hg	2015	CCCC	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	81.40487500	29.4754222	6.89	359.8	13.74	14.19							0.61	C	2016.239		iT24 1x3s. SNR B <20
2428	06:30:03.89	+27:57:46.4	4.8	159.0	9.40	10.90	-4	9		23	-26				2015		WDS06301+2756
	97.51621438	27.9629274	4.95	157.2	11.29	12.58	-1.62	7.08	5.00	0.01	4.03	5.00	0.96	Hg	2015	CCCC	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	97.51625417	27.9629111	4.94	157.1	11.47	12.92							0.61	C	2016.239		iT24 1x3s
2431	06:32:43.72	+30:58:52.6	5.6	178.0	11.20	11.50	-8	12		2	-16				2001		WDS06328+3111
	98.18218564	30.9812657	5.66	177.7	13.08	13.61	-3.18	-4.12	5.03	0.33	-4.84	5.03	0.96	Hg	2015	CBCC	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
	98.18218750	30.9812500	5.59	178.2	13.27	13.88							0.61	C	2016.239		iT24 1x3s

Explanations Notes column:

- "iT24 1x3s" indicates the use of stacked telescope iT24 images with 3s exposure time and use of URAT1 for plate solving
- "Touching star disks" indicates that the rims of the star disks are touching and that the measurement results might be a bit less precise than with clearly separated star disks
- "Touching/Overlapping star disks" indicates that the star disks overlap to the degree of an elongation and that the measurement results is probably less precise than with clearly separated star disks
- "SNR <20" indicates that the measurement result might be a bit less precise than desired due to a low SNR value but this is already included in the calculation of the magnitude error range estimation
- "SNR <10" indicates that the measurement result is probably a bit less precise than desired due to a very low SNR value but this is already included in the calculation of the magnitude error range estimation
- "Image quality questionable" or similar indicates rather large average errors for the reference stars used for plate solving for different reasons (mostly atmospheric influences). But this is at least to some degree already included in the calculation of the error range estimation

Appendix A

Below, Table 2 gives the plate solving errors for the iT24 images and error information derived therefrom for the measurements provided in Table 1 and also the measured positions for both components.

Table 2: Error estimations for the in Table 1 provided measurements for the given objects:

J#		RA	Dec	dRA	dDec	Err Sep	Err PA	Err Mag	SNR	dVmag
11	A	04 54 36.392	43 44 23.25	0.08	0.08	0.113	4.348	0.091	67.25	0.09
	B	04 54 36.441	43 44 24.64					0.091	65.80	
12	A	05 00 15.198	42 51 42.31	0.08	0.08	0.113	2.157	0.091	80.75	0.09
	B	05 00 14.978	42 51 40.53					0.093	47.04	
13	A	05 04 07.715	43 40 25.58	0.12	0.13	0.177	4.717	0.120	11.59	0.08
	B	05 04 07.727	43 40 23.44					0.099	18.19	
17	A	06 05 10.922	43 02 17.65	0.10	0.09	0.135	3.061	0.091	86.10	0.09
	B	06 05 11.015	43 02 15.35					0.091	74.77	
31	A	04 57 29.661	37 51 14.90	0.06	0.07	0.092	1.476	0.070	196.34	0.07
	B	04 57 29.607	37 51 18.42					0.071	76.65	
32	A	05 01 09.632	38 13 38.13	0.06	0.07	0.092	2.306	0.080	265.25	0.08
	B	05 01 09.449	38 13 38.90					0.081	89.99	
240	A	05 02 46.082	35 07 55.99	0.07	0.08	0.106	4.954	0.081	105.07	0.08
	B	05 02 46.023	35 07 55.00					0.081	115.00	
591	A	06 16 45.225	38 52 29.60	0.10	0.08	0.128	1.683	0.072	57.89	0.07
	B	06 16 45.108	38 52 25.46					0.079	28.97	
GCB 18	A	06 16 45.225	38 52 29.60	0.10	0.08	0.128	1.365	0.072	57.89	0.07
	C	06 16 44.941	38 52 33.83					0.083	23.64	
593	A	06 18 41.161	37 52 23.30	0.08	0.07	0.106	1.377	0.090	174.85	0.09
	B	06 18 41.070	37 52 19.01					0.091	80.69	
650	A	04 51 21.032	49 03 11.97	0.07	0.08	0.106	1.477	0.080	179.69	0.08
	B	04 51 21.294	49 03 15.19					0.081	84.74	
651	A	05 01 41.195	49 05 03.36	0.07	0.06	0.092	1.149	0.090	186.67	0.09
	B	05 01 40.797	49 05 00.94					0.091	102.97	
652	A	05 20 43.383	33 50 21.08	0.07	0.08	0.106	1.650	0.081	101.52	0.08
	B	05 20 43.360	33 50 24.76					0.081	80.98	
653	A	05 35 06.484	35 18 20.32	0.32	0.25	0.406	3.787	0.069	32.13	0.06
	B	05 35 06.519	35 18 14.20					0.115	10.54	
653	A	05 35 06.545	35 18 20.78	0.09	0.09	0.127	1.219	0.071	88.53	0.07
	B	05 35 06.609	35 18 14.85					0.074	45.27	
665	A	06 44 05.888	38 22 32.73	0.18	0.21	0.277	2.014	0.064	47.70	0.06
	B	06 44 06.493	38 22 36.08					0.227	4.47	
665	A	06 44 05.887	38 22 32.84	0.11	0.09	0.142	1.093	0.061	96.17	0.06
	B	06 44 06.469	38 22 35.79					0.078	21.35	
693	A	06 35 04.029	29 09 55.30	0.06	0.07	0.092	3.013	0.080	291.13	0.08
	B	06 35 03.897	29 09 55.58					0.080	173.60	
897	A	05 20 38.730	44 52 41.98	0.06	0.06	0.085	1.443	0.080	237.95	0.08
	B	05 20 38.473	44 52 40.01					0.081	82.96	
898	A	05 23 06.985	33 58 17.12	0.06	0.08	0.100	1.453	0.071	88.58	0.07
	B	05 23 07.144	33 58 13.71					0.072	69.09	
899	A	05 31 39.194	32 24 42.48	0.07	0.07	0.099	3.064	0.091	71.09	0.09
	B	05 31 39.128	32 24 44.13					0.095	35.60	
901	A	05 38 32.842	32 01 24.20	0.09	0.09	0.127	2.339	0.055	47.95	0.05
	B	05 38 32.963	32 01 21.49					0.054	53.15	
902	A	05 47 19.224	32 21 52.08	0.11	0.12	0.163	3.093	0.106	31.44	0.10
	B	05 47 19.037	32 21 50.22					0.120	15.91	
903	A	05 49 12.424	33 22 41,71	0.10	0.08			0.130	110.71	0.13
	B									
904	A	06 01 34.923	39 36 28.48	0.11	0.09	0.142	2.151	0.093	22.55	0.08
	B	06 01 34.822	39 36 24.88					0.105	15.61	

Table 2 continues on the next page.

Jonckheere Double Star Photometry – Part VI: Auriga

Table 2 (continued): Error estimations for the in Table 1 provided measurements for the given objects:

J#		RA	Dec	dRA	dDec	Err Sep	Err PA	Err Mag	SNR	dVmag
905	A	06 02 45.928	39 39 06.19	0.11	0.10	0.149	1.989	0.095	33.95	0.09
	B	06 02 46.177	39 39 09.36					0.135	10.25	
906	A	06 07 48.405	38 36 58.13	0.10	0.12	0.156	1.825	0.095	33.59	0.09
	B	06 07 48.033	38 37 00.37					0.104	20.17	
WSI 32	A	06 07 48.438	38 36 58.07	0.11	0.09	0.142	3.055	0.119	24.09	0.11
	C	06 07 48.215	38 36 58.58					0.153	9.71	
907	A	06 07 47.965	35 30 50.61	0.06	0.07	0.092	2.328	0.081	117.95	0.08
	B	06 07 47.814	35 30 49.29					0.081	114.39	
908	A	06 19 25.825	40 59 04.64	0.11	0.08	0.136		0.131	61.60	0.13
	B									
910	A	06 28 27.572	43 04 04.62	0.07	0.08	0.106	3.444	0.110	167.87	0.11
	B	06 28 27.484	43 04 06.10					0.113	41.55	
910	A	06 28 27.572	43 04 04.62	0.07	0.08	0.106	0.134	0.110	167.87	0.11
	C	06 28 29.789	43 04 43.14					0.110	160.73	
935	A	05 02 26.298	37 48 11.95	0.08	0.07	0.106	1.955	0.100	155.34	0.10
	B	05 02 26.484	37 48 14.15					0.103	43.46	
939	A	05 42 43.982	30 54 19.58	0.11	0.11	0.156	1.887	0.063	56.93	0.06
	B	05 42 44.254	30 54 22.75					0.080	19.75	
940	A	05 43 27.242	30 55 24.74	0.09	0.10	0.135	1.813	0.116	12.43	0.08
	B	05 43 27.237	30 55 28.99					0.191	5.76	
941	A	05 45 25.301	30 44 28.27	0.10	0.10	0.141	2.419	0.026	40.96	0.06
	B	05 45 25.319	30 44 24.93					0.025	42.92	
942	A	05 49 57.536	31 33 33.67	0.12	0.11	0.163		0.017	62.78	0.09
	B									
943	A	05 50 06.723	31 34 31.53	0.10	0.10	0.141		0.071	88.25	0.07
	B									
947	A	05 52 54.878	31 45 42.54	0.10	0.11	0.149	1.544	0.105	32.18	0.10
	B	05 52 54.628	31 45 47.04					0.112	20.87	
949	A	05 53 21.224	31 29 14.47	0.13	0.08	0.153	2.721	0.111	76.90	0.11
	B	05 53 20.998	31 29 13.07					0.113	43.95	
950	A	05 54 11.164	44 35 56.49	0.07	0.08	0.106	1.323	0.090	156.81	0.09
	B	05 54 11.534	44 35 58.85					0.091	66.95	
951	A	05 53 40.287	32 53 08.70	0.09	0.10	0.135	1.563	0.113	45.53	0.11
	B	05 53 40.614	32 53 11.41					0.122	20.49	
952	A	05 54 31.291	33 32 30.21	0.07	0.07	0.099	1.534	0.081	117.91	0.08
	B	05 54 31.054	33 32 28.00					0.081	95.52	
953	A	05 55 55.040	28 47 06.42	0.07	0.07	0.099	1.129	0.090	236.46	0.09
	B	05 55 54.658	28 47 06.36					0.091	112.10	
960	A	06 00 53.595	30 53 28.36	0.10	0.09	0.135	1.385	0.071	79.02	0.07
	B	06 00 53.484	30 53 22.98					0.125	9.95	
961	A	06 06 26.000	28 49 13.78	0.10	0.10	0.141	1.940	0.062	78.22	0.06
	B	06 06 26.172	28 49 10.27					0.065	44.09	
962	A	06 06 44.844	33 37 02.87	0.11	0.10	0.149	1.538	0.105	33.02	0.10
	B	06 06 44.822	33 37 08.40					0.133	11.94	
963	A	06 06 59.088	33 37 28.62	0.08	0.07	0.106	0.970	0.082	55.98	0.08
	B	06 06 59.005	33 37 34.81					0.086	34.45	
965	A	06 09 14.187	33 59 47.04	0.11	0.12	0.163	1.829	0.072	63.35	0.07
	B	06 09 13.850	33 59 44.14					0.096	15.93	
966	A	06 10 47.435	34 59 44.95	0.09	0.11	0.142	1.239	0.081	76.22	0.08
	B	06 10 47.740	34 59 50.35					0.099	17.88	
983	A	06 35 11.085	29 02 47.25	0.07	0.07	0.099	1.060	0.080	182.42	0.08
	B	06 35 10.746	29 02 44.27					0.083	47.71	
983	A	06 35 11.085	29 02 47.25	0.07	0.07	0.099	0.616	0.080	182.42	0.08
	C	06 35 11.312	29 02 55.96					0.082	67.34	
988?	A	06 39 46.427	30 27 34.11	0.07	0.07	0.099	1.740	0.090	131.49	0.09
	B	06 39 46.286	30 27 31.41					0.101	23.30	

Table 2 concludes on the next page.

Jonckheere Double Star Photometry – Part VI: Auriga

Table 2 (conclusion): Error estimations for the in Table 1 provided measurements for the given objects:

J#		RA	Dec	dRA	dDec	Err Sep	Err PA	Err Mag	SNR	dVmag
988?	A	06 39 42.549	30 27 39.67	0.07	0.07	0.099	1.227	0.091	73.65	0.09
	B	06 39 42.597	30 27 35.09					0.092	60.89	
1249	A	05 07 37.810	43 43 12.31	0.09	0.09	0.127	3.789	0.101	68.42	0.10
	B	05 07 37.867	43 43 14.13					0.101	79.09	
1250	A	05 14 50.246	31 45 28.57	0.09	0.07	0.114	2.501	0.111	74.20	0.11
	B	05 14 50.063	31 45 29.74					0.112	51.31	
1253	A	05 12 22.637	42 48 08.22	0.08	0.07	0.106	2.000	0.111	65.54	0.11
	B	05 12 22.368	42 48 07.51					0.112	57.25	
1904	A	05 38 12.921	30 04 47.13	0.06	0.06	0.085	0.527	0.071	86.59	0.07
	B	05 38 12.440	30 04 53.92					0.077	33.76	
2392	A	05 20 43.683	39 46 48.46	0.10	0.11	0.149	1.197	0.072	59.87	0.07
	B	05 20 44.187	39 46 44.35					0.073	48.31	
2393	A	05 22 11.873	39 46 34.95	0.08	0.07	0.106	0.770	0.091	94.04	0.09
	B	05 22 11.581	39 46 42.11					0.101	23.34	
2414	A	05 25 33.545	29 29 47.32	0.08	0.08	0.113	0.917	0.081	70.92	0.08
	B	05 25 33.585	29 29 40.27					0.090	25.79	
2415	A	05 25 37.170	29 28 31.52	0.09	0.08	0.120	1.001	0.109	25.18	0.10
	B	05 25 37.168	29 28 38.41					0.115	18.59	
2428	A	06 30 03.901	27 57 46.48	0.07	0.08	0.106	1.233	0.141	88.55	0.14
	B	06 30 04.046	27 57 41.93					0.144	29.97	
2431	A	06 32 43.725	30 58 52.50	0.07	0.07	0.099	1.014	0.082	56.98	0.08
	B	06 32 43.739	30 58 46.91					0.085	39.12	

Table 2 Notes

- dRA and dDec = average RA and Dec plate solving errors in arcseconds
- Err_Sep = separation error estimation in arcseconds calculated as SQRT(dRA^2+dDec^2)
- Err_PA = position angle error estimation in degrees calculated as arctan (Err_Sep/Sep) assuming the worst case that Err_Sep points perpendicular to the separation vector
- dVmag as average mag plate solving error (Vmag for images with made V-filter and Imag for images made with I-filter)
- Err_Mag = magnitude error estimation calculated as SQRT(dVmag^2+(2.5*LOG10(1+1/SNR))^2)
- SNR as signal to noise ratio for the given object

Appendix B

CPM rating scheme according to Knapp/Nanson 2017 with extensions:

Four rating factors are used: Proper motion vector direction, proper motion vector length, size of position error in relation to proper motion vector length and relationship separation to average proper motion speed:

- Proper motion vector direction rating: "A" for within the error range identical direction, "B" for similar direction within the double error range and "C" for outside
- Proper motion vector length rating: "A" for within the error range identical length, "B" for similar length within the double error range and C for outside
- Error size rating: "A" for error size of less than 5% of the proper motion vector length, "B" for less than 10% and "C" for a larger error size
- Rating for relation separation to average proper motion speed: "A" for less than 100 years, "B" for 100 to 1000 years and "C" for above.

To compensate for (depending on the selected objects and available catalogs) excessively large position errors resulting an "A" rating despite rather high deviations absolute upper limits are applied regardless calculated error size:

- Proper motion vector direction: Max. 2.86° difference for an "A" and 5.72° for a "B"
- Proper motion vector length: Max. 5% difference for an "A" and 10% for a "B"

Modification for cases of very small position errors (when for example using SDSS9 instead of 2MASS) with the consequence that the requirements to get an A or even B CPM rating get unreasonable hard:

- The from the position error resulting error estimation for proper motion vector direction and length is in this case calculated as root mean square from both position errors (instead of so far only the larger 2MASS one)
- If the PM vector direction difference is larger than this calculated "allowed" error but still less than 0.5° then an "A" is given, a "B" is given for larger than 0.5 but less than 1 degree, and a "C" is given if above
- If the PM vector length difference is larger than this calculated "allowed" error but still less than 0.5% then an "A" is given, a "B" is given for larger than 0.5 but less than 1 percent, and a "C" is given if above.

Measurements of 208 Aitken Visual Binary Stars with a 280 mm Reflector

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Abstract: This paper presents the measurements of 208 visual binary stars discovered by R.G. Aitken and listed in the WDS catalog. These measurements were obtained between November 2016 and January 2017 with an 11" reflector telescope and an ASI 290MM CMOS-based camera. Binaries with a secondary component up to magnitude 15 and separation between 0.6 and 5 arcsec have been measured. Measurements were carried out on auto-correlograms computed on sequences of a thousand images. This approach allowed us to obtain reliable measurements for pairs with very large difference of magnitude (up to 6). A significant part of the observed pairs had not been observed in the previous decades and show significant movement compared to their last measurement. We also report the discovery of a yet unobserved component for the star A 2455 (WDS 06426+1937).

1. Introduction

Observing – and *a fortiori* measuring – Aitken double stars is notoriously difficult. These stars, listed with the "A" discoverer code in the Washington Double Star Catalog (WDS, [7]), often exhibit very small separation, faint companions and/or large delta mag. For example, among the 3494 Aitken pairs listed in the WDS, 1455 have a separation $\rho < 1$ arcsec and 796 a separation $\rho < 0.5$ arcsec; 1016 have a companion with mag > 12 and 1009 exhibit a delta mag > 3. As a result, these pairs are not frequently observed. As reported in the WDS[1], 2301 pairs (66%) have not been observed in the last decade and 1286 in the last two decades (37%). In the same catalog, 1878 pairs (54%) are listed with less than 10 observations in total. A consequence of this lack of observational data is the fact that only 56 Aitken pairs have a known orbit (as reported in the Nov 2016 edition of the Sixth Catalog of Orbits [9]). Aitken stars therefore make very interesting - but challenging - targets for the double star observer. Their distinctive features also provide an interesting testbed for the assessment of the most recent cameras with CMOS back-illuminated high-sensitivity sensors, such as the ASI 290MM model evaluated in our previous JDSO paper [4]. We devoted 10 nights, between November 2016 and January 2017 to this task. The result of this short observing campaign are reported in this paper.

2. Instrumental setup

The instrumental setup is the same as that described in [4]. The telescope is a 280 mm Schmidt-Cassegrain reflector (Celestron C11) and the camera an ASI 290MM from ZWO [3]. In the previous paper we showed that with this setup we could obtain reliable measurements down to $\rho = 0.5$ arcsec and $m_2 = 12$, with individual exposure times in the range 10-50 ms.

The main motivation for the work described here was to assess the extent to which the limit in magnitude could be pushed. The optical train - wheel filter + 2x barlow + ADC - is unchanged compared to that described in [4], giving a resulting plate scale of 0.095"/pixel. An L-band (400-700 nm) filter is systematically used in order to reach the faintest magnitudes possible. With this configuration, the use of an atmospheric dispersion corrector (ADC) is mandatory, especially for stars with a zenithal distance > 20°. Our ADC configuration allows a full correction up to $z = 45°$.

3. Image acquisition and reduction

As in [1,2,4], acquisition is carried out with the Genika Astro software [5]. The gain of the camera is set at 550 (range is 0 - 600). Exposure time for individual images range from 10 to 100 ms typically. For faintest stars (*mag* > 14.5), this time has been pushed to 150 ms

Only for the closest pairs (typically $\rho < 1$ arcsec) did we make several acquisitions and hence did compute an estimation of standard errors[2] on the measured

1. As published Dec. 1, 2017

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separation and position angle. The corresponding measures are reported with these errors indicated after the ± symbol in Table 1.

A small number of pairs were observed more than two nights. The values reported in Table 1 are then obtained by averaging those obtained on each night (the observation dates never differed by more than 15 days). In this case, the total number of measurements reported in Table 1 is the sum of the numbers for each date (with the number of nights indicated between brackets.

Calibration is, as reported in [4], carried out by analyzing timed star drifts thanks to D. Rowe's Speckle Toolbox [6]. Precise timing of each frame is performed by the Genika software.

Image reduction is carried out with the Reduc software [8] using the pixel autocorrelation technique described in [1,2,4]. A master dark frame is first computed by averaging 50 dark frames taken with a fixed 40 ms exposure. We did experiments with separate dark frames for each distinct exposure time but did not notice a significant improvement. This can be explained by the fact that the exposure times are here sufficiently small so that thermal noise (the one that depends on integration time) is negligible compared to the other sources of noise (and in particular the photon shot noise). Dark subtraction is therefore essentially used here to remove permanent hot pixels (which do show at this very high gain setting). Pragmatically, using a single master dark also allows us to use Reduc in batch mode, which significantly reduces the burden of processing the acquired data. The master dark is then subtracted from all acquired frames and the auto-correlogram (AC) is computed on each sequence of 1000 frames. Each acquisition sequence is also sorted by quality so that a manual selection can be further performed in order to compute a direct image. All of these operations are carried out automatically using the Reduc *batch* mode. User intervention is only required for i) selecting the best frames from the quality sorted sequence and stack them in order to obtain the direct image ii) perform the post-processing filtering step[3] on the computed auto-correlogram and make the actual measurement by adjusting the size of the peak-matching area and registering its position.

Using an AC-based technique for measuring pairs with separation above the seeing limit may appear unnecessary. In fact, in many cases the companion is clearly visible on the image obtained by selection, shift and addition of a few dozen of best frames. But measuring on this direct image is often problematic for two reasons. First, in the case of faint companions, the image of the companion is often "spread out", which makes estimation of its relative position imprecise. This is illustrated, for example, with the images of A 1802 reproduced on Plate 1. Here, the auto-correlation peaks (right image), exhibit a much more regular and symetrical aspect than the direct image of the companion (left image). Second, in case of pairs with a large delta mag, the image of the primary component quickly gets overexposed which in turn can cause two problems: i) estimating the position of this primary becomes itself difficult because classical profile matching techniques do not work well with flattened overexposed profiles ii) the image of the companion can be hidden in the halo of the primary. In all these cases, we have found that the AC images were much more amenable to precise measurement either because the position of the primary does not depend on its luminosity (it is always centered on the middle of the frame, by construction) and/or the correlation peaks corresponding to the companion show a much more regular and smooth profile. This is for example illustrated with the images of A 1821 or A 918 on Plate 1.

4. Results

The reported measurements were obtained over 10 nights, between 2016-11-01 and 2017-01-06. The total number is 283 measures, concerning 208 binaries. Only one (A 1813AB,C) has a published orbit.

Figures 1, 2, 3, and 4 show the distribution of all measurements according to the magnitude of the primary and secondary component, their separation, and their difference in magnitude. Comparing these results with those reported in [4] (obtained with the same instrumental setup and camera) immediately shows that our previous estimation of the magnitude limits - at least for pairs with a separation greater than 1 arcsec - was greatly underestimated. The histogram of Figure 4 also shows that many pairs with so-called "large" delta mag (≥ 3, typically), which are often neglected because viewed as "too difficult", are indeed accessible.

The measures themselves are listed in Table 1. As indicated in Section 3, the values for the position angle (PA) and separation (SEP) are given with their corresponding standard errors when the latter can be computed. These errors were derived, as described in Section 3, from n distinct measures, where n is given in column 9 ("N"). A selection of reduced images from which the measures were obtained in given in Plate 1.

(Text continues on page 443)

2. Standard errors are computed, classically, by dividing the standard deviations by the square root of the total number of measurements.

3. Practically, this means selecting the size of the 2D mean-rejection filter which is used by Reduc to remove the "halo" around the center of the auto-correlogram and improve peak detection.

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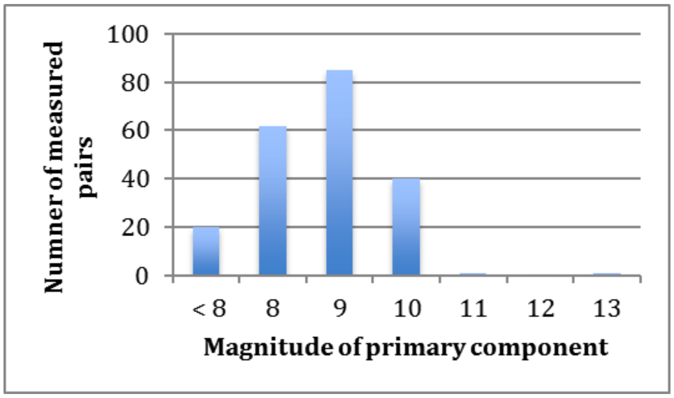


Figure 1. Distribution of measurements according to the magnitude of the primary component.

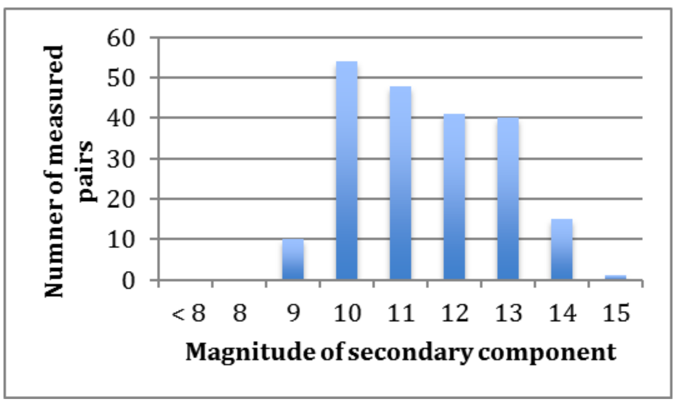


Figure 2. Distribution of measurements according to the magnitude of the secondary component

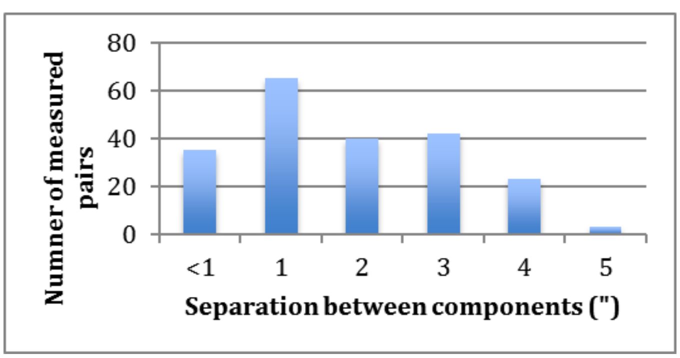


Figure 3. Distribution of measurements according to the separation of components.

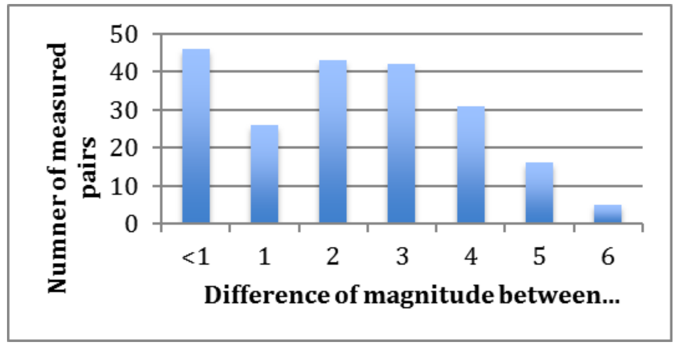


Figure 4. Distribution of measurements according to the difference in magnitude between the components

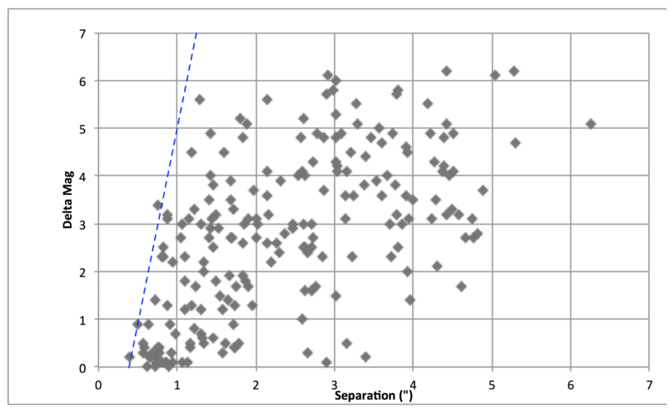
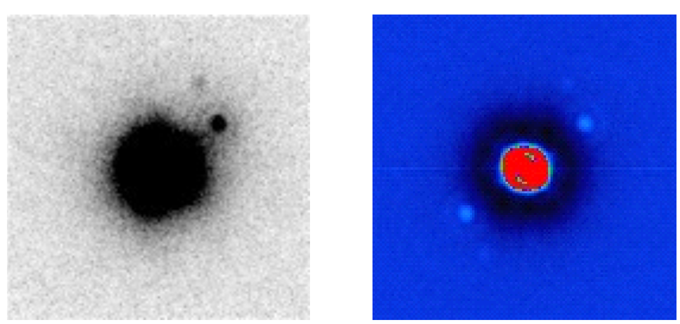


Figure 5. Plot of the all observations with the separation as X and the difference in magnitude of the two components as Y.



A 2455 (06426+1937) - 2016-12-09

Figure 6. Images of A 2455 (WDS 06426+1937) showing the new companion in Q4. Left: co-addition of 200 best frames; Right: auto -correlogram computed on 1000 frames. North is up, East is to the left.

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Plate 1 – Examples of images after reduction

(left : co-addition of 30-200 best frames, right : auto-correlogram computed on 1000 frames. N up, E left)

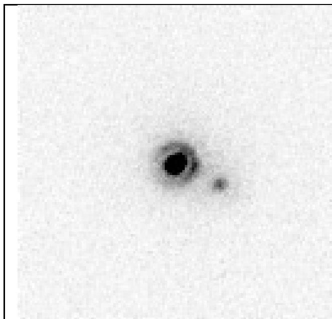
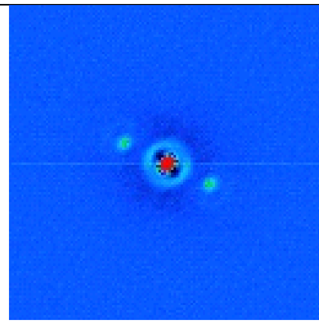
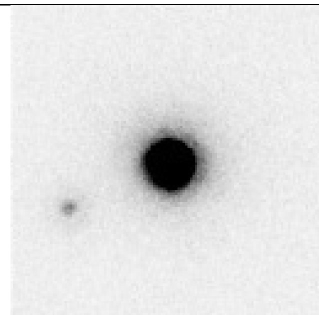
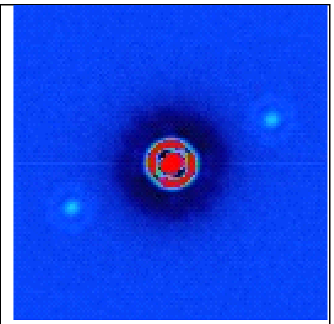
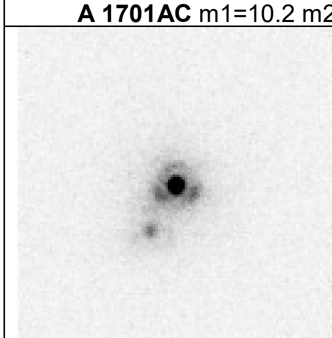
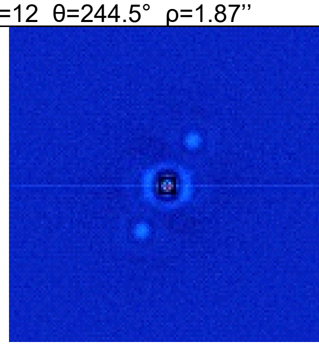
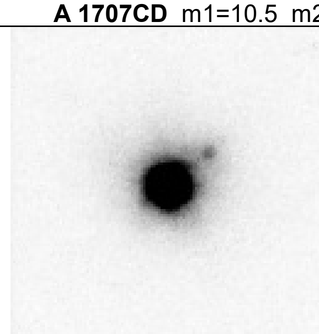
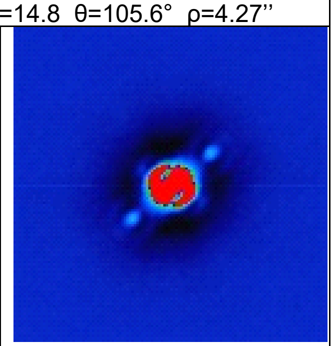
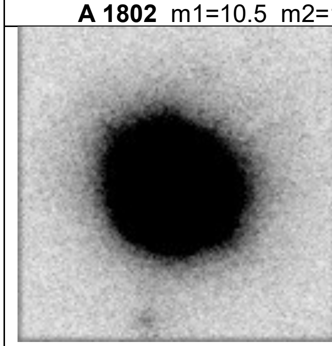
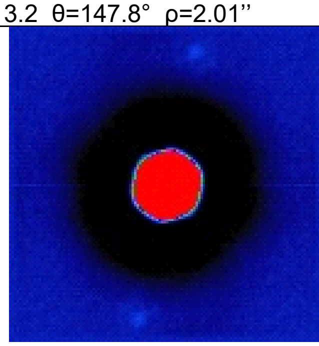
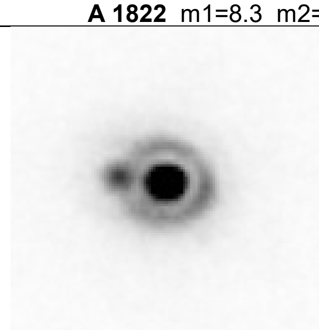
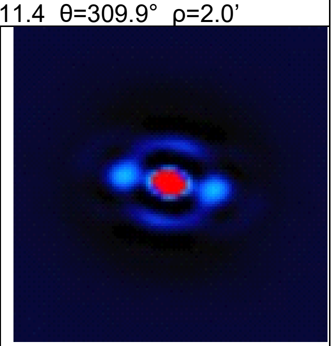
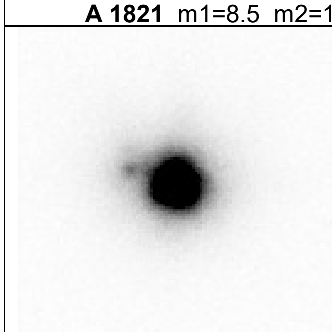
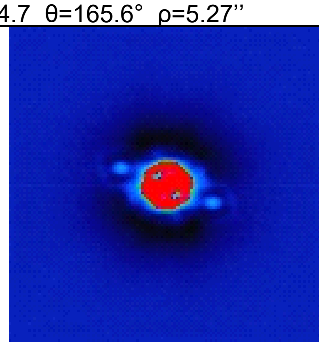
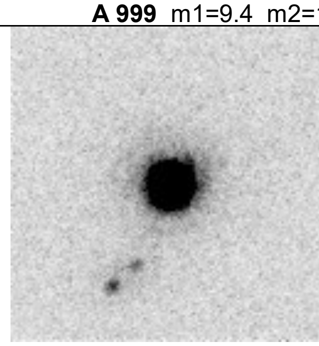
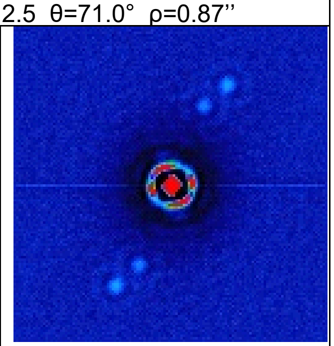
			
30 x 60ms	1000 x 60 ms	100 x 150ms	1000 x 150 ms
A 1701AC m1=10.2 m2=12 θ=244.5° ρ=1.87''		**A 1707CD** m1=10.5 m2=14.8 θ=105.6° ρ=4.27''	
			
50 x 60ms	1000 x 60 ms	50 x 40ms	1000 x 40 ms
A 1802 m1=10.5 m2=13.2 θ=147.8° ρ=2.01''		**A 1822** m1=8.3 m2=11.4 θ=309.9° ρ=2.0'	
			
200 x 100ms	1000 x 100 ms	50 x 60 ms	1000 x 60 ms
A 1821 m1=8.5 m2=14.7 θ=165.6° ρ=5.27''		**A 999** m1=9.4 m2=12.5 θ=71.0° ρ=0.87''	
			
100 x 80 ms	1000 x 80 ms	50 x 80 ms	1000 x 80 ms
A 918 m1=8.7 m2=13.8 θ=64.4° ρ=1.89''		**A 963BC** m1=13.3 m2=13.7 θ=301.8° ρ=1.17''	

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Table 1. Measurements

NAME	WDS ID	M1	M2	DATE2	PA (°)	SEP (arcsec)	DATE	N	NOTES
A 1499	00026+5534	8.4	9.9	1995	209.2	1.55	2016.929	1	
A 1253	00076+5246	7.7	11.2	1991	83.1	4.00	2016.929	1	
A 2201AB	00137+1838	8.2	11.3	1991	199.4 ± 0.65	1.15 ± 0.009	2016.953	2	
A 1802	00141+1207	10.5	13.2	2006	147.8	2.01	2016.953	1	
A 1804	00174+1002	9.2	10.4	2005	26.6	1.30	2016.953	1	
A 1805	00240+0955	9.9	13	2000	316.	4.74	2016.953	1	
A 2301	00254+2036	8.9	11.2	2001	228.4	2.84	2016.953	1	
A 805	00291+1119	8	14.2	2000	307.9	4.43	2016.929	1	1
A 806CD	00355+1150	10.9	13.9	1932	235.9	1.31	2016.929	1	
A 2302	00380+0234	10.1	10.2	1994	153.6 ± 0.03	0.74 ± 0.001	2016.929	4	
A 1806	00403+0517	9.8	12.9	2000	18.4	3.13	2016.929	1	
A 2204	00415+1731	10.1	11.3	2001	340.4	1.09	2016.953	1	
A 917	00428+2924	10.4	11.1	2001	118.6	1.31	2016.953	1	
A 2304	00429+0051	10.1	12.5	1996	73.	2.29	2016.929	1	
A 810	00434+1136	9.3	14.6	1933	314.2	3.02	2016.953	1	
A 1807	00438+0529	10.1	11.7	2002	153.4	2.62	2016.953	1	
A 918	00440+5436	8.7	13.8	1964	64.4	1.89	2017	1	
A 2305	00442+0229	10.2	10.8	2000	2.3	1.32	2016.929	1	
A 2206	00466+2013	8.7	11.9	1997	293.7	4.57	2016.953	1	
A 920	00469+1232	8.9	11.5	1966	231.1	1.84	2016.953	1	
A 1509AB	00516+3925	9.8	9.8	2008	26.8 ± 1.43	0.72 ± 0.006	2016.953	2	
A 1509AC	00516+3925	9.8	14.9	1929	334.1	6.26	2016.953	1	
A 1901	00523-0022	9.4	10.8	2000	311.7 ± 0.86	0.72 ± 0.006	2016.929	3	
A 2207	00530+1806	9.1	12.3	2000	164.8	3.78	2016.929	1	
A 2208	00549+1928	9.3	10.5	2001	91.3	1.57	2016.929	1	
A 1511	00554+4023	6.9	11.4	2002	43.4	1.19	2017	1	
A 925	00587+4457	7.7	10.4	1994	108.6	1.04	2016.953	1	
A 1513	01015+3936	10	12.3	2002	298.6	3.72	2017	1	
A 2309	01036+0313	10.4	13.1	1934	60.8	1.69	2017	1	
A 2004	01038+0646	7.1	10.4	1996	242.5	1.72	2017	1	
A 2312	01100+0305	9.6	12.8	1954	311.	0.88	2017	1	
A 2103	01163+1015	9.1	12.4	2000	184.2	4.49	2017	1	
A 1520	01167+4028	9.5	11	2002	238.9	3.01	2017	1	
A 2211	01204+0931	8.7	12.7	1967	359.1	2.63	2017	1	
A 1906	01216+2123	9.5	12.3	2004	38.2	4.82	2017	1	
A 938	01219+4717	7.9	11	2002	290.1	3.94	2017	1	
A 1263	01254+4405	9.7	12.8	2002	211.7	4.23	2017	1	
A 1907	01257+3621	7.8	13.4	1932	220.1	2.14	2017	1	
A 2316	01285+0338	9.7	13.4	2000	65.9	4.88	2017	1	
A 941AB	01286+4509	8.6	11.5	1991	242.4	1.43	2017	1	
A 941CD	01286+4509	10.9	11.2	1994	358.3 ± 0.41	0.77 ± 0.004	2017	4	
A 2214	01292+2004	10	10.2	1999	215.6	0.74	2017	1	
A 2318	01305+0258	8.9	12.5	1991	156.9	3.60	2016.915	1	
A 2215	01322+1142	9.1	11.8	1987	356.	1.68	2016.915	1	
A 2401	01351+0145	9.8	12.1	1951	338.1	1.10	2016.915	1	

Table 1 continues on next page.

Measurements of 208 Aitken Visual Binary Stars with a 280 mm Reflector

Table 1(continued). Measurements

NAME	WDS ID	M1	M2	DATE2	PA (°)	SEP (arcsec)	DATE	N	NOTES
A 2402	01364+0347	8.5	14.2	1933	318.6 ± 0.02	3.79 ± 0.065	2016.915	2	
A 817	01372+4843	10	9.1	1999	17.95 ± 1.20	0.5 ± 0.005	2016.9945	9 (2)	
A 2319	01374+1955	10.4	10.7	2006	201.7	0.92	2016.989	1	
A 1265CD	01376+5511	10.8	11	1991	352.9 ± 1.88	0.39 ± 0.000	2017	5	
A 2007	01379+2554	8.7	10.4	2003	220.2	4.61	2016.989	1	
A 1915	01391-0048	9.9	10.1	1991	267 ± 0.54	0.66 ± 0.007	2017	4	
A 2405	01459+0411	10.6	10.7	1991	226.7 ± 0.33	0.86 ± 0.016	2017	2	
A 1811	01547+3801	8.7	11.9	1997	93.4	1.50	2017	1	
A 2323	01548+1728	9.5	10.8	2001	146.2	1.74	2017	1	
A 1525	01564+4243	9.6	11.3	1991	209.3	1.23	2017	1	
A 2011	01584+2547	8.8	13.7	1987	296.6	3.74	2017	1	
A 2410	01594+0258	10.2	12.6	1937	221.1	2.66	2017	1	
A 1812AB	02003+3738	8.2	13.9	1929	236.2	2.90	2016.929	1	
A 1921	02009+5258	9.6	9.7	2007	66.5	2.90	2016.989	1	
A 820	02018+4738	9.7	12.7	1991	246.3	2.02	2016.915	1	
A 2216	02021+1211	8.6	10.5	2002	143.3	1.66	2016.989	1	
A 1924	02021+3347	10.6	10.9	2008	160.6	0.56	2016.915	1	
A 1813AB,C	02022+3643	8.2	11.1	2009	198.2	1.52	2016.915	1	10
A 1925	02035+3422	9.3	12.3	1991	230.5	3.70	2016.915	1	
A 205	02144+3946	9	10.7	2001	310.3 ± 0.10	1.75 ± 0.000	2016.922	2 (2)	
A 1271	02169+5328	9	11.7	1998	349.2	4.67	2016.915	1	
A 959AB	02180+3116	9.2	12.2	2011	3.9	3.85	2016.915	1	
A 1273	02180+5614	8.9	12.5	1999	335.6	3.91	2016.915	1	
A 1701	02210+4239	10.2	12	1991	244.5	1.87	2016.915	1	
A 963AB	02227+5705	9.3	13.3	1999	142.5	4.45	2016.929	1	2
A 963BC	02227+5705	13.3	13.7	1953	301.8	1.17	2016.929	1	2
A 658	02279+4129	9.3	10.9	2002	212.1	2.70	2016.989	1	
A 1815	02282+3850	6.9	10.8	1970	156.1	1.68	2016.929	1	7
A 1817	02294+4000	9.4	11.9	1929	228.9	2.71	2016.929	1	
A 2017	02297+0453	9.2	13.1	1946	65.7	3.53	2016.953	1	
A 2019	02300+0632	10.1	10.6	2000	251.2	1.34	2016.953	1	
A 966	02300+4649	9.8	12	1991	320.5	2.19	2016.929	1	
A 967	02304+4526	7.3	12.8	1927	220.1	4.18	2016.915	1	
A 2332	02313+0131	8.3	13.1	1930	149.5	3.47	2016.953	1	
A 968	02313+4703	9	9.4	2009	26.1	1.74	2016.989	1	
A 2218	02344+2040	9.2	13.3	1972	114.2	2.15	2016.929	1	
A 2021	02352+0649	9	13.8	2000	16.9	4.39	2016.953	1	
A 2336	02392+0343	8.8	12.5	1978	313.3	2.86	2016.953	1	
A 2337AB	02414+0426	6.9	12.7	1955	252.7	2.99	2016.953	1	
A 826	02448+3129	9.2	12.4	2001	164.3	4.42	2016.953	1	
A 2024	02459+0714	8.7	11.4	1978	234.4	1.41	2016.929	1	
A 1821AB	02471+3744	8.5	14.7	1999	165.6	5.27	2016.953	1	
A 2222AB	02473+1717	8.6	13.5	1961	302.7	4.50	2016.929	1	8
A 1822	02496+3648	8.3	11.4	1991	309.9	2.00	2016.915	1	
A 2340	02522+0352	10	10	1991	37.4 ± 0.42	0.61 ± 0.009	2016.929	4	

Table 1 continues on next page.

Measurements of 208 Aitken Visual Binary Stars with a 280 mm Reflector

Table 1(continued). Measurements

NAME	WDS ID	M1	M2	DATE2	PA (°)	SEP (arcsec)	DATE	N	NOTES
A 1929	02542+2658	9.4	14.2	1930	301.7	3.02	2016.915	1	
A 2341BC	02544+0946	10.1	10.7	2000	4.1	1.46	2016.929	1	
A 1823	02550+3644	8.5	13.4	1987	162.6	3.08	2016.915	1	
A 2415	03024+0238	10.5	10.8	2000	246.4	2.66	2016.934	1	
A 1284	03077-0032	9.5	11.6	1999	35.5	4.31	2016.934	1	
A 2031	03112+0710	8.3	13.2	1933	249.2	1.42	2016.953	1	
A 828	03143+0911	10.3	11.1	1991	204.3	1.22	2016.929	1	
A 1285	03164-0025	10.4	10.9	2001	288.8 ± 0.00	1.79 ± 0.000	2016.9435	2 (2)	
A 2032	03168+0501	9.3	11.8	1991	270.	2.62	2016.929	1	
A 2032	03168+0501	9.3	11.8	1991	269.8	2.61	2016.934	1	
A 1705	03211+4322	9.9	10.1	2008	187.7	3.40	2016.915	1	6
A 2343	03233+1634	8.5	13.2	1989	15.6	5.29	2016.915	1	
A 1287	03247+4046	7.8	13.8	1931	94.5	3.02	2016.915	1	4
A 979	03258+3044	10.1	11	1999	268.4	1.72	2016.915	1	
A 2417BC	03282+0409	10.3	10.3	1997	133.2	0.89	2016.915	1	
A 982BC	03294+4656	11.3	13.8	2007	233.	3.80	2016.915	1	
A 1825	03313+2515	8.1	14.2	1930	305.9	2.92	2016.929	1	
A 2418	03364+0153	10.5	10.6	1995	243.3	0.73	2016.915	1	
A 1538	03389+4243	10.3	10.7	2000	263.2 ± 0.11	0.59 ± 0.003	2016.929	4	
A 1537	03389+4308	8.9	13.6	1916	117.2	3.60	2016.929	1	
A 1539	03402+4059	9.9	14.4	1916	192.8	3.20	2016.929	1	
A 2421	03412+1936	10.4	10.9	1991	152.6	1.17	2016.929	1	
A 1707CD	03419+4331	10.5	14.8	1987	105.6	4.27	2016.929	1	
A 2422	03421+1657	9	12.6	1991	290.	2.15	2016.915	1	
A 1540	03422+4149	9.5	15.6	1998	220.9	5.04	2016.929	1	5
A 987	03425+2946	10.2	10.3	2001	188.3	1.13	2016.915	1	
A 2346	03435+0109	10.1	11.8	1991	61.4	1.91	2016.915	1	
A 989AB	03435+2935	9.8	10.3	2013	356.6	3.16	2016.915	1	
A 988	03441+4728	8.8	13.7	1932	143.3	4.22	2016.929	1	
A 1827	03450+0819	9.4	10.8	2013	19.9	3.96	2016.915	1	
A 1291	03481-0034	10	10.1	1999	49.9	0.86	2016.915	1	
A 991	03488+4641	8.2	11.2	1991	317.9	1.86	2016.929	1	
A 1829	03491+0649	9.8	11.7	1986	303.2	1.83	2016.915	1	
A 832AB	03491+1139	10	10.4	2000	114.2	1.74	2016.934	1	
A 2347	03528+0145	7.9	12.1	1929	258.	4.38	2016.915	1	
A 1542	03530+4112	9.5	12.2	2002	289.1	4.77	2016.934	1	
A 992	03537+4627	9	11.3	1993	198.	3.23	2016.929	1	
A 993	03545+4547	8.3	11.3	1991	59.4 ± 0.42	1.06 ± 0.031	2016.929	3	
A 2348	03548+1911	9.1	13.2	1929	321.6	3.16	2016.929	1	
A 2349	03552+0417	9.3	11.3	1982	58.6	1.34	2016.915	1	
A 2423	03561+0043	9.6	12.3	1991	344.7 ± 0.05	2.73 ± 0.032	2016.915	2	
A 1935	03565+0734	8.6	9.5	2008	359.7	0.63	2016.915	1	
A 465	03598+2848	9.5	10.8	2000	202.35 ± 0.25	1.96 ± 0.000	2016.9315	2 (2)	
A 995	03599+4454	9	13.2	1991	276.	3.04	2016.929	1	
A 1709CD	04035+4211	9.4	13.2	2000	208.3	3.77	2016.94	1	

Table 1 continues on next page.

Measurements of 208 Aitken Visual Binary Stars with a 280 mm Reflector

Table 1(continued). Measurements

NAME	WDS ID	M1	M2	DATE2	PA (°)	SEP (arcsec)	DATE	N	NOTES
A 997	04057+4537	8.9	11.1	2008	190.2	1.34	2016.94	1	
A 1294	04057+5304	8.1	11.8	1989	208.9	1.97	2016.934	1	
A 999	04147+4512	9.4	12.5	2008	71.	0.87	2016.94	1	3
A 2618	04166+0247	8.3	11.6	1929	10.5 ± 0.14	1.22 ± 0.013	2016.934	2	
A 1000	04180+4536	8.3	13.1	1933	273.1 ± 0.41	2.57 ± 0.026	2016.934	3	
A 1833	04197+3955	8	13.8	1917	94.5	3.80	2016.934	1	
A 1001	04205+4559	9	13.1	2008	183.5	3.04	2016.94	1	
A 1299	04239+4548	8.9	13	1933	177.8	2.59	2016.934	1	
A 1300	04302+5343	9.9	12.4	2010	151.5	0.82	2016.94	1	
A 1838	04308+0427	10.3	10.4	1999	151.2	0.95	2016.934	1	
A 1008	04321+5713	8.5	12.3	1991	140.9	3.38	2016.94	1	
A 1301	04332+4507	9.4	14.3	1933	225.3	2.77	2016.94	1	
A 836	04343-0045	9.7	10.7	2013	205.6	2.58	2016.94	1	
A 1715	04353+4305	9.3	13.4	1998	239.8	4.37	2016.94	1	
A 1841	04368+0523	8.6	13.8	1933	149.8	2.61	2016.94	1	
A 837	04373+0017	9	12	1991	345.5	2.60	2016.934	1	
A 1842	04374+0528	10.7	11	2002	118.6	1.57	2016.934	1	
A 839	04389+0011	9.4	12.6	1989	297.7	2.16	2016.94	1	
A 2036	04391+1024	9.7	11.4	2001	292.	2.76	2016.934	1	
A 1940	04424+0559	8.8	13.3	1933	204.4 ± 0.23	1.6 ± 0.006	2016.94	2	
A 2620AB	04438+0155	10.2	10.5	1991	263.9	0.69	2016.934	1	
A 3006CD	04441+0205	10	13.5	1930	316.7 ± 1.09	1.4 ± 0.012	2016.94	2	
A 1941BC	04458+0708	10.3	14.4	2012	12.	4.51	2016.94	1	
A 2507	04465+0242	10.6	10.9	1991	337.6 ± 1.66	0.75 ± 0.010	2016.934	4	
A 2037	04471+1003	7.3	12.3	1989	87.6	3.56	2016.94	1	
A 1015AB	04478+5716	9.9	11.2	2007	175.7	1.18	2016.94	1	
A 1017	04492+0002	10	10.9	1991	355.75 ± 0.04	0.905 ± 0.011	2016.937	2 (2)	
A 1546AB	04503+4350	9.1	14.2	1919	40.5	3.29	2016.94	1	
A 1943	04523+0541	8.7	11.3	1993	232.4	2.26	2016.934	1	
A 2426	04527+2000	9.5	11.5	2007	192.6	3.93	2016.94	1	
A 2040	04532+0833	7.8	12.6	1919	256.9 ± 0.01	2.86 ± 0.001	2016.94	2	
A 1548	04538+4405	9.4	14.2	1916	324.5	1.83	2016.94	1	
A 1549	04564+4130	9.5	11.8	1961	205.9 ± 0.45	0.83 ± 0.008	2016.94	4	
A 2626	04578+0359	9.2	13	1931	279.	1.46	2016.94	1	
A 2628	04589+0210	10.1	10.2	1999	158.9 ± 0.20	0.81 ± 0.004	2016.934	4	
A 2427	04594+2012	8.4	11.9	1991	258.7	4.28	2016.94	1	
A 2713	05510+0953	9.2	12.7	1981	133.4	1.68	2017.014	1	
A 1948	05560+0753	10.7	11.2	1989	108.5 ± 1.12	0.57 ± 0.017	2017.014	4	
A 2805	05573+1127	8.5	14.1	1922	170.1	1.29	2017.014	1	
A 1949	06011+0706	9.3	10.6	1991	359.8 ± 0.47	0.87 ± 0.005	2016.94	4	
A 2662	06031+0025	9.3	12.3	1971	161.	2.47	2017.014	1	
A 2513	06059+1636	9.3	11.1	1991	302.2	1.10	2016.94	1	
A 215	06062+3107	10.4	10.9	1992	30.6	1.62	2016.94	1	
A 1048	06064-0058	7.7	13.2	1916	283.7	3.27	2017.014	1	
A 2664	06084+0135	9.2	9.6	1995	259.1 ± 0.35	0.77 ± 0.001	2017.014	4	

Table 1 concludes on next page.

Measurements of 208 Aitken Visual Binary Stars with a 280 mm Reflector

Table 1(conclusion). Measurements

NAME	WDS ID	M1	M2	DATE2	PA (°)	SEP (arcsec)	DATE	N	NOTES
A 121	06093+2839	10.8	11	1991	163.8 ± 0.37	0.66 ± 0.003	2016.94	4	
A 1572	06109+5330	9.5	10.2	1991	99.6	0.97	2016.94	1	
A 2808	06123+0827	9.6	11	1991	1.7	1.64	2017.014	1	
A 2114	06143+3906	9.6	12.7	1919	281.6	1.44	2016.94	1	
A 667	06150+3053	10.5	10.6	1991	175.7	1.06	2016.94	1	
A 1730	06192+5410	9.4	13	1986	107.2	3.14	2016.94	1	
A 1319	06224+4612	7.5	9.8	1991	129.5 ± 0.37	0.8 ± 0.005	2016.94	4	
A 2811	06238+0528	9.1	13.5	1921	38.8	3.39	2017.014	1	
A 2813	06263+1059	8.6	13.7	1922	109.5	4.42	2017.014	1	
A 2670	06264+0311	9.8	13.7	1920	334.5	2.32	2017.014	1	
A 2725	06284+1143	9.2	13.2	1987	126.7	1.43	2017.014	1	
A 2450	06296+1659	8	11	1991	52.1	2.70	2016.94	1	
A 854	06298-0006	8.6	11.2	1991	166.2	2.14	2017.014	1	
A 2816AB	06312+0956	8	10.2	1991	317.3	0.95	2016.94	1	
A 2673AB	06344+0318	7.4	9.9	1991	299.1	1.45	2017.014	1	
A 2674	06367+0032	8.9	11.7	1921	313.	2.37	2017.014	1	
A 2675AB	06374+0253	9.3	13.3	1921	175.4	2.53	2017.014	1	
A 2822	06379+0855	10.3	10.7	1991	122.7 ± 0.24	0.76 ± 0.001	2016.94	4	
A 2676	06397+0203	8.8	13.3	1921	353.1	3.92	2017.014	1	
A 2933	06416+0413	9.1	10.9	1991	183.6	1.49	2016.94	1	
A 2455	06426+1937	9.3	13.6	1919	297.8	3.02	2016.94	1	
A 2455AC	06426+1937	9.3	14.5	1919	16.7	1.80	2016.94	1	9
A 2454	06429+4137	9.8	12.7	1986	257.1	2.46	2016.94	1	
A 2824	06438+0327	8.8	11.9	1989	339.6	1.90	2017.014	1	
A 2829	06478+0015	8.8	12.8	1987	91.5	3.67	2017.014	1	
A 2832	06548+1126	8.1	11.7	1991	329.8	3.24	2016.94	1	
A 2834	06562+1430	8.2	12.5	1975	267.9	2.72	2016.94	1	
A 2121	06590+2105	8.3	12.9	1987	122.1	3.90	2016.94	1	

Notes for Table 1:

1. $\Delta M = 6.1$
2. See Plate 1
3. $\Delta M = 3$ sep<1 – see Plate 1
4. $\Delta M = 6$
5. $m_2 = 15.6$; exp = 100ms
6. Possible quadrant inversion. Companion is viewed in Q3
7. R filter
8. m_2 as reported in WDS is likely to be under-estimated (probably >13.5)
9. New companion C - see Sec. 5 and Fig 6
10. Has orbit (ref: Nov2006e, grade=5). O-C(θ)=-2.2° O-C(ρ)=-0.25

Measurements of 208 Aitken Visual Binary Stars with a 280 mm Reflector

Table 2 – Pairs with showing a significant displacement (Delta(PA)>10° and/or Delta (SEP)>0.5'') wrt. their last measurement as reported in the WDS

NAME	WDS ID	DATE2	NOBS	Delta(SEP)	Delta(PA)	Note
A 805	00291+1119	2000	5	0.53	2.9	
A 806AB	00355+1150	1991	5	0.05	84.8	3
A 1806	00403+0517	2000	10	0.53	3.4	
A 810	00434+1136	1933	3	0.72	1.9	
A 1509AC	00516+3925	1929	3	2.36	18.9	
A 1901	00523-0022	2000	6	0.12	27.7	
A 2207	00530+1806	2000	9	0.62	1.2	
A 925	00587+4457	1994	6	0.16	11.6	
A 1907	01257+3621	1932	3	0.64	1.1	
A 941CD	01286+4509	1994	6	0.17	14.7	
A 1265CD	01376+5511	1991	6	0.31	195.9	1
A 963AB	02227+5705	1999	6	0.55	3.5	
A 1817	02294+4000	1929	3	0.51	1.9	
A 2337AB	02414+0426	1955	4	0.79	0.3	
A 2222AB	02473+1717	1961	4	0.3	13.3	
A 1929	02542+2658	1930	3	0.62	4.3	
A 828	03143+0911	1991	13	0.02	10.7	
A 1705	03211+4322	2008	17	0	179.7	2
A 1825	03313+2515	1930	3	0.82	5.1	
A 2418	03364+0153	1995	12	0.07	10.7	
A 1707CD	03419+4331	1987	3	0.63	0.4	
A 988	03441+4728	1932	3	0.52	0.3	
A 2348	03548+1911	1929	3	0.56	0.4	
A 2349	03552+0417	1982	4	0.47	13.4	
A 995	03599+4454	1991	5	1.04	20	
A 2618	04166+0247	1929	5	0.58	18.5	
A 1000	04180+4536	1933	3	0.57	2.1	
A 2620AB	04438+0155	1991	5	0.19	12.1	
A 2805	05573+1127	1922	2	0.09	39.9	
A 1949	06011+0706	1991	5	0.17	10.2	
A 1048	06064-0058	1916	2	0.57	0.3	
A 2811	06238+0528	1921	2	0.99	11.2	
A 2670	06264+0311	1920	2	0.52	4.5	
A 2676	06397+0203	1921	2	0.02	12.1	
A 2455	06426+1937	1919	1	0.62	3.8	

Notes for Table 2

1. There may be a quadrant inversion in the latest WDS measure (1991: PA=157). The first measure (1906) gives PA=348
2. Quadrant inversion ? Our images definitely shows the companion in Q3
3. We have no explanation for the large Delta(PA) observed here. . The first WDS measure (1904) gives PA=146

Measurements of 208 Aitken Visual Binary Stars with a 280 mm Reflector

(Continued from page 434)

The details of all measurements is available online [10].

Figure 5 shows a plot of all measurements with the separation as the X axis (in arcsec) and the delta mag as the Y axis. This plot can be viewed as an approximation of the "accessible domain" with the instrumental setup used here. The blue dotted line on the left, in particular, gives an idea of the how much the former quantity limits the latter. For example, pairs with a delta mag > 3 seems to require a separation > 0.8" to be reliably measured.

For several pairs our measurement shows a significant variation compared to the latest one reported in the WDS catalog. Table 2 lists the pairs for which the variation in PA is greater than 10° and/or the variation in SEP is greater than 0.5 arcsec. The columns DATE2 and NOBS respectively gives the date of the last measurement and the total number of measurements reported in the WDS (as of 2016-11-01). The variations Delta (PA) and Delta(SEP) are computed as the absolute value of the difference between these values and ours. Pairs with the greatest variations and a sufficient number of observations (such as A 1901, A 1907, A 828, or A 2418) could make good candidates for a preliminary orbit calculation.

5. A New Component for WDS 06426+1937

WDS 06426+1937 (A 2455) is a pair with a large delta mag (m_1=9.3, m_2=13.6). The WDS only lists two observations, in 1911 and 1919. We observed it on the night of December 9, 2016. When reducing the data, a very faint companion was noticed on an image obtained by adding the 100 best frames of the sequence. The presence of this companion was confirmed on the autocorrelogram computed on 1000-frames sequences (see Figure 6). We did not find mention of this component in the literature and it has no entry in the WDS catalog. The measured position angle and separation are:

PA = 324.8° and SEP=3.89"

The magnitude of this new component, based upon that of the B component, is estimated between 14 and 15.

Conclusion

The results reported here confirm and extend the conclusions given in [4]. They show that pairs with a secondary component up to mag 14 and/or separation down to 0.6 arcsec can be routinely measured with an 11" telescope. This increases the probability to discover yet unobserved companions with small amateur-level instrumental setups, as demonstrated here with the case of A 2455.

From a technical point of view, this paper also demonstrates that using autocorrelation-based reduction methods is not reserved to the measurement of close pairs, relatively bright pairs, under the seeing limit but that these techniques can be fruitfully applied to obtain precise measurements of pairs with very faint components and/or large delta mag.

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