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A New Double Star in Perseus

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Abstract: A new double star has been found 15' from RZ Per, (1:29:42.1 +50:51:23.9, J2000) in PA 344°. A preliminary measurement of the new double gives 14" separation and a PA of 98 degrees, and APASS visual magnitudes of 10.3 and 10.6.

The pair was found while observing RZ Per, on 2013 Sep 14, at 3:22 Eastern Daylight Time. It was plainly seen in the 20 cm Schmidt-Cassegrain telescope that was in use at the time. A quick check with the Night Assistant program [1] revealed that the stars were in the UCAC4 [2], Tycho [3], and AC2000 [4] catalogs, but not in the Washington Double Star catalog (WDS) [5]. The pair's J2000 coordinates are: 01:30:24.16 +51:09:53.5.

Information about the find was first posted on the Cloudy Night's Double Star observing forum [6]. Two of the observers there immediately responded to the author with more data about the star. David Cotterell of Toronto, Ontario [7] found the pair in the Millennium Star Atlas [8]. Wilfried Knapp suggested that the proper motion of the stars be examined.

Further study was done using the Aladin program [9], which gave the UCAC4 designations of the two stars:

706-011096, 022.6006527, +51.1648573
706-011101, 022.6068245, +51.1642987

More designations can be found in the SIMBAD [10] database.

The UCAC4 proper motions of both stars were also given, in milliarcseconds per year:

pmRA: 1, pmDE: 5
pmRA: 1, pmDE: 5

William Hartkopf, of the USNO [11], points out that these are very small proper motions, and will require further study before the pair can be labeled a common proper motion pair with confidence. He adds that the fact the pair has similar magnitudes and spectral types makes it more likely that the pair is physical.

The pair has been entered into the WDS under designation 01304+5110 TVB 1, and the pair has been verified in the UCAC4, 2MASS, Tycho-2, APASS, and the Washington Fundamental Catalog.

Figure 1 is a photo of the new binary from the DSS as rendered by WikiSky [12]. The scale is 14x14 arc minutes; north is at the top.

Acknowledgements

The author wishes to acknowledge the editorial assistance of David Cotterell, William Hartkopf, and Kathleen Bryant in making this short paper more readable.

A New Double Star in Perseus

Figure 1. Image of the new double star from DSS.

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6) http://www.cloudynights.com/ubbthreads/postlist.php/Cat/0/Board/double

7) cotterell_david51@yahoo.ca

8) Sinnott, Perryman, 1997, Millennium Star Atlas

9) http://aladin.u-strasbg.fr/

10) http://simbad.u-strasbg.fr/simbad/

11) william.hartkopf@usno.navy.mil. Astrometry Department, U.S. Naval Observatory 3450 Massachusetts Ave, NW, Washington, DC 20392

12) http://www.wikisky.org/

A New Double Star from an Asteroidal Occultation: TYC 7444-01434-1

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RASNZ Occultation Section

Abstract: An occultation of TYC 7444-01434-1 by the asteroid (481) Emita on August 15, 2013 showed this star to be a double star with a separation of about 31 mas.

Observation

On August 15, 2013 Steve Kerr observed the asteroid (481) Emita occult the star TYC 7444-01434-1 from Rockhampton, QLD, Australia. The observation was made with equipment in Table 1.

Video was analyzed and light curves produced by the observer using Tangra V1.4 [1] software by Hristo Pavlov and results were analysed by Herald and Talbot using Occult4 [2] and Asteroidal Occultation Timing Analysis (AOTA) software by Dave Herald.

The star is of magnitude 10.5 (V), and has a corresponding expected apparent diameter of less than 0.1 mas. The expected magnitude drop at occultation was 2.5 magnitudes with an expected maximum duration of 10.7 sec and 1 sigma error in central time of ±5 sec.

The star is not listed in the Fourth Interferometric Catalog, nor in the Washington Double Star Catalog.

The light curve (Figure 1) obtained from the occultation shows clear steps that are characteristic of an ABAB double star occultation event.

The observations were analyzed in the standard manner described by Herald [3]. The plot in Figure 2 below shows one possible solution along with the predicted path as a dotted line

There is a large range of possible shape limits for an ellipse approximation of Emita ranging from 1.09 to 1.30 and diameters from 98 to 121 km are found at MPC LCDB [4]. This impacts the accuracy of possible solutions. No entries for 3D shapes were found in the DAMIT or ISAM databases of asteroid shapes. The longer chord measured here is about 129 km and the

(Continued on page 109)

Table 1: Observer and Equipment

Observer	Telescope	Camera	Timing	Event
S. Kerr, QLD,AU	30 cm	Watec 120N+ video	GPS Time Inserted	Stepped D and R

A New Double Star from an Asteroidal Occultation: TYC 7444-01434-1

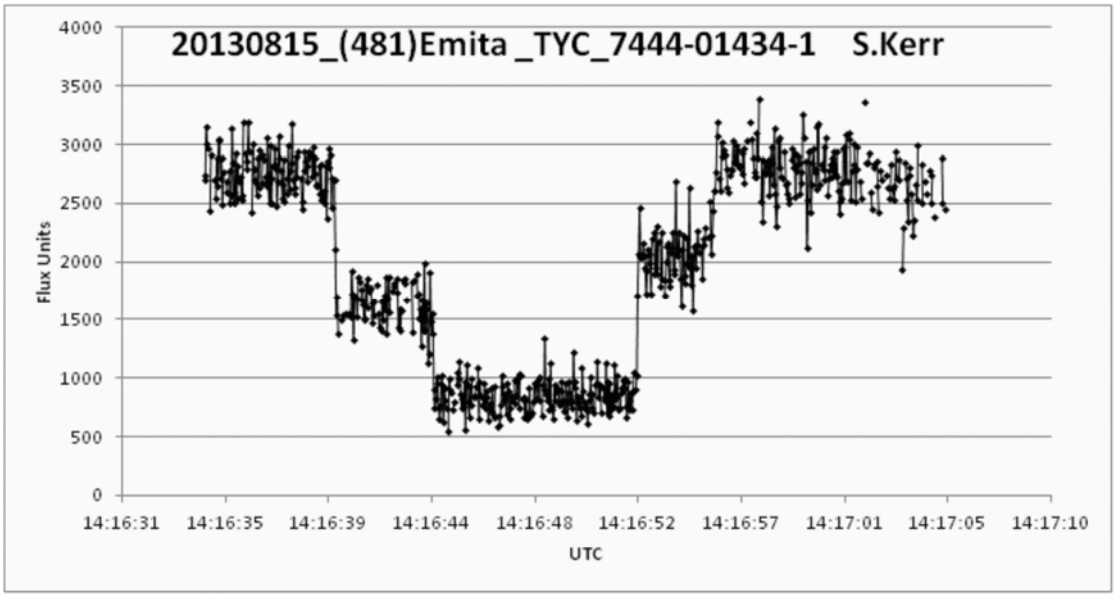

Figure 1: Steve Kerr's Light curve from Tangra analysis

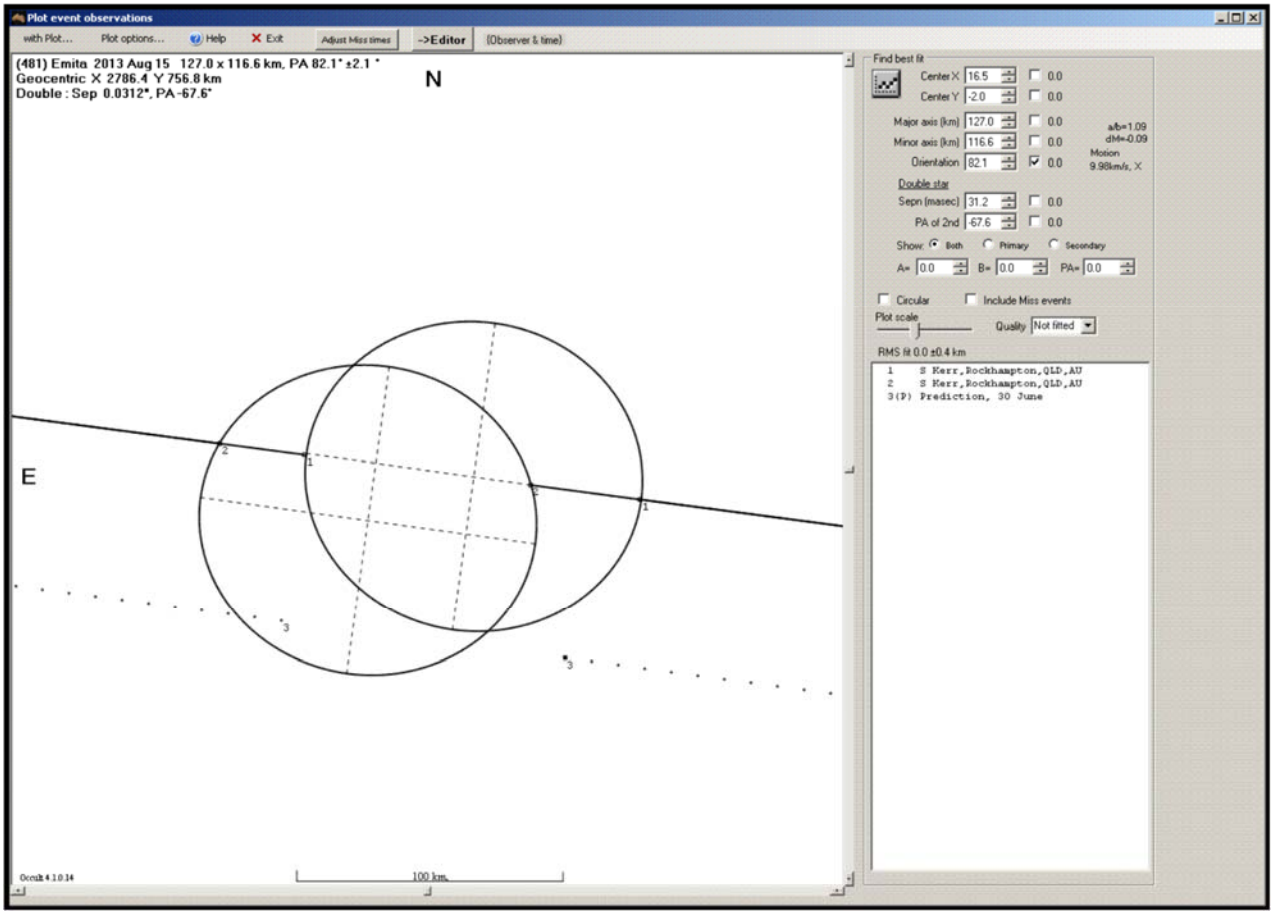

Figure 2. Plot of result and predicted times.

A New Double Star from an Asteroidal Occultation: TYC 7444-01434-1

(Continued from page 107)

shorter about 119 km.

For the rest of this analysis we have used an ellipse 129 km x 99 km (a/b=1.3) and examined the four possible solutions for PA and Separation. We have also used the plot with stars aligned as it is easier to see the vector of PA and Separation.

With only one observer we get 4 known points and are trying to fit 7 parameters (see Figure 2) Even when fixing the size and shape parameters, there are four possible solutions shown in Figure 3.

Examination of the star in Google Sky shows a hint of double diffraction spikes that sometimes indicate a double star. The star image is much larger than the measured separation. The double star characteristics are:

Star	TYC 7444-01434-1 = UCAC2 17843758 = UCAC4 284-205625 = GSC O000673
Coord. (J2000)	RA 20h 03m 37.24s
	DEC -33° 15' 15.57"
Spectral type	(none found)
Mag A	11.02 ± 0.5 (V)
Mag B	11.54 ± 0.5 (V)
Separation	31 mas ±10.0 mas
Position Angle	Ambiguous 290º ±10º or 235 º ± 10º
Epoch	2013.6210 (Besselian)

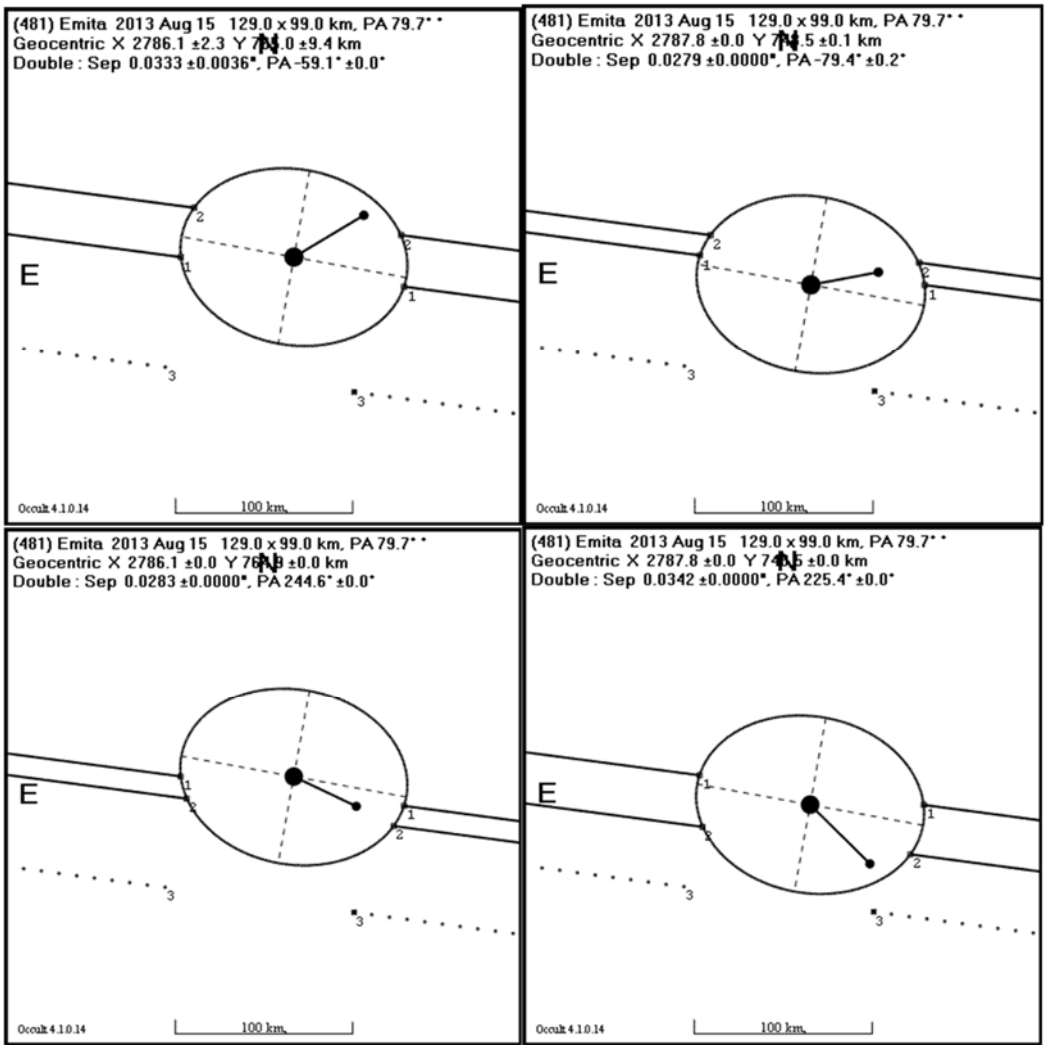

Figure 3. Offset centers for the two stars for the observation.

References

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4. Minor Planet Information Centre http://www.minorplanet.info/PHP/lcdbsummaryquery.php

Observation Report for the Year 2010, Humacao University Observatory

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Abstract: This is a report on observations of binary stars using Lowell Observatory's 31 inch telescope in June and September in the year 2010. The data was gathered in the form of images using the NASACAM CCD at the prime focus of the 31 inch. The data was downloaded to the Humacao University Observatory computers for analysis by the undergraduate student authors.

Introduction

In this paper we continue reporting measurements of position angle and separation of binary stars gathered from CCD images. The observations reported in this paper are the result of the analysis of data gathered during the year 2010. A team of undergraduates from the Department of Physics and Electronics of the Humacao Campus of the University of Puerto Rico traveled to Flagstaff, Arizona twice during that year to gather the data. They observed during June 1, 2, and 3 and, again, in September 10, 11, and 12. They used the 31 inch NURO telescope located at the Anderson Mesa facilities of Lowell Observatory, east of Flagstaff, at an altitude of 7200 feet. The Cassegrain telescope has, at its prime focus, a 2Kx2K CCD with 15 micron pixels. Its field of view is 16 arcminutes. There is an optical reducer in the optical path of the telescope.

Four students went to observe in June and two in September. The students operated the telescope, recorded the data, and brought it to our campus for further analysis.

We use the pixelization of the images and also a software application to obtain and check for the separation measurements. We described this procedure in an article of the Double Star Observer (Muller et al. 2003). To obtain the position angle from the images, we use a property of fork and German equatorial mounts (Muller et al. 2006). The measurement of the position angle introduces a systematic error that we call the offset and its correction is included in the values presented in this report (Muller et al, 2006).

Data

We include our 73 June observations in Table 1 and 107 September observations in Table 2. We must state that sometimes more than one image is obtained of a binary in a particular night or in various nights. However, in the analysis and calculations of position angle and separation, only one image is used for each case; this image is duplicated and assigned to various students to average their results. On both tables, UPRH ρ stands for our measurement of separation and UPRH Θ stands for position angle.

(Continued on page 117)

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Table 1. Observations Made in June 2010

NAME	R.A.	Declination	Mag1	Mag2	UPRH ρ	UPRH Θ	Date
HDO 122	09 16 41.99	-09 41 02.3	10.94	11.3	9.6	88.46	2010.4192
HJ 2491	09 16 43.52	+34 31 06.9	11.41	11.5	15.3	199	2010.4192
HJ 2492AB	09 18 35.41	+52 30 50.0	9.8	12.3	17	119	2010.4192
HJ 129	09 19 27.7	+06 06 13.5	12.2	12.9	12.7	241	2010.4192
BAL2833	09 20 14.28	+03 51 40.5	10.1	11.2	13.2	173	2010.4192
HJ 462	09 23 07.94	+30 07 41.7	10.78	11.37	18	9	2010.4192
HJ 818AB	09 36 11.79	-07 25 12.3	10.9	11.5	8.8	39.5	2010.4192
GRV 795	09 41 18.2	+26 50 56.3	11.6	13.8	23.4	234	2010.4192
POU3057	09 46 44.5	+23 22 47	11.7	12.2	6.28	26.2	2010.4192
STI2236	09 48 34.3	+55 37 21	11.8	13.3	5.85	58.5	2010.4192
STI 695	09 49 25.47	+58 39 26.4	11.1	12.9	12.1	126	2010.4192
HJ 828	10 06 23.97	+27 02 51.6	10.9	11.4	12.3	309	2010.4192
WEI 22	10 06 30.40	+43 33 06.8	9.87	10.57	11.8	296	2010.4192
ARA 668	10 22 21.88	-19 34 56.4	11.42	12.2	12.3	87	2010.4219
ES 2222	10 24 33.4	+32 57 53	10.15	11.4	8.2	290	2010.4192
BAL2841	10 29 04.9	+03 42 28	10.16	10.93	3.94	359	2010.4192
SEI 520	10 30 07.4	+30 50 53	12.0	12.0	8	2.5	2010.4192
STI 707	10 32 30.2	+59 00 47	10.8	11.8	6.75	213	2010.4192
BVD 82	10 34 00.56	-13 54 14.1	10.69	11.39	17.4	211	2010.4219
STF1452A,BC	10 35 48.16	+02 33 16.9	9.59	9.81	9.3	325	2010.4192
LDS1248	10 36 05.34	+29 06 18.0	16.0	16.3	14.5	275	2010.4219
STF1456	10 38 17.33	+01 14 38.4	8.24	9.75	15.2	49	2010.4192
ES 603	10 42 41.50	+48 10 33.0	9.95	12.3	12.7	101	2010.4192
STI2256	10 48 22.62	+55 32 47.8	10.8	11.2	12.3	134	2010.4192
GRV 821	10 51 12.34	+10 26 58.7	11.8	13.2	14.7	82.5	2010.4219
STF1482	10 52 10.61	+07 27 39.4	8.25	9.20	13.1	295	2010.4192
ES 722	11 00 31.3	+52 37 07	9.95	11.4	7.0	103	2010.4219
HJ 2553	11 02 11.1	+07 25 00	10.66	12.78	16.6	264	2010.4219
BAL1443	11 08 30.9	+01 17 44	10.8	11.0	9.6	183	2010.4219
POU3097	11 14 09.37	+22 58 37.6	11.94	13.6	12.0	326	2010.4219
STF1520	11 16 04.03	+52 46 23.4	6.54	7.81	13.4	341	2010.4219
STF1535	11 22 54.19	+00 55 38.9	9.39	12.0	15.1	60	2010.4219
HJ 1205	12 02 45.94	+04 21 34.4	11.94	12.1	15.6	30	2010.4219
STF1636	12 22 32.1	+05 18 20	6.53	9.31	23.7	343	2010.4219
STF1657	12 35 07.7	+18 22 37	5.11	6.33	21.4	263.6	2010.4219
HO 54BD	12 41 56.32	+09 52 45.6	11.8	14.8	20.2	89	2010.4219
B 2740	13 00 12.59	-19 29 02.7	8.16	11.4	10.4	120.7	2010.4219

Table 1 concludes on next page

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Table 1 (conclusion). Observations Made in June 2010

NAME	R.A.	Declination	Mag1	Mag2	UPRH ρ	UPRH Θ	Date
STF1707	13 01 14.16	+15 51 45.2	9.70	11.5	10.3	46	2010.4219
STF1718AB-C	13 05 30.27	+50 59 11.0	9.84	10.7	15.5	273	2010.4219
POU3134	13 14 27.47	+23 58 03.7	12.9	14.3	14	59	2010.4219
BAL 224	13 21 52.68	-02 39 17.3	10.92	11.24	12.3	70	2010.4219
HJ 231	13 46 19.3	+11 37 21.5	11.02	12	11.0	81	2010.4219
COU 59AB	14 00 42.1	+17 53 55	10.55	13.8	9.74	172.5	2010.4192
ARA 74	14 01 26.4	-16 36 00	13.3	13.3	13.8	10	2010.4192
HJ 2699BC	14 03 04.6	+11 54 18	13.0	13.4	14.8	304	2010.4192
ARA 695	14 03 29.2	-19 32 20	12.6	12.9	7.3	58	2010.4192
HJ 542	14 12 21.2	+36 46 12	12	12	12.2	247	2010.4192
LDS 953	14 13 29.8	+21 37 39	13.7	15.2	11.0	187	2010.4192
STFA 26AB	14 16 10.0	+51 22 01	4.76	7.39	38.6	30	2010.4192
GRV 888	14 30 53.35	+28 06 52.2	10.92	11.64	12.9	48	2010.4192
POU3176	14 52 43.4	+23 53 47	12.39	14.0	5.0	3	2010.4192
HJ 560	14 55 36.9	+34 57 23	9.82	11.2	39.0	298	2010.4192
HJ 1264	14 58 21.7	+40 16 15.8	10.22	12.83	19.4	320	2010.4192
BAL1175	15 00 23.7	+00 06 44	10.8	11.2	17.0	196	2010.4192
HJ 2758	15 00 40.2	-17 30 34	11.76	13.8	18.6	343	2010.4192
KZA 80	15 20 42.0	+31 33 15	12.13	12.82	25.3	53	2010.4192
HJ 2777	15 22 25.3	+25 37 27	7.5	10.4	42.31	343.5	2010.4192
KZA 87	15 24 48.6	+29 34 28	12.0	12.5	11.8	1.5	2010.4192
KZA 90	15 27 25.4	+31 01 41	12.5	13.0	19.7	294	2010.4192
GIC 131	15 32 30.2	+08 32 08	13.57	14.68	14.6	310	2010.4192
POU3193	15 35 22	+24 08 18	13.2	13.7	9.5	300	2010.4192
HDS2205	15 38 16.34	-09 34 27.5	9.89	12.39	10.1	45.5	2010.4192
STT 300	15 40 10.35	+12 03 10.6	6.32	10.07	15.1	261	2010.4192
STF1981	15 51 16.00	+25 08 39.2	9.37	10.86	13.7	3	2010.4192
STF1983	15 51 57.93	+35 27 39.0	10.19	11.74	13.5	65	2010.4192
HJ 580	16 02 50.6	+37 05 27	9.20	12.2	41.0	8	2010.4192
ARA 433	16 06 35	-18 19 11	11.6	14.1	9.5	50	2010.4219
POU3214	16 07 48	+23 05 29	11.1	13.3	13.3	88	2010.4219
HJ 1288	16 12 40	-16 45 18	11.0	12.3	17.2	123	2010.4219
ES 627	16 18 35.7	+51 19 51	9.88	10.98	12.2	285	2010.4219
BAL2429	16 54 51.2	+03 18 41	11.77	12.8	11.4	51	2010.4219
POU3252	16 56 22.97	+24 01 14.3	11.4	13.4	13.4	11	2010.4219
ARA 434	16 57 40.02	-18 10 55.5	9.82	13.0	12.7	156.5	2010.4219

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Table 2. Observations Made in September 2010

NAME	R.A.	Declination	Mag1	Mag2	UPRH ρ	UPRH Θ	Date
ARA 243	16 01 04.07	-17 40 59.3	11.84	12.0	13.4	297	2010.6932
AG 349	16 01 04.36	+28 06 42.4	9.59	10.86	11.8	288	2010.6932
AG 200	16 01 09.14	+39 36 11.8	10.62	10.94	3.3	215	2010.6932
HJ 580	16 02 50.56	+37 05 26.8	9.20	12.2	40.9	6.80	2010.6932
BEM 21	16 02 58.26	+51 11 40.4	10.54	11.02	18.9	105	2010.6932
VKI 25	16 03 10.46	+42 13 01.1	11.4	13.4	6.6	162.5	2010.6932
BAL1911	16 03 20.00	+02 31 26.8	12.19	12.7	16.9	235	2010.6932
STF1999AB	16 04 25.9	-11 26 57	7.52	8.05	13.6	102	2010.6932
ARA 433	16 06 35.8	-18 19 11	11.6	14.1	9.9	56	2010.6932
ALI 370	16 07 26.8	+35 48 29	12.06	12.5	12.9	146.8	2010.6932
POU3214	16 07 48.8	+23 05 29	11.1	13.3	12.1	82	2010.6932
HJ 1289	16 10 38.01	+39 28 38.2	11.39	12.3	11.2	239	2010.6932
GRV 924	16 11 43.26	+35 07 29.1	8.8	12.1	10.8	304	2010.6932
HJ 1288	16 12 40.8	-16 45 18	11.0	12.3	18.3	122	2010.6932
ES 627	16 18 35.71	+51 19 51.5	9.88	10.98	11.5	287	2010.6932
BAL2418	16 35 09.74	+02 54 20.0	11.06	11.25	11.9	189.3	2010.6932
STF2098AB	16 45 43.47	+30 00 17.2	8.77	9.61	14	144.5	2010.6932
BAL2429	16 54 51.2	+03 18 41	11.77	12.8	11.4	52.7	2010.6932
BAL1486	17 05 55.9	+00 55 57	10.86	12.4	7.4	12	2010.6932
BAL1931	17 06 09.8	+02 06 05	11.4	11.5	16.9	187	2010.6932
COU 109	17 06 27.9	+22 07 57	10.01	13.1	8.26	141	2010.6932
SLE 78BC	17 06 49.8	+33 56 00	11.27	12.15	14.3	202.5	2010.6932
STF2123	17 06 57.50	+06 48 03	9.82	9.98	18.6	216.5	2010.6932
AG 353	17 07 01.4	+12 13 22	9.83	11.7	9.8	248.5	2010.6932
STF2127	17 07 04.42	+31 05 35.1	8.70	12.30	15.1	281	2010.6932
SLE 9	17 07 06.29	+20 29 21.7	10.49	11.94	19.8	173	2010.6932
GRV 946	17 07 14.12	+25 44 34.5	10.54	11.71	20.5	42.5	2010.6932
STN 34	17 16 42.44	-17 09 11.5	9.57	10.58	17.4	290.2	2010.6932
HDS2441	17 15 56.29	-13 29 39.0	9.63	11.74	12.5	233	2010.6932
BAL1934	17 17 45.85	+02 07 05.9	10.85	11.8	12.9	234	2010.6932
SLE 13	17 18 17.06	+19 12 14.0	10.14	11.7	11.2	308	2010.6932
BAL2454	17 51 08.47	+03 11 18.9	11.78	11.66	13.2	92.5	2010.6932
STI2366	18 00 33.71	+58 40 56.1	10.65	12.1	9	296.5	2010.6932
ES 640	18 00 42.85	+54 52 38.1	9.51	10.1	8.4	80	2010.6932
ES 1558	18 00 50.53	+41 45 12.5	10.22	13.7	6.2	297.8	2010.6932
SLE 107	18 01 49.80	+26 31 23.4	12.45	12.6	12.9	206.5	2010.6932
HJ 1314	18 07 05.32	+32 22 54.6	10.33	11.09	17.9	155.3	2010.6932
SLE 110	18 07 14.5	+27 16 04	10.56	13.3	10.9	111.5	2010.6932

Table 2 continues on next page.

Observation Report for the Year 2010, Humacao University Observatory

Table 2 (continued). Observations Made in September 2010

NAME	R.A.	Declination	Mag1	Mag2	UPRH ρ	UPRH Θ	Date
STF2280AB	18 07 49.5	+26 06 04	5.81	5.84	14.25	183	2010.6932
BAL2474	18 08 03.4	+03 43 12	10.0	11.0	15.6	282	2010.6932
POU3351	18 08 08.8	+23 27 12	12.05	12.05	10.4	157.5	2010.6932
SLE 111	18 08 53.9	+27 24 56	10.8	12.5	14.6	309.5	2010.6932
POU3353	18 08 55.1	+23 19 00	12.26	12.4	15.7	345	2010.6932
HJ1315	18 09 53.5	+29 41 16	11.85	13.1	8.8	128.8	2010.6932
STF2293	18 09 53.83	+48 24 05.7	8.08	10.34	12.2	80	2010.6932
ARA 267	18 09 54	-17 09 38	11.22	12.4	14.4	349	2010.6932
SEI 559	18 10 27.8	+33 55 55	11.0	11.0	11.5	170.5	2010.6932
BAL2481	18 10 37.2	+03 27 23	11.3	11.3	10.8	110	2010.6932
AG 217	18 11 05.89	+53 29 37.8	10.77	11.85	14.37	240.8	2010.6932
ALI 140	18 11 25.14	+35 06 45.5	10.97	11.79	14.3	249	2010.6932
BAL2483	18 14 41.6	+03 42 05	12.00	12.7	12.7	196	2010.6932
SLE 145	18 14 58.3	+03 03 43	11.2	11.9	11.6	27.8	2010.6932
WLY 10AC	18 30 31.14	+08 51 54.4	10.6	11.3	11.3	82	2010.6932
POU3419	18 32 02.77	+25 04 01.7	7.7	12.1	9.86	234	2010.6959
J 1745	18 32 49.40	-13 03 35.4	9.47	12.8	9.0	52.8	2010.6959
STF2459	19 07 22.01	+25 58 23.9	9.12	10.07	14.1	230.5	2010.6959
POU3718	19 08 00.6	+24 58 09	10.69	13.7	14.1	272	2010.6959
HJ 877	19 10 04.2	+19 33 15	10.8	11.1	12	293	2010.6959
POU3745	19 12 00.7	+23 46 18	12.47	13.7	11	23	2010.6959
HJ 1375	19 12 34	+28 14 47	11.0	13.6	11.1	86.5	2010.6959
HLM 18	19 13 15.0	+39 08 57	10.94	11.33	12.2	331.8	2010.6959
ARA1175	19 15 30.0	-19 55 19	11.60	12.5	12.5	12.5	2010.6959
HJ 2861	19 16 30.4	+07 12 10	10.84	13.8	12.0	54	2010.6959
BAL1516	19 17 00.2	+01 45 03	11.5	11.6	10.5	271.5	2010.6959
HJ 2868	19 17 56.9	+58 07 58	11.9	11.9	11.3	103.3	2010.6959
POU3940	19 35 12.15	+25 01 29.6	10.6	10.7	9.6	29	2010.6959
HJ 1421	19 36 21.95	+35 35 51.5	9.37	11.72	14.9	232	2010.6959
ALI 892	19 37 20.68	+39 04 19.2	10.74	12.6	10.8	67	2010.6959
ES 2297AB	19 37 28.79	+33 32 31.2	9.14	9.4	7.2	189	2010.6959
HJ 1429	19 37 57.45	+56 14 05.9	10.6	11.0	7.1	238.5	2010.6959
SMA 101	19 50 51.42	+44 44 38.6	11.40	11.9	9.6	49	2010.6959
POU4178	20 00 12.25	+24 20 45.5	11.30	12.3	11.5	6	2010.6959
CHE 235	20 14 36.6	+14 52 35.2	12.3	13.6	13.8	31	2010.6959
POU4392	20 21 09.47	+25 07 24.0	10.98	11.9	9.9	334.3	2010.6959
ES 362AB	20 23 05.60	+30 35 49.6	10.18	12.5	11.5	233.5	2010.6959

Table 2 concludes on next page.

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Table 2 (conclusion). Observations Made in September 2010

NAME	R.A.	Declination	Mag1	Mag2	UPRH ρ	UPRH Θ	Date
POU4500	20 26 52.84	+23 40 16.1	11.99	12.1	8.5	278	2010.6959
A 1674AC	20 27 31.64	+14 53 33.6	9.72	12.5	7.7	288.5	2010.6959
SEI1483	21 16 06.47	+35 47 58.0	11.0	11.0	10.1	25.5	2010.6959
POP 186AB	21 16 57.43	+41 39 52.6	10.3	11.1	10.2	294	2010.6959
MLB 489AC	21 17 38.12	+28 40 46.1	10.32	12.0	10.9	286	2010.6959
WSI 23AC	21 24 42.86	+36 30 30.1	11.0	12.2	9.2	79	2010.6959
POU5363	21 25 07.59	+24 01 10.1	10.4	11.9	7.9	281.3	2010.6959
BAL1230	21 27 50.46	+01 04 48.4	11.4	11.5	12.0	273	2010.6986
STF2800	21 28 43.09	+49 52 06.6	9.50	10.41	9	249	2010.6986
J 1896	21 29 11.79	+23 10 49.4	10.88	13.7	6.9	110.5	2010.6986
STI2586	21 42 40.45	+56 14 56.9	10.71	11.72	12.6	3	2010.6986
STI2720	22 21 30.0	+58 36 48	12.1	12.1	14.2	161	2010.6986
STI2722	22 21 59.1	+56 19 52	10.67	13.1	14.8	71	2010.6986
BU 174	22 29 18.56	-09 39 45.8	8.83	11.74	8.53	288	2010.6986
ES 837AC	22 31 45.72	+50 04 24.4	9.64	12.9	11.2	234.5	2010.6986
HO 475AC	22 32 45.49	+26 24 32.8	9.34	11.3	8.5	223	2010.6986
POU5723	22 35 11.58	+23 41 55.6	12.3	12.7	10.9	183	2010.6986
CHE 347	22 40 37.34	+30 19 50.5	13.1	13.6	8.2	47.5	2010.6986
CHE 396	22 43 18.39	+33 14 38.8	8.93	12.0	10.6	168	2010.6986
STI2872	22 50 16.7	+57 36 20	11.85	11.9	11.4	56.5	2010.6986
STF2999AD	23 18 46.4	+05 11 18	8.90	11.9	27.4	21	2010.6986
HJ 1876	23 25 56.79	+36 50 32.5	11.1	11.6	9.4	210	2010.6986
HJ 986	23 27 07.33	+35 20 28.2	11.23	12.2	9.5	296	2010.6986
STF3019	23 30 40.76	+05 14 58.0	7.77	8.37	11.6	184.5	2010.6986
BRT 602	23 32 07.02	-14 31 33.3	10.8	11.0	4.7	139	2010.6986
STI3012	23 38 24.5	+58 00 27	12.6	12.6	8.0	102.3	2010.6986
MLB 506	23 38 28.67	+28 44 56.2	11.1	11.6	8.6	239	2010.6986
STI3007	23 36 42.8	+58 19 49	13.2	13.2	8	120	2010.6986
BAL1249	23 41 02.7	+00 43 07	10.36	12.4	13.6	340	2010.6986
ES 269AB	23 49 03.25	+41 19 26.2	9.93	12.1	10.5	224.5	2010.6986
STF 23AB	00 17 28.7	+00 19 15	7.88	10.28	9.5	218	2010.6986
BAL1611	00 43 18.50	+02 51 01.2	11.4	11.5	20.1	179.5	2010.6986

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(Continued from page 111)

Acknowledgements

This research has made extensive use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory. We would like to acknowledge support from the Puerto Rico Space Grant Consortium and the L.S.AMP of the University of Puerto Rico. We also thank Ed Anderson of NURO for his efforts on behalf of our students.

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Data Mining the MOTESS-GNAT Surveys as a Source of Double Star Observations

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Abstract: New measurements of eleven double stars selected from the Washington Double Star Catalog are presented. The measurements were made using archival images that formed the basis of the MOTESS-GNAT variable star catalog. In addition to these new observations, this work demonstrates that the MOTESS images are a viable source for double star measurement.

Introduction

The Moving Object and Transient Event Search System (MOTESS) is a three telescope, scan-mode, CCD imaging survey of the region around the celestial equator [1]. The MOTESS surveys provided time series imaging over durations of around two-three years at fixed declinations. The Global Network of Astronomical Telescopes (GNAT) has processed MOTESS images to create the MOTESS-GNAT (MG) variable star catalogs [2].

We selected and analyzed data from eleven double stars with the goal of determining whether the MOTESS images could be productively utilized to measure position angles and separations in order to better define the orbits of these systems. In this process we established constraints on such use of the MOTESS images.

The process was initiated when we accumulated Washington Double Star Catalog (WDS) data for double star candidates located in the MOTESS images. For each given star, a series of measurements that included the position angle, separation, magnitude of the primary and secondary star, Right Ascension, and the Declination coordinates were obtained from the WDS catalog.

Observations/ Source Data

Historical observations of the double stars were taken from the WDS: the first and most recent observation dates. For our purposes, we preferred the gap between the first and last observation date to be at least 40 years in hopes of easily detecting relative motions between the double stars.

More recent observational data were derived from raw MOTESS images, as obtained from a set of 14-inch aperture telescopes. The MOTESS images used for the MG surveys were unfiltered. The images from the CCD camera measure 1024 x 1128 pixels with a field of view of 48 arc minutes at a fixed declination of +03 18'. This produces an image scale of about 2.8 arc seconds per pixel.

The images of each double star selected from the MOTESS/GNAT System had to meet a range of requirements in order to be measurable. The software we used to help sort the images was the Vizier tool in the Simbad catalog. We set the range of magnitude for each of our candidates to be between 12th and 18th magnitude. We adopted a bright limit of 12th magnitude because we believed any star with a brighter magnitude would be saturated in the images. Likewise, we adopted a faint limit of 18th magnitude because we found that any star with a fainter magnitude would be difficult to locate against background stars.

After experimenting with a number of possible candidates, we also set limits on the separation of the double stars. We concluded that stars with separations less than 25 arc seconds were too close to measure, causing the images to easily merge, especially if both were

bright. We set the upper limit of separation at 100 arc seconds, because locating the secondary star at a great distance, especially in crowded fields, was very difficult.

After setting these requirements, we narrowed down the list of possible candidates to 20 double stars. We then used the program Aladin to produce finding charts for each double star. After using these criteria, we were able to narrow the list down to 13 candidate double stars.

Data Reduction

The first step in the process was to plate solve each image file using the PinPoint astrometric software (DC-3 Dreams, Mesa, Arizona). After plate solving each image for the desired night, World Coordinate System parameters were written to the FITS image header. This allowed us to examine the images in PinPoint, while simultaneously returning a display of the equatorial coordinates of the cursor. This made location of the double star of interest relatively easy. Upon viewing each image, the usability of the image was determined by whether or not the stars were on edges of the frames or disrupted by light from a nearby bright source, such as a bright star or scattered moonlight. This resulted in deleting two stars from our candidate list, leaving 11 stars in our project.

MPO Canopus (Palmer Divide Observatory, Colorado Springs, CO) was then used to measure position angle and separation for both the primary and secondary stars of the double star pair. Measurements were made using six images obtained on three successive nights. For each star, the measurements were averaged and the standard deviation around the mean was calculated.

Results

Results of our measurements are shown in Table 1. A comparison of these observations with the historical data for each star is shown in Table 2.

Table 1. Observed Separation and Position Angles for the Target Stars.

WDS Name / Disc. Code	RA+DEC	MAGS (P,S)	PA (°)	SEP (")	DATE	N	NOTES
04463+0329 / LDS3617	044621+0329	15.9, 16.4	281.3	72.1	2002.862	6	1,2
05164+0321 / GWP 664	051625+0321	14.3, 14.6	115.8	89.9	2002.848	6	1,3
05297+0338 / GWP 683	052943+0337	14, 15.8	178.2	94.9	2002.848	6	1,4
08024+0320 / LDS5160	080223+0320	13.5, 18.3	223.1	49.3	2002.862	6	1,5
11275+0340 / SLE 601	112728+0440	12.18, 13.2	10.0	31.49	2003.01	6	1,6
13468+0255 / LDS5794	134644+0254	12.3, 17.4	157.64	42.4	2002.342	6	1,7
15259+0340 / UC 3002	152551+0339	12.7, 16.2	35.9	23.7	2002.346	6	1,8
16216+0255 / FMR 125	162128+0254	13.7, 16.7	134.0	34.0	2002.39	6	1,9
18270+0258 / LDS5864	182707+0258	14.6, 16	43.5	67.8	2003.42	6	1,10
22284+0305 / LDS4970	222820+0304	15.4, 16.1	244.9	26.1	2002.71	6	1,11
23258+0305 / LDS6032	232551+0304	16.98, 16.92	177.1	71.4	2002.86	6	1,12

Table 1 Notes:

1. All magnitudes in this table are extracted from the WDS Catalog.
2. Std Dev (PA)= 0.29; Std Dev (Sep)= 0.72
3. Std Dev (PA)= 0.14; Std Dev (Sep)= 0.22
4. Std Dev (PA)= 0.18; Std Dev (Sep)= 0.48
5. Std Dev (PA)= 0.22; Std Dev (Sep)= 0.16
6. Std Dev (PA)= 0.49; Std Dev (Sep)= 0.33
7. Std Dev (PA)= 0.66; Std Dev (Sep)= 0.49
8. Std Dev (PA)= 0.75; Std Dev (Sep)= 0.38
9. Std Dev (PA)= 0.25; Std Dev (Sep)= 0.70
10. Std Dev (PA)= 0.43; Std Dev (Sep)= 0.62
11. Std Dev (PA)= 0.41; Std Dev (Sep)= 0.13
12. Std Dev (PA)= 0.10; Std Dev (Sep)= 0.31

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Table 2. Trends of position angle and separation.

RA+Dec	Year 1	PA	Sep	Year 2	PA 2	Sep 2	Year 3	PA 3	Sep 3
044621+0329	1960	283	77	2000	281	72.5	2002[1]	281.29	72.12
051625+0321	1954	116	89.9	2002[1]	115.8	89.94	2010	115	89.7
052943+0337	1954	178	94.2	2002[1]	178.18	95.39	2010	178	94.3
080223+0320	1949	223	49	1960	223	49	2002[1]	223.08	49.33
112728+0440	1955	9	30.5	2002	13	31.3	2003[1]	10.04	31.49
134644+0254	1960	176	72	2000	177	71.9	2002[1]	177.71	71.42
152551+0339	1955	36	24.7	2002[1]	36.11	23.92	2010	36	24.9
162128+0254	1951	246	25.6	2000	245	26	2002[1]	244.91	26.11
182707+0258	1960	153	42	2000	156	43.1	2003[1]	157.64	42.43
222820+0304	1960	49	73	2000	43	66.2	2002[1]	43.5	67.8
232551+0304	1999	136	32.1	2000	136	32.1	2002[1]	134.03	33.99

1. Original observation from Table 1.

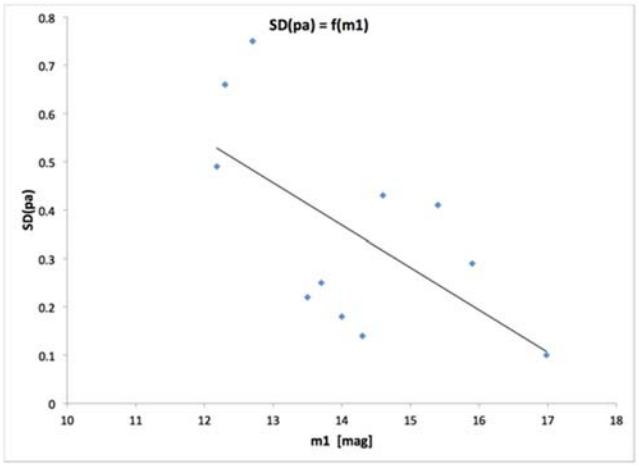

Figure 1. This is a plot of standard deviation about the mean position angle as a function of the brightness of the primary star. The straight line is a least squares linear regression fit.

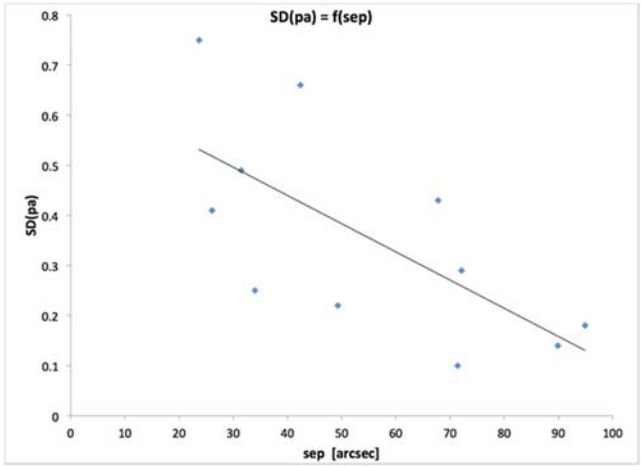

Figure 2. This is a plot of standard deviation about the mean position angle as a function of the separation of the components of the double stars. The straight line is a least squares linear regression fit.

Analysis

In order to gain empirical insight on the origins of the errors and position angles, we examined correlations of standard deviation versus observational parameters that include magnitude and separation. We display in Figure 1 a plot of standard deviation of position angle versus magnitude (of the primary star) along with a least squares regression line. Though there is considerable scatter present, there is nevertheless a trend of decreasing error with the fainter magnitude of the primary.

Likewise, we show in Figure 2 the correlation between standard deviation of position angle as a function of separation in the system. As in Figure 1, scatter is present, though as confirmed by the regression line there is a trend of decreasing standard deviation with increasing separation between the stars.

Similar analysis of the standard deviation about the mean separation does not show similar dependencies.

Conclusions

The primary goal of the project was fulfilled in that we measured all 11 double stars successfully, thus adding additional points to better define the orbits of these systems.

We found that the MOTESS images could be used within the defined constraints. The precision of the position angle measures was found to be a function of the brightness of the primary star and the separations. References to Figures 1 and 2 could provide a useful tool for future MOTESS image users.

Since the double stars were observed in the MOTESS images, the source for the MOTESS-GNAT variable star catalog, we are able to report that none of the components of our double star cohort were detected as a variable star.

Acknowledgements

The author would like to thank Mr. Roy Tucker for constructing the MOTESS system from which the images used in this study were obtained. We also acknowledge the software of Aladin viewer to help create the finding charts used to locate each double star. Finally, this research has made use of the VizieR catalogue access tool, CDS, Strasbourg, France.

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Matthew Giampapa is a senior at University High School located in Tucson, Arizona. He partnered with Dr. Eric R. Craine, President of STEM Laboratory, Inc. and CEO of the Global Network of Astronomical Telescopes, Inc.

A New Visual Double Star in Gemini

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Abstract: This paper highlights a new common proper motion double star in Gemini, currently not included in the WDS catalog. The components show virtually identical photometric and spectral properties and share similar proper motions, with a close separation of 10.53 arcseconds. This suggests the pairing is more likely to be binary rather than optical.

This new pair was identified while evaluating the double star pairs POU1030, KUI23 and BU1241 from the Washington Double Star Catalog [1] in the vicinity of the galactic open cluster M35 in Gemini (Figure 1).

The Pourteau double star POU1030 (WDS 06090+2416) was in particular analyzed to some level of detail, with no conclusive proof as to whether this pair is in fact a physical member of the open cluster or merely a foreground alignment with no true association to M35, which lies at a distance of around 3,000 ly.

Observations and Analysis

The new pair identified in this paper is situated 1° 22′ south of M35 in a rich starfield. An observation was made by the author using a 4.75-inch refractor, and a sketch of the field was produced at a magnification of x159 (Figure 2) utilizing a Super Plossl 6.3mm eyepiece.

The primary has the designation HD252129 and the companion BD+22° 1186p, and they have V magnitude 9.87 and 9.97, respectively. Differencing the coordinates between each star yielded the latest measurements for epoch 2000.0:

Position Angle (θ): 284.0° (2000.0)

Separation (ρ): 10.53" (2000.0)

These measurements were further confirmed and found to be in agreement with astrometry performed on high resolution J-band imagery taken from the 2MASS database for epoch 1997-11-15.

The PPMXL catalog [2] highlighted the components to be sharing common proper motions, as shown in Table 1.

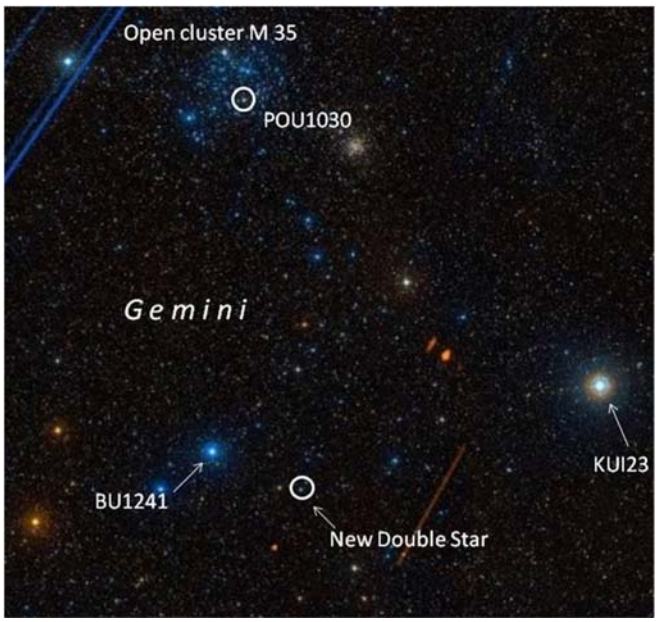

Figure 1: Three studied double stars in the neighborhood of M35 and the identified new pair.

These tiny annual proper motions suggest the pair is likely to reside at a great distance, and the two stars have shown no relative movement between the POSS1 and POSS2 surveys. By the Aitken criterion, the angular separation limit for this pair was computed to be 9.26" [3]. The observed angular separation of 10.53", however, falls marginally outside this limit by just 1″. The pair may nevertheless still be considered physical

A New Visual Double Star in Gemini

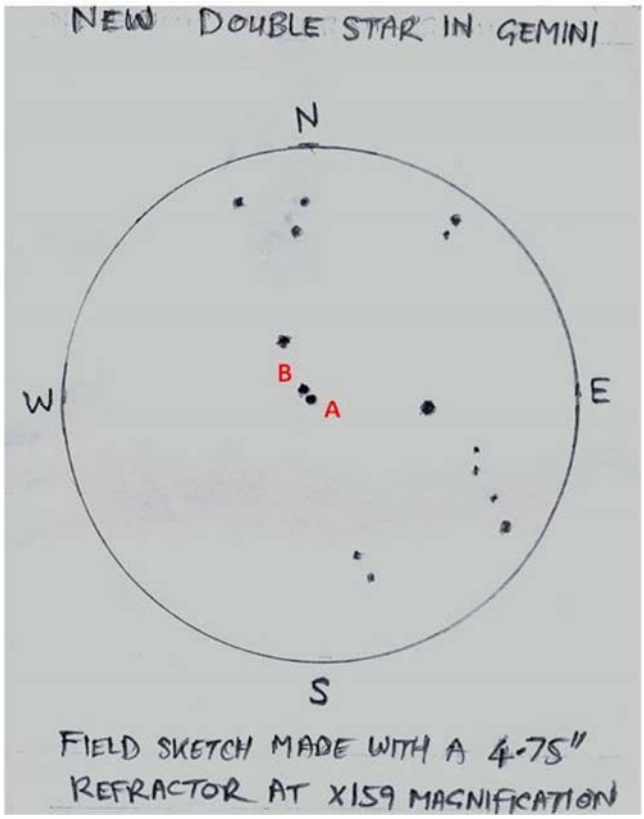

Figure 2. A sketch of the telescopic field surrounding the proposed new double star made by the author at 23:30 UT on October 28, 2013. The faintest stars are of magnitude 12.

on other analytical grounds. As highlighted in (Rica 2006), the Aitken criteria serves as a useful tool for making general deductions of binarity over a large sample of visual double star pairs, though it does not allow one to reach a satisfactory conclusion on every single double star system on an individual basis. The nearby binary system Groombridge 34 is a classic example of a pair in which the components are separated by twice the angular distance required to satisfy Aitken's criterion, yet rigorous observations accumulated over many decades of study have confirmed this to be a bona-fide binary system, with a consensus orbital period of some 2,600 years.

From the 2MASS Catalog [4], we provide the J- and K-band magnitudes for the component stars of this Gemini pair shown in Table 2.

These 2MASS (J – K) color indices would categorize the pair into two white stars of spectral class A7 [5]. They compare with the (J – K) color indices of other similar well-known stars as follows: the prominent summer star Altair (α Aquilae) and the third magnitude θ^2 Tauri (a member of the winter Hyades

Table 1: Proper Motion of the Components

	Proper Motion in RA	Proper Motion in Dec
A-component	-0.3 mas/year	-3.4 mas/year
B-component	-1.0 mas/year	-4.0 mas/year

Table 2: J and K magnitudes and Color Indices

	J-magnitude	K-magnitude	Color Index (J-K)
A-component	8.502	8.316	+0.186
B-component	8.616	8.423	+0.193

star cluster) are both stars of spectral class A7. Altair is a main sequence A7 V star whose (J – K) color index is known to be +0.21, whereas θ^2 Tauri is a giant A7 III star whose (J – K) color index is +0.11. Using these two stars as comparative 'candles,' we can infer that the stars in this Gemini pair are probably more likely to be A7-class main sequence stars, rather than A7-class giants.

Consequently, it seems reasonable to suppose they would be of absolute magnitudes in the region of +2, yielding a spectral distance of the pair of about 1300 ly (400 pc) from the Solar System.

It is also interesting to note that both Altair and θ^2 Tauri are Delta Scuti-type variables, with small amplitudes, and this type of brightness variation may well prove to be mirrored in either component of this Gemini double.

Conclusions

Given the fixed nature of this pair, with no appreciable movement between POSS 1 and POSS2 surveys, the similar proper motions, and the match of observed photometric characteristics to physical properties, it seems this pair is more likely to be binary rather than optical. The close angular separation, which virtually satisfies the Aitken criterion, also argues in favour of physically related components.

Acknowledgments

This research has made use of the SIMBAD database and VizieR databases operated at the Centre de Données Astronomiques, Strasbourg, France and the Washington Double Star Catalog maintained at the US Naval Observatory, Flagstaff, Arizona.

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Double Star Measurements at the Southern Sky with a 40 cm Cassegrain and a Fast CCD Camera in 2010

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Abstract: Using a 40 cm Cassegrain in Namibia, recordings of double stars were made with a fast CCD camera and a notebook computer. From superpositions of “lucky images,” measurements of 66 systems with 85 pairs were obtained and compared with literature data. Occasional deviations are discussed. Black-and-white and color images of some remarkable systems are also presented.

Introduction

As has already been demonstrated in earlier papers in this journal, the accuracy of double star measurements can significantly be improved by the technique of “lucky imaging.” Using short exposure times, only the best frames out of some thousands are registered and stacked. Thus, seeing effects are effectively reduced, and the resolution of a telescope can be pushed to its limits, even under non-optimum average seeing conditions. The accuracy of position measurements can even be better than this by about one order of magnitude. In this paper, measurements on double and multiple systems made in fall 2010 are reported. Star brightness is mostly greater than magnitude 8, and only a few dimmer companions go down to around magnitude 12. While in the majority of cases, literature data are scarce or exhibit large scatter, 8 pairs with sufficiently well documented separations could be used to verify the calibration. About 33 pairs are binaries with more or less well known orbits. In some cases, deviations from ephemeris data were found, and possible causes are discussed.

Instruments

The telescope is of Cassegrain type with aperture 40 cm and focal length of 6.3 m. It is located on a guest farm in Namibia and owned by the *Internationale Amateur-Sternwarte* (IAS) [1]. It is the same telescope which I have already used in 2008 and 2009, and results of measurements have been reported in this journal [2]. I only replaced the former DMK21AF04 camera by the type DMK31AF03 (*The Imaging Source*). While both use b/w-CCD´s, the main difference is the number and size of the pixels, 1024 x 768 of 4.65 µm square for type 31 instead of 640 x 480 of 5.6 µm for type 21, resulting in a correspondingly increased resolution of 0.155 arcsec/pix, or 0.0805 arcsec/pix with a nominally 2x Barlow lens. These values were both calculated from the scaling factors obtained in the previous work, and from the ratio of the pixel sizes, and were as well verified by calibration stars in this work (see below).

Position angles are measured as usual against trails in east-west direction, which are recorded while temporarily switching off the telescope drive.

Generally, I used a red or near infrared filter to reduce seeing effects and the atmospheric spectrum, and especially when using the Barlow lens, to reduce chromatic aberration. A few systems with color contrast were in addition recorded with green and blue filters in order to produce RGB composite images. Exposure times varied between 0.5 msec and 100 msec, depending on the star brightness. Under good seeing conditions, some systems were also recorded with exposures up to 0.5 sec, in order to image faint companions. The yield of “lucky” frames ranged from only a few percent to more than ten, depending on the seeing. The best

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frames were selected, re-sampled, registered, and stacked, mostly with automatic programs, in critical cases also manually. This process resulted in smooth intensity profiles and in position measurements with sub-pixel accuracy. More details of the technique and image processing are, for example, described in reference [3].

Results

All measurements are listed in Table 1, which is followed by individual notes. Numbering of the notes (last column at right) is with rounded R.A. values, which may make locating in the listings easier. Names, position, and magnitude data are taken from the *WDS* [4]. Several systems were recorded repeatedly, with or without Barlow, or with different filters. Measures of the position angle, P.A., and of the separation, ρ, were then averaged. N is the total number of recordings. Shaded lines denote systems which were used for calibration of the image scale (see below). The residuals, Δ P.A. and Δρ, refer to the trends of literature data, if sufficiently available, or for binaries, to the currently assumed ephemeris. Main sources are the *Fourth Catalog of Interferometric Measurements of Binary Stars ("speckle catalog")* [5], and the *Sixth Catalog of Orbits of Visual Binary Stars* [6]. Data available up to fall 2013 are taken into account, as of writing this article. In several cases, larger deviations were found, which often agree with trends of literature data, however. These will be discussed in more detail below. In other cases, literature data are so scarce and/or exhibit so large scatter that no reasonable residuals can be given.

Discussion

In Table 1, systems used for calibration of the image scale are marked with shaded lines, and comprise both measurements with and without Barlow. In Figures 1 and 2, individual residuals are plotted separately, partly to demonstrate that the calibration constants for both modes, as given above in the section *Instruments*, are consistent. In fact, the ratios of both constants referred to those obtained earlier with the DMK21 camera (0.830) correspond virtually exactly to the ratio of the nominal pixel sizes of both cameras (0.8304). The ratio of the constants with and without the nominally 2x Barlow is 1.925.

Generally, and according to earlier work, error margins for separation measurements are expected to be of the order of ±0.02 arcsec, and not to exceed ±0.05 arcsec, at least in the range of small separations. As can be seen in Figure 1, several pairs are clearly off, and interestingly, these are mostly binaries. It seems that one reason is that the residuals are calculated with respect to the current ephemeris, which may not be up to date. In fact, in many cases, residuals against the trend of recent measurements are found to be smaller.

The error margins of measurements of the position angle are expected to be of the order of about ±0.2 degrees for large separations, but to increase toward small separations, and can reach several degrees for very close pairs. The reason is the fixed resolution in the images. In fact, this is apparent in the plots in Figure 2. However, a number of pairs seem to stand out more

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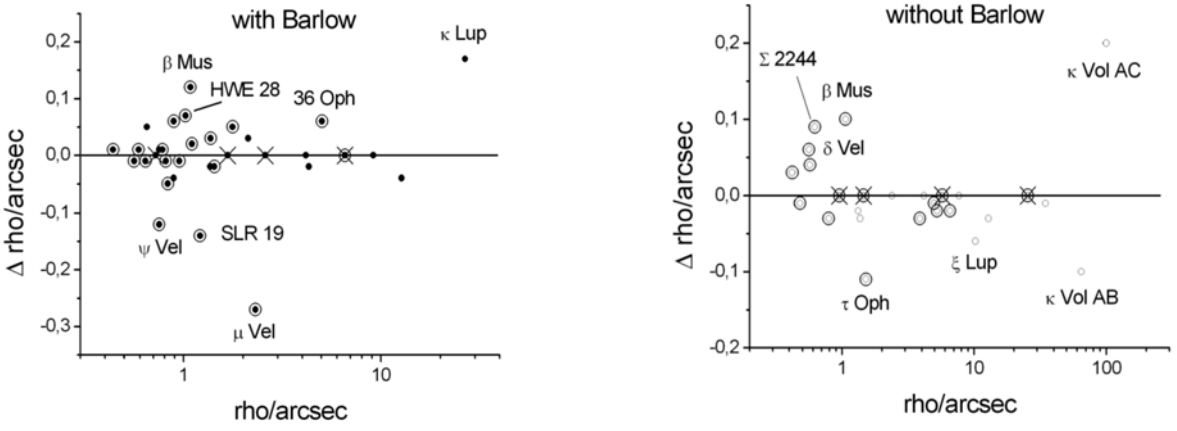

Figure 1: Plots of the residuals of rho versus rho. Semi-logarithmic scale. With Barlow (Left) and without. Symbols with crosses denote systems used for calibration. Additional circles indicate binaries. Some systems with large deviations are marked with their names. See text.

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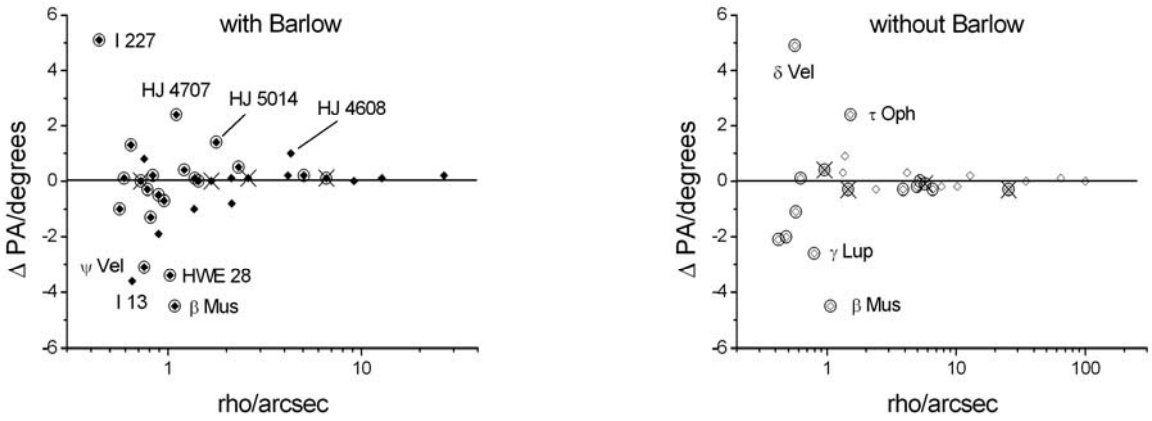

Figure 2: Plots of the residuals of the position angle versus rho. Semi-logarithmic scale. Left with Barlow, right without. The increase of scatter toward small separations is caused by scatter of literature data, as well as by the fixed image resolution. Calibration pairs are marked as in Figure 1. (They are not used for calibration of the position angle.)

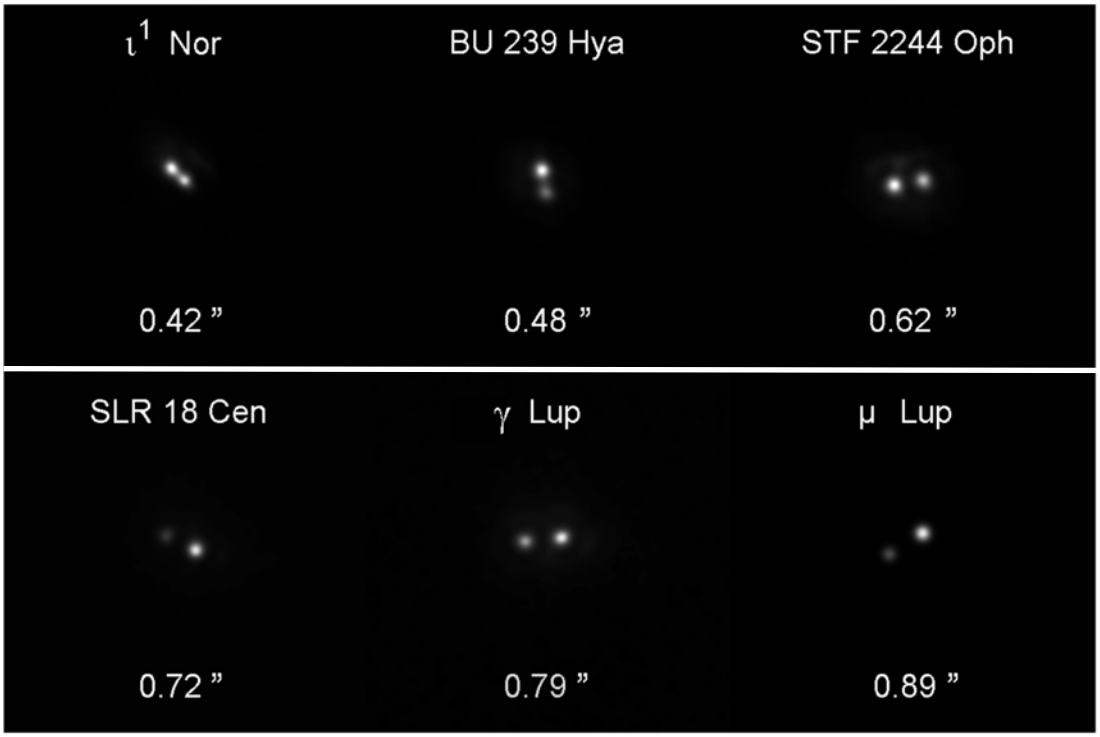

Figure 3: Some close doubles. Iota Normae is a binary with a rather short period of only 26.9 years. For BU 239 in Hydrus, less than a quarter of its assumed orbit is documented. The case of STF 2244 in Ophiuchus is further illustrated in Figure 4. Pairs SLR 18 in Centaurus and μ Lupi possibly are binaries, while γ Lupi is a binary with a period of 190 years

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Table 1: List of all measurements. Systems used for calibration of the image scale are marked by shaded lines. Position angles (P.A.) are in degrees, separations (rho) in arcseconds. N is the number of different recordings. Residuals delta P.A. and/or delta rho are given, when extrapolations of literature data appear reasonable. Data written in italics were obtained from recordings with Barlow, normal letters indicate no Barlow.

PAIR	RA + DEC	MAGS	P.A. meas.	rho meas.	DATE	N	delta P.A.	delta rho	NOTES
RMK 6	07 20.4 -52 19	6.00 6.51	*26.0*	*9.15*	*2010.297*	1	*~0*	*~0*	07 20
RMK 7	08 07.9 -68 37	4.38 7.31	23.1	6.03	2010.275	1	-1.0	-0.02	08 08
RMK 8	08 15.3 -62 55	5.27 7.62	69.1	4.05	2010.275	1	*	*	08 15
BSO 17AB	08 19.8 -71 31	5.31 5.59	58.1	64.66	2010.275	1	+0.1	-0.1	08 20
BSO 17AC		5.31 7.67	48.0	99.42		1	~0	+0.2	
BSO 17BC		5.59 7.67	30.4	37.51		1	-1.6	+0.8	
RMK 9AB	08 45.1 -58 43	6.87 6.93	292.3	4.15	2010.275	1	+0.3	~0	08 45
RMK 9AC		6.87 11.0	359.7	51.74		1	*	*	
RMK 9AD		6.87 10.8	222.7	60.50		1	*	*	
I 11	09 15.2 -45 33	6.56 7.65	*293.2*	*0.75*	*2010.295*	1	*+0.8*	*+0.01*	09 15
COP 1	09 30.7 -40 28	3.91 5.12	*99.5*	*0.75*	*2010.284*	1	*-3.1*	*-0.12*	09 31
SEE 115	09 37.2 -53 40	6.12 6.28	*8.8*	*0.69*	*2010.295*	1	*	*	09 37
RMK 11	09 47.1 -65 04	3.02 6.00	126.1	4.98	2010.275	1	*	*	09 47
I 173	10 06.2 -47 22	5.32 7.10	*6.4*	*0.95*	*2010.295*	1	*-0.7*	*-0.01*	10 06
I 13AB	10 09.5 -68 41	6.63 6.47	*103.7*	*0.65*	*2010.278*	1	*	*	10 10
HJ 4306	10 19.1 -64 41	6.26 6.48	*313.1*	*2.59*	*2010.278*	1	*+0.1*	*~0*	10 19
R 155	10 46.8 -49 25	2.82 5.65	*56.2*	*2.31*	*2010.295*	1	*+0.5*	*-0.27*	10 47
SEE 143	12 03.6 -39 01	7.05 7.65	35.0	0.57	2010.300	1	-1.1	+0.04	12 04
DUN 252AB	12 26.6 -63 06	1.25 1.55	111.9	3.92	2010.276	4	-0.1	+0.02	12 27
DUN 252AC	12 26.6 -63 06	1.25 4.80	203.7	89.9	2010.269	2	+0.3	*	12 27
ANT 1G	12 26.6 -63 06	1.25 12?	145.3	56.7	2010.269	2	*	*	12 27
ANT 1H	12 26.6 -63 06	1.25 13?	166.2	48.2	2010.269	1	*	*	12 27
ANT 1I	12 26.6 -63 06	1.25 12?	226.7	63.7	2010.269	1	*	*	12 27
Ax	12 26.6 -63 06	1.25 12?	343.6	29.6	2010.269	1	*	*	12 27
Ay	12 26.6 -63 06	1.25 13?	217.8	125.2	2010.269	1	*	*	12 27
DUN 124AB	12 26.6 -63 06	1.83 6.45	25.5	128.9	2010.269	1	*	*	12 27
DUN 124AC	12 26.6 -63 06	1.83 9.7	70.0	165.7	2010.269	1	*	*	12 27
STF1669AB	12 41.3 -13 01	5.88 5.89	312.8	5.22	2010.286	1	~0	-0.02	12 41
STF1670AB	12 41.7 -01 27	3.48 3.57	21.8	1.45	2010.295	2	-0.3	~0	12 42
R 207	12 46.3 -68 06	3 .52 3.98	48.3	1.07	2010.286	5	-4.5	+0.11	12 46
I 362AB	12 47.7 -59 41	1.28 11.4	326.2	42.62	2010.270	1	*	*	12 48
I 362AX	12 47.7 -59 41	1.28 ~11?	139.9	10.38	2010.270	1	*	*	12 48
I 362AY	12 47.7 -59 41	1.28 >11	213.1	29.58	2010.270	1	*	*	12 48
DUN 126AB	12 54.6 -57 11	3.94 4.95	17.2	34.70	2010.289	1	~0	-0.01	12 55

Table 1 continues on next page.

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Table 1 (continued): List of all measurements. Systems used for calibration of the image scale are marked by shaded lines. Position angles (P.A.) are in degrees, separations (rho) in arcseconds. N is the number of different recordings. Residuals delta P.A. and/or delta rho are given, when extrapolations of literature data appear reasonable. Data written in italics were obtained from recordings with Barlow, normal letters indicate no Barlow.

PAIR	RA + DEC	MAGS	P.A. meas.	rho meas.	DATE	N	delta P.A.	delta rho	NOTES
I 83	12 56.7 -47 41	7.39 7.68	*233.5*	*0.83*	*2010.273*	*1*	*+0.2*	*-0.05*	12 57
R 213	13 07.4 -59 52	6.59 7.04	*21.1*	*0.69*	*2010.273*	1	*	*	13 07
SLR 18	13 22.9 -47 45	6.73 7.18	*242.9*	*0.72*	*2010.273*	1	*~0*	*~0*	13 23
DUN 141		5.20 6.53	*162.9*	*5.64*		4	*+0.1*	*+0.06*	
HJ 4608	13 41.7 -54 34	7.42 7.47	*188.9*	*4.31*	*2010.273*	1	*+1.0*	*-0.02*	13 41
HWE 95		7.51 7.85	*184.8*	*0.95*		1	*	*	
HWE 28AB		6.27 6.38	*312.7*	*1.02*		1	*-3.4*	*+0.07*	
SLR 19	13 53.5 -35 40	7.14 7.38	*322.8*	*1.21*	*2010.273*	1	*+0.4*	*-0.14*	13 53
HWE 75AB		7.96 8.60	*214.5*	*4.16*		1	*+0.2*	*~0*	
RHD 1AB	14 39.6 -60 50	0.14 1.24	246.6	6.58	2010.279	3	-0.1	~0	14 40
HJ 4707	14 54.2 -66 25	7.53 8.09	*275.8*	*1.10*	*2010.295*	1	*+2.4*	*+0.02*	14 54
I 227AB	14 56.5 -34 38	8.06 8.39	*105.7*	*0.44*	*2010.285*	2	*+5.1*	*+0.01*	14 56
HJ 4715	14 56.5 -47 53	5.98 6.82	*277.9*	*2.12*	*2010.275*	1	*+0.1*	*+0.03*	14 57
H N 28AB	14 57.5 -21 25	5.88 8.18	306.2	25.43	2010.292	1	-0.3	~0	14 58
BU 239AB	14 58.7 -27 39	6.17 6.79	7.9	0.48	2010.292	2	-2.0	~0	14 59
HJ 4728AB	15 05.1 -47 03	4.56 4.60	*65.0*	*1.67*	*2010.273*	1	*~0*	*~0*	15 05
DUN 177	15 11.9 -48 44	3.83 5.52	*142.9*	*26.68*	*2010.275*	1	*	*	15 12
STF3091AB	15 16.0 -04 54	7.74 8.48	*224.9*	*0.56*	*2010.296*	1	*-1.0*	*-0.01*	15 16
HJ 4753AB	15 18.5 -47 53	4.99 4.93	*302.4*	*0.89*	2010.275	1	*-1.9*	*-0.04*	15 19
DUN 180AC	15 18.5 -47 53	4.99 6.34	*129.1*	*23.18*	*2010.275*	1	*	*	15 19
DUN 180BC	15 18.5 -47 53	4.93 6.34	*128.9*	*24.07*	*2010.275*	1	*	*	15 19
HJ 4786	15 35.1 -41 10	2.95 4.45	274.8	0.79	2010.278	3	-2.2	-0.03	15 35
HJ 4788	15 35.1 -41 10	4.68 6.51	*10.3*	*2.13*	2010.278	1	*-0.8*	*+0.08*	15 35
PZ 4	15 35.1 -41 10	5.09 5.56	49.1	10.18	2010.278	1	*	*	15 35
RMK 21AB	16 00.1 -38 24	3.37 7.50	19.0	15.14	2010.275	1	*	*	16 00
SEE 258AB	16 00.1 -38 24	5.20 5.76	227.9	0.42	2010.275	2	-2.1	+0.03	16 00
HJ 4825AB-C	16 00.1 -38 24	4.64 8.02	242.6	11.07	2010.275	2	+1.6	-0.13	16 00
STF1998AB	16 04.4 -11 22	5.16 4.87	355.8	0.95	2010.277	2	+0.4	~0	16 04
STF1998AC	16 04.4 -11 22	5.16 7.30	42.2	7.92	2010.277	2	*	*	16 04
STF1998BC	16 04.4 -11 22	4.87 7.30	46.8	7.30	2010.277	2	*	*	16 04
BSO 11	16 09.5 -32 39	6.70 7.23	84.0	7.65	2010.300	1	-0.2	~0	16 10
BU 120AB	16 12.0 -19 28	4.35 5.31	1.5	1.32	2010.299	2	-0.9	-0.02	16 12
H 5 6AC	16 12.0 -19 28	4.35 6.60	335.9	41.56	2010.299	2	*	*	16 12
MTL 2CD	16 12.0 -19 28	6.60 7.23	56.4	2.36	2010.299	2	+0.8	+0.01	16 12

Table 1 concludes on next page.

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Table 1 (conclusion): List of all measurements. Systems used for calibration of the image scale are marked by shaded lines. Position angles (P.A.) are in degrees, separations (rho) in arcseconds. N is the number of different recordings. Residuals delta P.A. and/or delta rho are given, when extrapolations of literature data appear reasonable. Data written in italics were obtained from recordings with Barlow, normal letters indicate no Barlow.

PAIR	RA + DEC	MAGS	P.A. meas.	rho meas.	DATE	N	delta P.A.	delta rho	NOTES
SH 224Aa-B	16 21.2 -25 36	2.89 8.42	273.0	19.97	2010.297	1	*	*	16 21
STF2055AB	16 30.9 +01 59	4.15 5.15	*37.2*	*1.43*	*2010.296*	1	*~0*	*-0.02*	16 31
BU 1118AB	17 10.4 -15 44	3.05 3.27	*235.2*	*0.59*	*2010.279*	1	*+0.1*	*+0.01*	17 10
SHJ 243AB		5.12 5.12	142.6	5.00		2	~0	+0.03	
H 3 25	17 15.3 -26 36	5.23 6.64	354.1	9.98	2010.277	1	*	*	17 15
MLO 4AB		6.37 7.38	*185.4*	*1.33*		1	*-0.9*	*-0.05*	
STF2173		6.06 6.17	*154.9*	*0.78*		1	*-0.3*	*+0.01*	
STF2244	17 30.4 -01 04	6.89 6.56	280.2	0.62	*2010.279*	1	+0.1	+0.09	17 30
STF2262AB		5.27 5.86	287.3	1.51		1	+2.4	-0.11	
STF2272AB	18 05.5 +02 30	4.22 6.17	131.0	5.73	2010.274	1	-0.1	~0	18 05
HJ 5014	18 06.8 -43 25	5.65 5.68	*3.6*	*1.77*	*2010.275*	1	*+1.4*	*+0.05*	18 07
STF2281AB	18 09.6 +04 00	5.97 7.52	*287.9*	*0.64*	*2010.296*	1	*+1.1*	*-0.01*	18 10
BU 132AB	18 11.2 -19 51	7.01 7.13	188.9	1.37	2010.293	1	+0.9	-0.03	18 11
BU 760AB	18 17.6 -36 46	3.30 8.0	99.9	3.55	2010.297	1	*	*	18 18
BU 760AD	18 17.6 -36 46	3.30 10.0	318.2	93.8	2010.297	1	*	*	18 18
AC 11	18 25.0 -01 35	6.71 7.21	*354.2*	*0.89*	*2010.296*	1	*-0.5*	*+0.06*	18 25
DUN 222	18 33.4 -38 44	5.58 6.16	358.4	21.19	2010.278	1	~0	-0.15	18 33
BSO 14	19 01.1 -37 04	6.33 6.58	280.6	12.77	*2010.279*	2	+0.2	-0.03	19 01
HJ 5084	19 06.4 -37 04	4.53 6.42	*11.1*	*1.37*	*2010.277*	2	*+0.1*	*+0.03*	19 06

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

07 20: also known as DUN 44, in Carina, few data, position about constant in recent decades.
08 08: ε Volantis, relfix, cpm, few data.
08 15: also known as c Carinae, relfix, cpm, few data, PA & rho seem to slowly increase.
08 20: $\kappa^{1,2}$ Volantis, wide triple, few data with large scatter.
08 45: in Carina, relfix, few data.
09 15: in Vela, PA increasing, rho decreasing.
09 31: ψ Velorum, binary, P = 34 y, the complete orbit is covered by visual measurements, but there are much less speckle data. Own measures deviate from ephemeris, but seem to be in line with recent speckle data. Rho is currently rapidly increasing.
09 37: in Vela, PA & rho increasing.
09 47: υ Carinae, relfix, cpm, few data, large scatter.
10 06: in Vela, binary, P = 232 y, own measures are close to recent speckle data, as well as to the revised ephemeris (Scardia 2008e).
10 10: in Carina, PA & rho decreasing, few data.
10 19: in Carina, “relfix”, PA decreasing, rho increasing, few data.
10 47: μ Velorum, binary, P = 138 y, few data, own measure of rho as well as recent speckle data significantly deviate from ephemeris.
12 04: also known as 89 Centauri, binary, P = 109 y, own measure of rho slightly deviates from orbit, in line with recent speckle measurements.
12 27: α Crucis, AB binary, no orbit determined, few data, even fewer for AC. Dim components G, H, and I have been observed already in 2007. Positions virtually did not change since then. Two other dim stars in the field are not listed in WDS. See fig. 6.
12 31: γ Crucis, optical triangle, few data. A fourth dim star is not listed in the WDS. See fig. 6.
12 41: in Corvus, binary, P = 4500 y estimated, rho data exhibit large scatter.

12 42: γ Virginis, binary, P =169 y, well documented.
12 46: β Muscae, binary, P = 383 y, while own measures of both PA and rho deviate from the recently re-calculated ephemeris, the position is close to the corresponding orbit.
12 48: β Crucis, optical?, few data. Dim companions X and Y are not listed in WDS. See fig. 6.
12 55: μ Crucis, relfix.
12 57: in Centaurus, binary, P = 294 y, position slightly deviates from ephemeris, but seems to better fit recent speckle data.
13 07: in Centaurus, relfix, PA decreasing, own measure seems to follow the long time trend, despite large scatter of recent speckle data, rho decreasing since about 1950.
13 23: in Centaurus, PA and rho increasing, reasonable extrapolation. See fig. 3.
13 41: in Centaurus, relfix, few data.
13 42: in Centaurus, few data, PA slowly increasing, rho data exhibit considerable scatter.
13 44: in Centaurus, few data, PA and rho decreasing.
13 53: in Centaurus, binary, P = 258 y, measured position deviates from ephemeris, but is in line with recent speckle data.
14 08: in Centaurus, binary, P = 233 y, measured position deviates from ephemeris, but seems to follow the trend of recent speckle data.
14 37: in Centaurus, relfix, few data.
14 40: α Centauri, AB binary, P = 79.9 y, well documented.
14 54: in Circinus, binary, P = 288 y, few data since 2000.
14 56: in Centaurus, binary, P = 40 y, few data, large residuals vs. ephemeris, own measures close to trend of literature data.
14 57: also known as DUN 174, in Lupus, although denoted as relfix by Burnham, rho has decreased since 1826, while the PA stays about constant in the last hundred years.
14 58: also known as 33 Librae, AB binary, P = 2130 y (?), only small portion of orbit documented.
14 59: also known as 59 Hydrae, binary, P = 429 y. See fig. 3.
15 05: π Lupi, PA decreasing, reasonable extrapolation.
15 12: κ Lupi, relfix, cpm, few data with large scatter. Extrapolation ambiguous.
15 16: in Libra, binary, P = 156 y.
15 19: μ Lupi, triple, all cpm, AB: PA & rho decreasing, AC: few data. See fig. 3.
15 35: γ Lupi, binary, P = 190 y, orbit highly inclined. See fig. 3.
15 36: also known as d Lupi, few data, PA & rho decreasing.
15 57: ξ Lupi, relfix, although a wide and easy pair, large scatter of literature data.
16 00: η Lupi, relfix, cpm, few data, large scatter.
16 03: ι^1 Normae, triple, all cpm, AB binary, P = 26.9 y, few data. See fig. 3.
16 04: ξ Scorpii, triple, AB: binary, P = 45.8 y, many speckle data. AC: few data, large scatter, own measures significantly deviate from ephemeris, but are close to recent speckle data.
16 10: also known as L 6706, in Scorpius, cpm, few data.
16 12: ν Scorpii, “double-double”, rho(AB) slowly increasing, PA(CD) slowly increasing, few data for AC.
16 21: σ Scorpii, Aa not resolved.
16 31: λ Ophiuchi, binary, P = 130 y.
17 10: η Ophiuchi, binary, P = 88 y, many speckle data with mostly small scatter.
17 15: also known as 36 Ophiuchi, binary, P = 550 y (?),”premature orbit”, although an easy pair, large scatter of recent data in the literature.
17 18: ο (39) Ophiuchi, relfix, cpm, few data.
17 19: in Scorpius, binary, P = 42.1 y.
17 30: in Ophiuchus, binary, P = 46.4 y, highly inclined orbit.
17 57: in Ophiuchus, binary, P = 280 y, highly inclined orbit, recent rho data (speckle as well as own) extend way off the ephemeris, while PA measures are close. See fig. 3.
18 03: τ (69) Ophiuchi, binary, P = 280 y, many speckle data, PA data exhibit peculiar variations at around 1997, 2003, and 2010. Own measures deviate from ephemeris, but seem to follow literature data.
18 05: also known as 70 Ophiuchi, binary, P = 88.3 y, many speckle data with only little scatter.
18 07: in Corona Australis, binary, P = 191 y, own measures deviate from ephemeris, but are close to results obtained in 2009, and all seem to follow the trend of speckle data.
18 10: also known as 73 Ophiuchi, binary, P = 286 y, many speckle data with small scatter.
18 11: in Sagittarius, PA decreasing, rho increasing.
18 18: η Sagittarii, triple, few data.
18 25: in Serpens Cauda, binary, P = 240 y, highly inclined orbit, own measure of rho significantly deviates from ephemeris, but fits well to recent speckle data.
18 33: κ Coronae Australis, relfix, few data.
19 01: in Corona Australis, relfix, cpm.
19 06: γ Coronae Australis, binary, P = 122 y.

Double Star Measurements at the Southern Sky with a 40 cm Cassegrain and a Fast CCD Camera in 2010

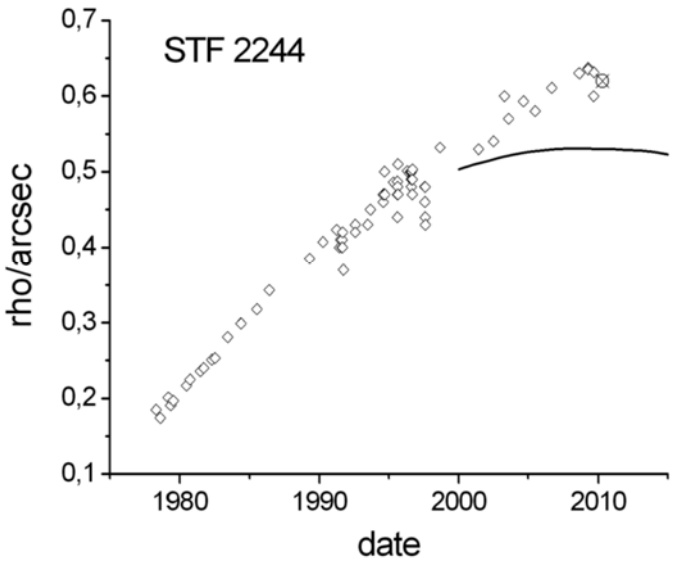

Figure. 4: Separation vs. time for STF 2244 in Ophiuchus. Open rhombi are speckle data [5], the crossed circle own measurement, and the curve represents part of the ephemeris [6]. See text.

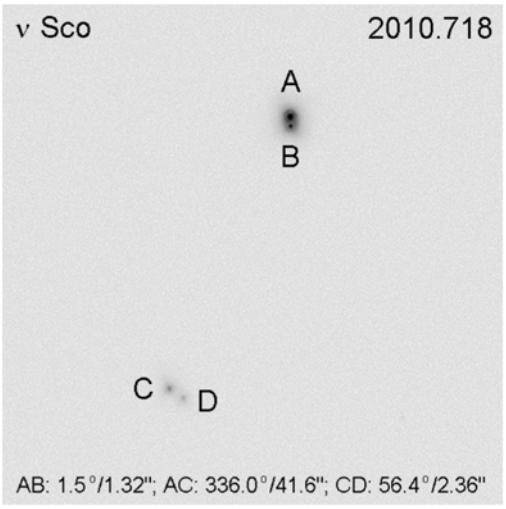

Figure 5: The "double-double" ν Scorpii. In contrast to famous ε Lyrae, orbital motion has not yet been confirmed for neither AB nor CD.

(Continued from page 126)

than this, and again, most are binaries.

Possible origins of deviations of PA and rho are already mentioned in the notes list. In particular, the following binaries deserve further attention in the (near and far) future (in order of increasing R.A.):

- psi Velorum,
- I 13 AB in Carina,
- mu Velorum,
- beta Muscae,
- I 83 in Centaurus,
- SLR 19 in Centaurus,
- I 227 in Centaurus,
- xi Scorpii AC (triple),
- STF 2244 in Ophiuchus (see also figs. 3 and 4),
- tau (69) Ophiuchi,
- HJ 5014 in Corona Australis,
- AC 11 in Serpens Cauda.

Some images of double and multiple systems are presented in the following figures. Figure 3 is a selection of close binaries with sub-arcsec separations. For one of these, STF 2244, recent separation measurements are plotted in Figure 4 and compared with the currently assumed ephemeris. While my own measure follows the trend of speckle data, the deviation from the ephemeris clearly exceeds the error margins. Figures 5 and 6 illustrate interesting multiple systems, in particular with large differences in brightness (Fig. 6). In all images, north is down, and east is right.

Conclusion

For many of the doubles investigated here there are only few data found in the literature, and often with large scatter, although most systems are fairly bright, and easily accessible. The accuracy of my own measurements is checked by comparing with mainly speckle data of systems, which have often been sufficiently observed. Generally, the scatter is of comparable magnitude. Similar to earlier work, this measuring campaign revealed several double star systems, which should more often be measured.

References

[1] Internationale Amateur-Sternwarte, http://www.ias-observatory.org

[2] Anton, R., *Journal of Double Star Observations,* **6** 2, 133-140, 2010.

[3] Anton, R., "Lucky Imaging" in *Observing and Measuring Visual Double Stars, 2nd Ed.*, Robert Argyle, ed., Springer, New York, 2012.

Double Star Measurements at the Southern Sky with a 40 cm Cassegrain and a Fast CCD Camera in 2010

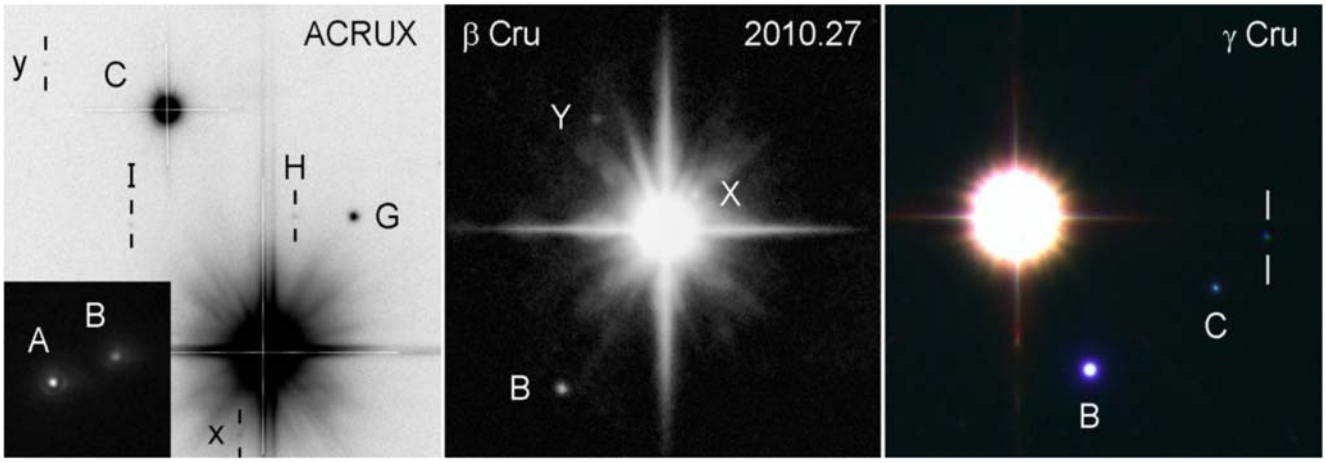

Figure 6: The three brightest stars in Crux. Left: alpha Crucis. The inset shows the pair AB recorded at higher magnification and with shorter exposure time. It is deemed as binary, but no valid orbit is listed in the catalogue. Two very weak stars (x and y) are not listed in the WDS. X was not seen in a similar image taken in 2007, while y was not in the field.

Middle: The pair beta Crucis AB probably is optical. The dim companions X and Y are not listed in the WDS.

Right: RGB composite of gamma Crucis, recorded with an 80/800 mm refractor, which is attached to the main scope, and normally used as a guidescope. In this wide field view, the main star of spectral class M3.5III forms an optical triangle with B and C. The dim star marked with white lines is not listed in the WDS.

[4] Mason, B.D. et al., *The Washington Double Star Catalog (WDS)*, U.S. Naval Observatory, online access Oct. 2013.

[5] Hartkopf, W.I. et al., *Fourth Catalog of Interferometric Measurements of Binary Stars,* U.S. Naval Observatory, online access Oct. 2013.

[6] Hartkopf, W.I. et al., *Sixth Catalog of Orbits of Visual Binary Stars,* U.S. Naval Observatory, online access Oct. 2013.

[7] *Burnham´s Celestial Handbook,* R. Burnham, Jr., Dover Publications, New York 1978.

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A New Common Proper Motion Pair in Crater

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Abstract: Presented in this paper is the discovery and observation of a new double star pair in Crater, currently not included in the WDS catalog. The components have a mean PM of 62.2 ± 3.0 mas yr^{-1} and exhibit particular kinds of photometric and astrophysical properties which suggest they might be physically associated.

This new pair is located 2°.6 north of the fifth-magnitude orange star ε Crateris and is within a couple of degrees of the well-known double stars Burnham 600 (WDS 11170 – 0708) and Struve 1530 (WDS 11197 – 0654) in the same region of sky (Figure 1).

Positional and Photometric Analysis

The primary has the designation BD-06° 3368, is located at ICRS: 11 22 45.024 -07 26 21.19, and is of V mag 9.6. The companion appears at least one magnitude dimmer, at V mag ~10.6. Measurements on high resolution J-band imagery taken from 2MASS yielded

Figure 1: Location of the identified new pair in Crater [Image credit: Stellarium]

A New Common Proper Motion Pair in Crater

Table 1: Proper Motion of the Components

	μ_α (mas yr^{-1})	Error (mas yr^{-1})	μ_δ (mas yr^{-1})	Error (mas yr^{-1})
Primary	+15.7	± 3.3	-57.5	± 3.0
Companion	+21.2	± 3.3	-61.3	± 3.0

Table 2: J and K magnitudes and color indices

	J-mag	K-mag	Color Index (J-K)
Primary	9.523	9.111	+0.412
Companion	10.582	10.041	+0.541

Position Angle (θ) = 38°.6 (ep 1997.0465) and Separation (ρ) = 11″.83 (ep 1997.0465).

The PPMXL Catalog [1] revealed the components to be sharing common proper motions, as shown in Table 1.

As highlighted in an earlier paper [2], there exists a broad inverse correlation between distance and proper motion which may be taken as a preliminary pointer for gauging the likely order of distance at which a proven (or probable) binary system might reside. Based upon that scale, a total PM of this pair of 62.2 ± 3.0 mas yr^{-1} suggests the pair ar located at a distance of about 100 to 200 ly (30 to 60 pc) from the Earth.

Near-infrared J and K-band photometry, taken from 2MASS [3], are shown in Table 2.

These 2MASS (J – K) color indices would tentatively categorize the components as two orange stars of spectral classes in the region of ~K2 and ~K8, respectively [4]. Interstellar reddening in the J and K magnitudes would perhaps be negligible for this particular pair, as they are positioned at a high galactic latitude of +49° on the celestial sphere and are not too far away in distance for interstellar absorption of their light rays to become significant.

Considering their observed visual brightnesses and a projected distance in the region of somewhere around 100 to 200 ly away (based on PMs), the components are both likely to be main-sequence dwarves of spectral types in the region of ~K2V and ~K8V, respectively. On these assumptions, the primary is likely to be of absolute magnitude around +7 and applying the distance mod formula to its apparent mag of +9.6 yields a more refined spectral distance of just 108 ly (33 pc) for the pair. Supposing that this system is in fact located at this precise distance of 108 ly away, the components would have a physical separation of 392 AU, which would certainly be close enough for them to gravitationally hold together as a binary pair.

Conclusions

From the observations, the astrometry and astrophysical analysis of this pair presented in this paper, it seems that this is a good candidate for being a prospective binary star.

Acknowledgments

This research has made use of the SIMBAD and VizieR databases operated at the Centre de Données Astronomiques, Strasbourg, France and the Washington Double Star Catalog maintained at the United States Naval Observatory.

References

[1] PPMXL Catalog, Roeser, et al., 2010.

[2] Ahad, A., *Webb Society Double Star Section Circular*, **19**, 48, 2011.

[3] *The Two Micron All-Sky Catalog of Point Sources*, Cutri, et al., 2003.

[4] Ahad, A., "A New Common Proper Motion Double Star in Cetus", *JDSO*, **8**, 332-334, 2012.

LSO Double Star Measures for the Year 2012

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Abstract: Reported here are the position angle and separation of 39 pairs in 30 systems. Eleven pairs are difficult large Δm objects requiring a special coronagraphic technique and (in the case of Sirius AB) a shaped pupil mask was employed in combination with the stellar coronograph. This set-up may be of interest and is further discussed.

The Measures

This year's measurements were mostly routine with only the unusually bad weather preventing a larger output. Thus only one note is included which describes the technique used in the imaging of AGC 1AB. Each of the 39 results listed is the average of 12 or more adequately sharp CCD frames. The CCD is an SBIG ST-7 non anti-blooming camera located at the Barlow amplified focus of a 9-inch Schupmann medial telescope. The effective focal length is 278.82 inches for the measure of normal pairs and 166.48 inches in the coronograph mode (Daley 2007) used to measure large Δm doubles.

The results are listed in order of the discoverer designation, their WDS positions (in order of right ascension), WDS magnitudes sometimes rounded off, the position angle in degrees, the separation in seconds of arc, the decimal date (average date in the case of more than one night), N, or the number of nights observed, and finally brief notes.

A Note Describing the Imaging of AGC 1AB

Recent interest in optimizing telescopes for the detection of exoplanets has led to cleverly designed aperture or pupil masks. With perfect optics and no atmosphere, these "shaped pupil" masks mathematically predict high contrast, typically reaching values of 10^{-10} over relatively narrow position angles. These dark sectors are freed of the diffracted light of a circular aperture by redirecting it over a broad region away from the "discovery zones." Unlike a square pupil mask, where four relatively wide low background regions are observed, the newer masks provide only two dark regions or sectors. The dark zones typically form a sector angle of about 20° close to the primary, thus to survey the close-in region around a star one must take ≈9 images, rotating the mask between each exposure. A newer class of rotational symmetric masks (Vanderbei, Spergel & Kasdin 2003) provides full coverage surrounding a star, but has much poorer throughput (≈9%) and also presents insurmountable construction difficulties for the amateur astronomer wishing to explore its possibilities.

Clearly, a mask designed for exoplanet discovery and imaging should also be useful when working on high Δm double stars such as AGC 1AB. The mask I chose was pioneered by Princeton University scientists David Spergel and Jeremy Kasdin. This mask (Figure 1) and other more complex variations were described by Spergel and Kasdin in a technical talk given some years ago to the Amateur Astronomers Inc (AAI) of New Jersey. Scale drawings of the various mask designs were sent to me by AAI member Clif Ashcraft, who attended the talk. I chose the mask shape that was physically realizable in my workshop.

The mask was cut to the required shape from manila folder stock with a single-edge razor blade. The mask is stiffened with a thin plywood disc somewhat larger than the telescope objective cell, enough to glue on retaining buttons for easy centralized rotation.

The mask opening outline was then band saw cut about 1 inch oversize. Woodworker's white glue was used to attach the mask to the plywood. A few coats of

(Continued on page 138)

LSO Double Star Measures for the Year 2012

Table 1. LSO Measurements of Double Stars

Discoverer	RA + DEC	Mags		PA	Sep	Date	nn	Notes
STT 547AB	00057+4549	8.20	8.26	187.2	6.15	2012.917	2	
GRB 34AB	00184+4401	8.07	11.0	65.3	34.81	2012.923	1	
BAR 1AB	01097+3537	2.06	14.4	234.0	29.91	2012.022	1	β And
DAL 39AK	01097+3537	2.06	13.6	89.4	59.70	2012.022	1	
DAL 39KL	01097+3537	13.6	13.7	180.7	5.97	2012.022	1	
ST 3HL	05167+4600	10.5	13.7	172.9	3.41	2012.161	1	Capella H
STF 919AB	06288-0702	4.6	5.0	132.7	7.13	2012.190	2	β Mon
STF 919AC	06288-0702	5.1	6.1	125.2	9.83	2012.190	2	
BU 570AD	06288-0702	4.7	12.2	55.0	26.61	2012.191	1	
STF 919BC	06288-0702	5.0	6.3	107.1	2.95	2012.190	2	
STF 924AB	06323+1747	6.31	6.88	211.2	20.09	2012.175	1	20 Gem
STT 154	06443+4037	7.06	9.68	85.0	23.41	2012.191	1	
AGC 1AB	06451-1643	-1.46	8.5	85.1	9.66	2012.156	1	Sirius
STF 948AB	06462+5927	5.4	6.0	68.3	1.87	2012.180	1	12 Lyn
STF 948AC	06462+5927	5.4	7.1	308.4	8.81	2012.180	1	
STF 948BC	06462+5927	6.2	7.2	299.0	9.85	2012.180	1	
STF 982AB	06546+1311	4.7	7.8	143.4	7.45	2012.178	1	38 Gem
STF1066	07201+2159	3.5	5.7	226.2	5.57	2012.195	1	δ Gem
STF1110AB	07346+3153	1.9	3.0	56.4	4.81	2012.210	1	Castor
STT 179	07444+2424	3.7	8.2	241.9	7.50	2012.219	1	κ Gem
STF1138	07455-1441	6.0	6.7	339.8	16.89	2012.219	1	2 Pup
STF1224A,BC	08267+2432	5.4	6.9	53.1	5.81	2012.265	1	24 Cnc
STF1223	08268+2656	6.1	6.2	218.9	5.22	2012.265	1	23 Cnc
STF1306AB	09104+6708	3.7	8.3	348.5	4.31	2012.284	1	σ2 UMa
STF1321AB	09144+5241	7.79	7.88	96.7	17.27	2012.271	2	
STF1424AB	10200+1950	2.4	3.6	126.7	4.73	2012.347	1	γ Leo
STF2093	16429+3855	3.58	12.5	265.6	115.87	2012.710	1	η Her
BU 1118AB,C	17104-1544	2.42	12.3	148.0	99.75	2012.707	1	η Oph
BU 1118AD	17104-1544	2.6	10.7	281.0	101.21	2012.707	1	
DAL 52AE	17104-1544	2.42	11.1	316.5	62.73	2012.707	1	
BU 1090AC	17304+5218	2.79	12.7	155.1	118.92	2012.693	1	β Dra
RST5090AB	17376-1524	3.54	13.0	78.2	24.85	2012.696	2	ξ Ser
BU 1459AB	17395+4600	3.76	11.8	48.9	116.66	2012.699	1	ι Her
STF2398AB	18428+5938	8.97	9.69	178.3	11.91	2012.713	1	Neat binary
STF2578AB	21069+3845	5.20	6.05	152.4	31.69	2012.803	1	61 Cyg
KR 60AB	22280+5742	9.93	11.4	344.6	1.47	2012.880	1	Near min sep
STF2910	22282+2332	9.05	9.67	332.8	5.57	2012.885	1	Slow binary
STF2909	22288-0001	4.34	4.49	168.0	2.25	2012.891	1	ζ Aqr
STF2922AB	22359+3938	5.73	6.50	185.5	22.42	2012.893	1	8 Lac

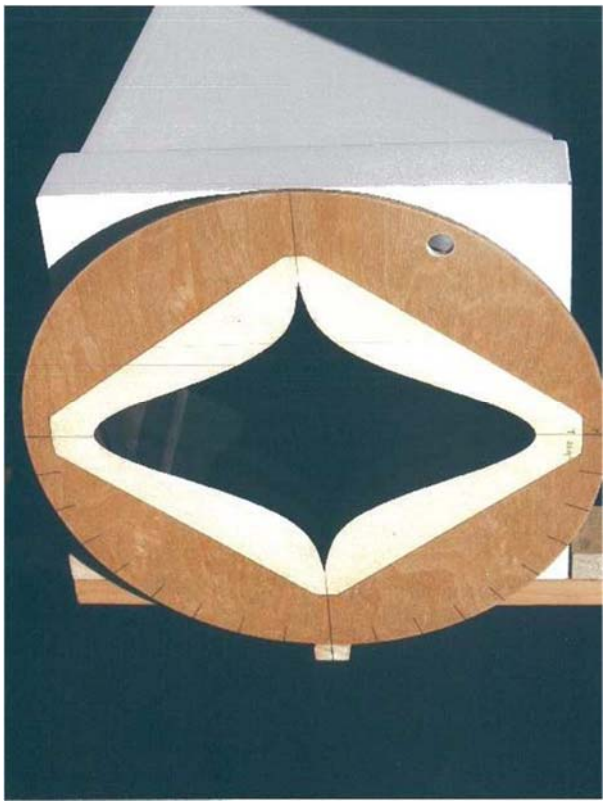

Figure 1. Shaped Pupil Mask mounted on 9 inch objective cell.

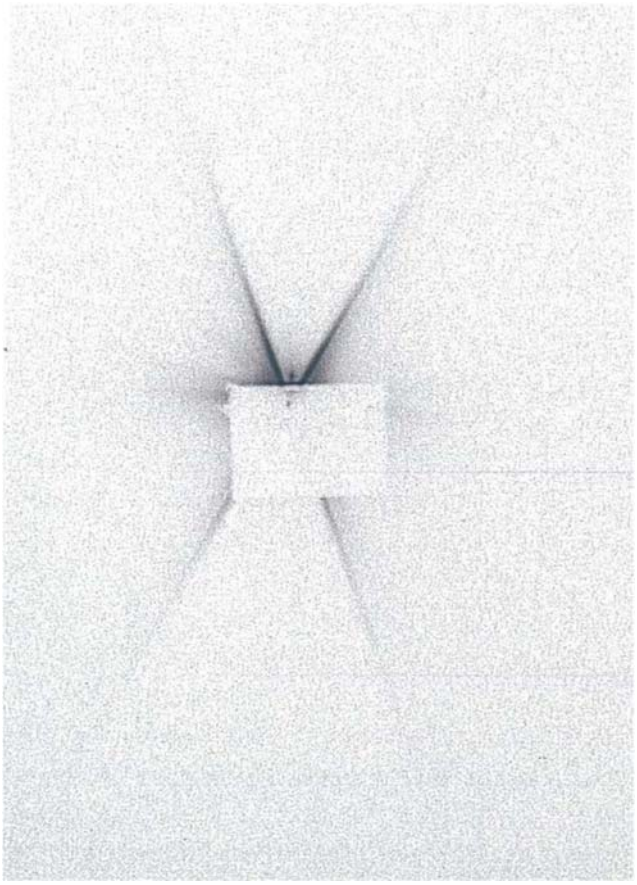

Figure 2. CCD image of AGC 1AB using shaped pupil mask and stellar coronagraph.

(Continued from page 136)

clear shellac greatly improves the card stock durability. The mask is spray painted flat black on the inner face.

You will note in the mask photo that PA is ruled in 10° steps along its rim. An indicator bar is clamped to the square telescope tube. Setting (rotating) the mask to the predicted PA of Sirius "B" is easily done to 2° accuracy by eye. Note that the two discovery regions are symmetrical about and in line with the pointed ends of the mask.

One downside of all the proposed and realized pupil masks of this general class is their relatively poor throughput, with the one shown here the best at 41% of the available light through my 9 inch refractor (the mask's maximum dimension just fits within the telescope's clear aperture). This drawback must be compensated with longer and, unfortunately, more atmospherically disturbed exposures. I use the mask described in conjunction with my tailpiece stellar coronagraph to make full use of the mask's potential.

A typical image of Sirius and its faint companion, using the described mask, is shown in Figure 2, where "B" is clearly seen in the dark zone. The primary image is a bit weak but easily measured. The almost square (1.0×1.26 mm) coronagraph focal mask foil is seen covering and greatly attenuating "A". I am replacing this foil with one transmitting about 2× more light for blue-white stars such as Sirius. Cutting these tiny (≈1 mm) square foils from aluminized mylar sheet is a story in itself!

References

Daley, J.A. 2007, JDSO 3, 159

Vanderbei, R.J., Spergel, D.N. & Kasdin, N.J. 2003, AJ 599, 686

The Demise of POP 1232 and New Measures of HLM 40 and POP 201

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Abstract: This paper discusses our effort to determine why POP 1232 disappeared from the WDS Catalog as well as how that search led to new measures of two obscure double stars.

It was a cool November night in 2011 when I pointed a telescope at Cygnus' east wing in search of STT 437. According to the data I had pulled from the WDS, I was looking for a triple star, one component of which was itself a double (Table 1). With magnitudes ranging from 7.2 to 11.2, and separations running from 2.4" to 79.9", I didn't expect much of a problem for my five inch refractor. Much to my surprise, the component that was double refused to split, although I thought I might have glimpsed some elongation in it. That pair was POP 1232, the CD components of STT 437. A return visit a week later with a six inch refractor failed to produce the "D" companion, which I wrote off as being the result of very poor seeing conditions. And that was that, and probably would have remained that, if it hadn't been for a non-sighting of "D" by Steve Smith almost a full two years later.

After you've spent a few years working with double stars, you begin to realize strange things happen sometimes in the heavens. Stars aren't always where their discoverer said they were and measurements aren't always what the records say they are. Measuring double stars is an occupation that requires constant vigilance, a demanding requirement even for people without the distraction of a daytime job. For those who do have daytime employment, the effort can sometimes be beyond demanding, especially when energy begins to flag. Errors occur. No one is immune from them no matter how many times they check and re-check their own efforts. Things happen in the dark that aren't supposed to happen.

Table 1. 2011 Data for STT 437

NAME	RA DEC	MAGS		PA	SEP	DATE
STT 437AB	21208+3227	7.2	7.4	19	2.4	2010
STT 437AC	21208+3227	7.2	11.2	142	79.9	1998
POP1232CD	21208+3227	11.2	11.2	21	15.0	1990

So when Steve sent me a photo of STT 437 and the surrounding area taken with an 80mm refractor, pointing out there was no sign of the "D" component of the CD pair (Figure 1), I became curious. He had also discovered that POP 1232 no longer existed in the WDS, which piqued my curiosity even more. Because it had been almost two years since I wrote the piece which included STT 437 and hadn't looked at it since, I went back and re-familiarized myself with what I had written and wondered if I had made some kind of mistake. I did the same searches Steve had done, with the same results – listings for POP 1232 were nowhere to be found. Still in the dark as to what had happened, I began searching for POP 1232 in the software I use for double star data and locations.

My first search was in SkyTools 3, which produced the same result for STT 437 – no mention of POP 1232 or of a companion to "C." Then I turned to an older program I still use from time to time, MegaStar 5, and

The Demise of POP 1232 and New Measures of HLM 40 and POP 201

Figure 1. 80mm Refractor Photo of STT 437 Area (Measurements are from the WDS catalog)

ran headlong into another mystery. It associated a POP 232 with STT 437, and showed the following data for it: magnitudes of 1.1 and 11.2, a position angle of twenty-one degrees, and a separation of fifteen arc seconds. The magnitude of 1.1 was clearly a typographic error, but the POP 232 designation puzzled me. Had I made a typographic error when I wrote about it, adding a "1" that wasn't there? I ran a search for POP 232 in Stelladoppie and found it didn't exist either. (If you haven't used this web site, it does an excellent job of presenting a variety of WDS data in a very accessible format).

The most valuable piece of information I gained from MegaStar was an observation date of 1990, which matched the data for POP 1232 included in my 2011 article. The POP identifier refers to G.M. Popović, so I launched an internet search and found he was associated with the University of Belgrade and published his measurements in their journal, the *Bulletin Astronomique de Belgrade*. Next I turned to the SAO/NASA Astrophysics Data System web site to search for his publications. Since his observation of POP 1232 was made in 1990, I concentrated on 1991, but came up empty-handed. The only entry for that date was a short abstract which provided me with no useful information. I went back to the internet and tried a variety of searches, and just as I was about to give up, I found what I was looking for. It was a January 8th, 2003, document entitled "The Survey of the Double Star Measurements Discovered in Belgrade with Zeiss Refractor 65/1055cm (v. 2003.0)", which lists all the double star discoveries made with the 650cm Zeiss refractor at Belgrade between about 1954 and 2000 by six observers, including G. M. Popović.

I scanned the list looking for POP 232 (the list is sorted by discoverer first and then numerical designation) and found the POP numbers suddenly jumped from POP 223 to POP 1219 and then became sequential again. Holding my breath, I continued down the list and found what I was looking for, which is shown in Table 2.

One thing was immediately clear: the POP 232 designation in MegaStar was the result of an error. The WDS number on the first line of the listing, 21208+3227, matches that of STT 437, which confirmed POP 1232's association with it, and the ADS number (14489) also matches that of STT 437. The numbers in the second line contain the position angle and separation for POP 1232 that I had listed in my earlier piece on STT 437. Next on that line is the number of observations (1) followed by two magnitudes (10.0, 10.0), which puzzled me since they were not what I had found two years prior. However, the third line, which is the listing as it appeared in the WDS, did include the two magnitudes of 11.2 I had previously found, leading me to guess the magnitudes on the second line were estimates.

There's also a reference to a note on that line (1n), so I scrolled down to the bottom of the document and found this note: "*POP1232 Magnitude for component C in WDS is wrong: instead of 1.12, needs to be 11.2.*" And that explained the magnitude error I had found in MegaStar.

It took a while longer for the last light to come on, but I later realized that "Pop1994" at the end of the second line was a bibliographic reference. Again holding my breath, I searched once more through the listings in

Table 2. Data from Zeiss Survey at Belgrade

```
POP1232 CD   21208+3227=ADS14889CD
POP1232 CD   1990.750 21.1 15.01  1  10.0 -10.0  Pop1994
POP1232 CD   1990     21   15.0   1n 11.2 -11.2  WDS
```

The Demise of POP 1232 and New Measures of HLM 40 and POP 201

MICROMETER MEASUREMENTS OF DOUBLE STARS (Series 48)

Table 1 (continues)

ADS	Disc. IDS Mag	Mult.	Epoch 1900+	P	ρ	Est.Mag.	Weight	Obs.	Notes
14889	STT 437	AB	90.746	25°.3	2″.22	0.5	1+1		
	21166N3202		90.750	23.0	2.32	7.0–7.7	2+3		
	6.9 – 7.6		**90.749**	**23.7**	**2.29**	**0.6**	**2n**	**POP**	**$\Delta\theta/146y = +44°$**
	6.4 – 11.2	AC	90.750	142.0	80.72	7.0–10.0	2+2		
			90.750	**142.0**	**80.72**	**7.0–10.0**	**1n**	**POP**	
	–	CD	90.750	21.1	15.01	10.0–10.0	2+2		The position related to AB:
			90.750	**21.1**	**15.01**	**10.0–10.0**	**1n**	**POP**	**$\Delta\alpha = +6^s$, $\Delta\delta = +3'$!**
									The first measurements.

Source: 1994BABel.150..109P

Figure 2. Listing for POP 1232 in Bulletin Astronomique de Belgrade, 1994, p. 115.

the SAO/NASA Astrophysics Data System site, looking for a 1994 publication by G.M. Popovich. Eventually I found a 1994 *Bulletin Astronomique de Belgrade* publication entitled "Micrometer Measurements of Double Stars", opened it, and began scrolling through several pages of double star observations until I struck gold on page 115 (Figure 2).

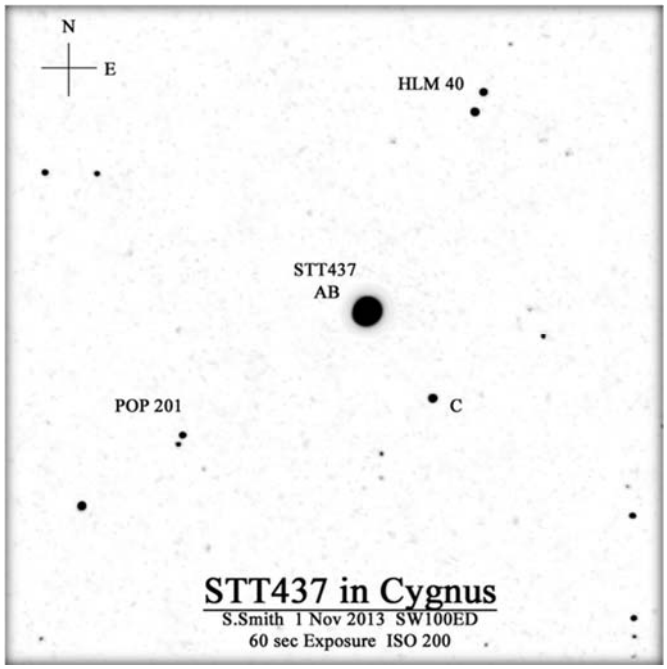

Figure 3. 100mm Refractor Photo of STT 437 area looking for "D"

There, finally, was the original observational data I had been searching for – and it contained the estimated magnitudes of 10.0 for both components that I had found in the 2003 Zeiss Refractor document.

Now that I knew for sure POP 1232 had actually existed, I was left with the next big question: *What happened to it?*

As I sat mulling that question over on a cloud-covered night, I was looking at the most recent photo Steve Smith had sent me, which went a bit deeper because it was taken with a 100mm refractor (Figure 3). Other than a few faint field stars in the general location of 'C", it was obvious there was no "D" that came anywhere near to matching the catalog data. Maybe it was because the field of view in the second photo was smaller than the first, but suddenly my eyes were drawn to the pair of stars northeast of the STT 437 primary, HLM 40. Both stars appeared to be about the same magnitude as STT 437 C, the position angle was similar to POP 1232's twenty-one degrees, and the distance between the two stars appeared to be close to the 15 seconds of arc listed for POP 1232.

On a hunch, I entered HLM 40 in the search box of Stelladoppie and found it was listed with a separation of 15.2" and a position angle of twenty-three degrees, both matching closely with the POP 1232 data. The magnitudes listed there caused me to hesitate – 11.8 and 12.6 – but I scanned down to the WDS notes section of the screen and found this:

The Demise of POP 1232 and New Measures of HLM 40 and POP 201

```
21218+3230 HLM 40   Also appears to be POP1232CD
       which is not related to 21208+3227. WDS po-
sition of HLM 40 far off and is corrected here.
```

Just to make certain, I switched over to the WDS and double-checked the data and notes. Everything matched the Stelladoppie screen. My next step was to send a request to Brian Mason at the WDS for the observational data on HLM 40. What I found was the 1990 observational data for POP 1232 had also been entered under HLM 40 for 1990 (Table 3).

So there it was. POP 1232 hadn't disappeared – it had been HLM 40 all along!

I passed my new found discovery onto Steve immediately, along with a question: would it be possible to measure the position angle and separation of HLM 40 using the existing data for STT 437 AC as a basis for calibration? I had seen Steve use AutoCAD to measure position angles and separations, and it looked like it should be possible to do it in this case as well. HLM 40 hadn't been measured since 2000, so it would be well worth the effort. *Eight separate photos were measured* and the results averaged. One of the photos showing the AutoCAD measurements of HLM 40 is shown in Figure 4, along with the measure of nearby POP 201, which hadn't been measured since 2002. A comparison of those measures with existing measures for HLM 40 and POP 201 are shown in Table 4.

Now obviously we weren't the first to discover POP 1232 is actually HLM 40. In our blissful unawareness of someone else's effort, we probably wandered down the same labyrinthine paths they did. Nevertheless, the

Table 3. HLM 40 WDS Data File and 1990 POP 1232 Observation

NAME	RA DEC	MAGS	PA	SEP	DATE
HLM 40	21218+3230	10.7 11.0	18.0	13.48	1925
HLM 40	21218+3230	10.0 10.0	21.1	15.01	1990
HLM 40	21218+3230	11.8 12.6	22.7	15.16	2000
POP1232 CD	21218+3230	10.0 10.0	21.1	15.01	1990

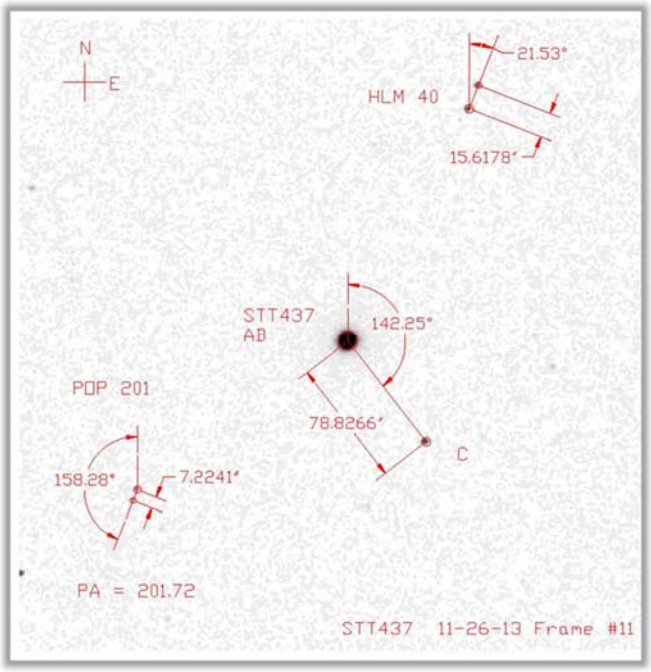

Figure 4. One of Eight Photos Showing Measurements of HLM 40 and POP 201 using AutoCAD (see Note 1 in Table 4).

Table 4. Measures of HLM 40 and POP 201

NAME	RA DEC	MAGS	PA	SEP	DATE	NOTES
HLM 40	21218+3230	10.7 11.0	18.0	13.48	1925	
HLM 40	21218+3230	10.0 10.0	21.1	15.01	1990	
HLM 40	21218+3230	11.8 12.6	22.7	15.16	2000	
HLM 40	21218+3230	11.8 12.6	22.9	15.50	2013.912	1
POP 201	21207+3226	12.5 13.0	204	7.3	1998	
POP 201	21207+3226	12.5 13.0	202	7.3	2002	
POP 201	21207+3226	12.5 13.0	202.8	7.2	2013.912	1

Notes:

1. The 2013 measures shown for both HLM 40 and POP 201 are the result of taking measures from eight separate photos and averaging the results.

process of discovery is still the process of discovery, even for those who come to it unaware they're duplicating a prior effort. The thrill is still the same and it's worth every second of it even when you later realize you're not the first.

And when it culminates in the opportunity to offer new measurements of a pair of obscure double stars not measured for the past ten years, the resulting reward is more than ample compensation for all the effort put forth. So in the same way that old stars give birth to new stars, the demise of POP 1232 gave birth to new measurements for a pair of double stars that otherwise would likely have remained obscure for many years longer.

Notes on Photo Images and Measurement

The photographs of STT 437 were taken through a Skywatcher SW100ED (4"-f9) refractor telescope at prime focus using an Olympus EPL-1 Camera and processed using Adobe Photoshop Elements. The photos were typically 30 to 60 second exposures at ISO 200. Drift timings of stars crossing the camera sensor yield a calibration constant of approximately 1 arc-second per pixel for this particular camera-scope combination. In addition to the guided frames, several 30-second unguided star trail photos were also taken to establish the east-west orientation of the frames for each night's observing session. In order to calibrate the photo frames and imaging system, several photos of the nearby triple star system S790 were also taken. It would have simplified things significantly if the A-C pairing of STT437 could have been used to calibrate the images as it falls in the same field-of-view as HLM 40 and POP 201, but at the exposure times required to image HLM 40 and POP 201, the A-B components of STT 437 could not be resolved as separate objects.

In Photoshop the star trail photos, the S790 calibration photos, and the STT437 photos for each night's observations were copied and pasted as individual layers into a single Photoshop document. The composite image was then rotated until the star trail was parallel to the upper or lower part of the editing window, thus squaring all of the photos and the celestial coordinate system to the edges of the editing window. The full frame photos could then be cropped in unison to a more manageable size. The fields-of -view of the three systems were encompassed in an area of approximately 900 x 900 pixels (15' x 15'). The photos were cropped square (1:1 aspect ratio) in order to reduce the possibility of introducing unwanted distortions or unequal scaling of the image when importing a rectangular image into AUTOCAD.

The double star measurements were made by importing bitmap copies of the photos into AutoCAD, a professional computer based engineering and technical drawing application. A circle was drawn and centered on each star image, the center point of the circle thus establishing the measuring point for each star. A line was then drawn connecting the center points of the circles representing the primary and secondary of each pair of stars. Since the image had previously been rotated and squared, a vertical line passing through the center point of each primary star established the North-South direction.

The dimensioning functions of the CAD Program (Angular and Linear) can then be used to measure the Position Angle (PA) and Separation of the pairs. The angular measurements can be read directly but the linear dimension (separations) will be in whatever default units (feet, inches, mm etc.) that are set by the user. The CAD program can be set to read the separation in arc seconds but requires that the image scale be established.

The nearby triple star system S790 in Cygnus was chosen as a suitable calibration object since the position measurements in the WDS are recent (2012) and have shown little change over the years. According to the WDS the current values are: A-B separation = 34.7" and A-C = 53.3". The image scale factors were then calculated as:

Scale Factor 1 = 34.7 arc-sec / Measured A-B Distance in inches = arc-sec/inch

Scale Factor 2 = 53.3 arc-sec / Measured A-C Distance in inches = arc-sec/inch

Table 5. Average of Measurements and Statistics

	POP 201		HLM 40	
	PA (deg)	Sep (arc-sec)	PA (deg)	Sep (arc-sec)
No. Obs.	8	8	8	8
Avg	202.8	7.2	22.9	15.5
Std Dev	2.06	0.37	0.91	0.23
Std Err Mean	0.73	0.13	0.32	0.08

The average of the two scale factors for each night's observations were then entered into the Dimensional Properties dialog box and from that point any CAD generated dimensions were directly converted into arcseconds. In all, eight separate frames taken over the course of three nights of observation were measured and averaged to come up with the new measures for HLM 40 & POP 201 presented herein. The averages of the measurements and statistics are presented in Table 5.

This procedure seems to produce reliable measures based on my measures of other systems and the calibration frames used for this project. These new measures for HLM 40 & POP 201 also appear to be in line with the trends of the historical measures for these systems. While the procedure is somewhat time consuming and does not lend itself to the reduction of large amounts of data, it illustrates the procedures and processes used by astrometric software programs such as Reduce and Astrometrica, and has the benefit of producing a permanent visual and graphic record of the measurements.

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Web Sites

AutoCAD: http://www.autodesk.com (AutoCAD is a Professional Computer Aided Design drawing program but there are other low-cost or shareware/freeware technical drawing software packages available that can provide the same functionality).

SAO/NASA Astrophysics Data System site: http://articles.adsabs.harvard.edu/

Stelladoppie WDS Interface: http://stelledoppie.goaction.it/index2.php?section=1

Observations of Three Double Stars with Varied Separations

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Abstract: As part of a summer semester introductory astronomy course, college students measured the position angles and separations of STF 2010AB, STF 2007AB, and STFA 48AB. The averages of our measurements are as follows: STF 2010AB had a ρ and θ of 25.71" and 10.78°. STF 2007AB had a ρ and θ of 38.63" and 320.3°. STFA 48AB had ρ and θ of 42.87" and 147.1°. Students compared recordings with averages of the past ten observations in the *Washington Double Star Catalog* and found that the agreement between our measurements and the past observations improved with increasing separation

Introduction

Observations of three double stars, STF 2010AB, STF 2007AB, and STFA 48AB were made as part of an introductory Astronomy course at Cuesta College during the 2013, six week summer semester. The observations were made at the Orion Observatory in Santa Margarita, California. Weather conditions on the first and last observing nights were ideal. On the second night, however, several clouds drifted into our field of view, making the process take a little longer than expected.

The goals of the project were two-fold: to contribute to our knowledge of double stars, and to give students first hand experience doing scientific research. We chose to observe three double stars of different separations in hopes of seeing how the variances in our measurements were affected by differences in apparent separation. Organizing and delegating tasks to our team of students of varied backgrounds was a great learning experience, and we were each able to learn how to work together toward a common goal.

Figure 1. The team poses at the Cuesta College Campus. From left to right: Nelly, Elena, Emily, Lindsey, Eric, Chris, Michael, Andrew, and Jacob.

Methods and Equipment

To gather observations, we used the Orion Observatory's 10 inch, f/10, equatorial mounted telescope with a Sidereal Technology control system equipped

Observations of Three Double Stars with Varied Separations

with a Celestron astrometric eyepiece. The control system was integrated with TheSky6 to help point the telescope at the target systems. After each measurement was made, the observer was changed so that all participants were given ample observing time.

We used the drift method to calibrate the linear scale in our eyepiece (Teague 2012). Following the steps of this method, the telescope tracking was turned off to allow a calibration star to drift along the linear scale. Drift times were recorded using a cell-phone application accurate to the nearest hundredth of a second. Ten drift times were recorded. The average drift time was used to calculate the scale constant, Z, in units of arc seconds per tick, using the equation below:

$$Z = \frac{15.0411\cos(\delta)d_t}{N}$$

where δ is the declination of the calibration star, dt is the average drift time, and N is the number of ticks in the scale, in our case, sixty. We calibrated our eyepiece using Arcturus and found our scale constant to be 6.72 arc seconds per tick, with a standard deviation of 0.05 arc seconds per tick.

The separation of each double star system was found by placing both stars on the linear scale and counting the ticks between the stars. The stars were randomly placed along the linear scale for each observation to reduce systematic bias. Each observer measured the separation of a system until ten data points were recorded. The average of these separations in ticks was multiplied by the scale constant, Z, to determine the separation of the system in arc seconds.

The position angle was found by aligning the primary star in the center of the eyepiece, and then rotating the eyepiece so that the secondary star was on the linear scale, and then turning off the tracking of the telescope to allow the primary star to drift to the outer protractor on the eyepiece. In order to reduce systematic bias, the protractor on the eyepiece was rotated 180 degrees between observations, and 180 degrees was then subtracted or added to the observations in order to disambiguate the results. Furthermore, a ninety degree correction was applied to correct for the rotational alignment of the protractor in the Celestron eyepiece.

At first our position angle measurements were considerably off from published results. However, further investigation proved this was because the image in the eyepiece was in fact real and not imaginary, therefore the inner protractor should have been used. The numbers on the inner protractor increase in a counter-clockwise direction. The outer protractor is converse. This issue was resolved by subtracting our measurements from 360, and then applying the 180 degree disambiguation and 90 degree correction.

History

The first double star officially recorded was Mizar. In 1650, Giovanni Battista Riccioli discovered this star in Ursa Major (Ondra 2013). Since then double stars have been discovered by astronomers such as Robert Hooke, Fontenay, and many others. At least 1 in 18 stars brighter than 9.0 magnitude in the northern half of the sky are known to be double stars visible with a 36-inch (910 millimeter) telescope (Aitken 1964).

One of the doubles we observed was discovered in the 17th century by Friedrich Wilhelm von Struve. It is known as Kappa Herculis and has been given the discover code STF 2010AB. It is a binary star with primary and secondary magnitudes of 5.10 and 6.21 in V band, respectively. The primary is a yellowish white and the secondary is a blue star (Sordiglioni 2013). According to the *Washington Double Star Catalog* (WDS), the double star has been observed since 1779. Figure 2 below is a graph of observations of STF 2010AB, courtesy of the U.S. Naval Observatory.

The system STF 2007AB has primary and secondary magnitudes of 6.89 and 7.98, respectively. The double star is located in the constellation Serpens Caput. According to the *WDS*, the star has been observed since 1823, and past observations suggest that this pair may

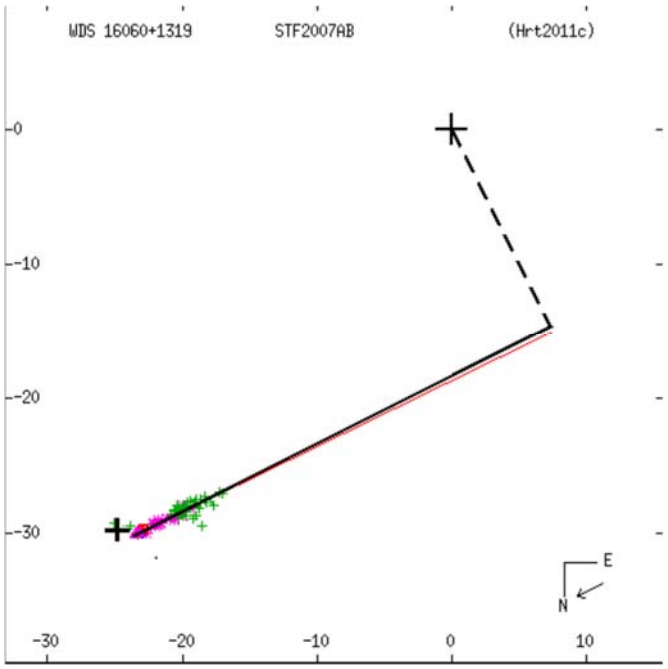

Figure 2: Graph of the motion of STF 2007AB (Mason and Hartkopf 2013). Our observation has been marked with the black plus to the lower left. The scale is marked in arc seconds.

(Continued on page 147)

be an optical binary.

The system STFA 48AB has primary and secondary magnitudes of 7.14 and 7.34, respectively, and is located in the constellation Vulpecula. According to the *WDS*, STFA 48AB has been observed since 1782.

Results

In Tables 2 through 4, we present our data compared with the last ten observations reported to the Washington Double Star Catalog, which we obtained from the U.S. Naval Observatory (Mason and Hartkopf 2013). The standard deviation of our separation was found by adding in quadrature the standard deviations of the scale constant, *Z*, and the separation in ticks, using the equation below:

$$\frac{\sigma_\rho}{\rho} = \sqrt{\left(\frac{\sigma_{ticks}}{ticks}\right)^2 + \left(\frac{\sigma_z}{Z}\right)^2}$$

where ρ is the separation in arc seconds, "ticks" is the number of divisions on the linear scale between the star images, *Z* is the scale constant calculated in the Equipment and Methods section, and σ represents the standard deviation of the corresponding subscript.

Analysis

Comparisons with Past Observations

In the tables 5 and 6 we compare our values to the average of the ten most recent observations reported to the WDS. The values in the table rows have he following significance: Δ is representative of the accuracy of our measurements, σ is the statement of our precision, and Δ/σ is the unit-less value telling us how many standard deviations we were off from past observations.

Comparisons to Rectilinear Elements

Two of the double star systems that we observed have solutions in the Catalog of Rectilinear Elements that is maintained by the USNO (Mason and Hartkopf 2013). The ephemerides for 2010 and 2015 were obtained for these two systems from this catalog. The position angle and separation were calculated for the dates we observed each star. These values were calculated using the following method: First the 2014 and 2015 ephemeris values for position angle and separation, θ and ρ, were converted into Cartesian coordinates, x and y. Assuming that the velocity of the secondary star relative to the primary is constant, then the velocity components, v_x and v_y, will also be constant. Thus, the change in either coordinate can be calculated by:

$$r_{epoch} = r_{2010} + \frac{(r_{2015} - r_{2010})(epoch - 2010)}{5}$$

Table 2: STF 2010AB, observed on B2013.494. Only nine measurements were made of the position angle during the observation run. This was not noted until during the data analysis. Past observations from the WDS were made between 2007.534 and 2012.491.

	Our Data		Past Data from the WDS	
	Separation	Position Angle	Separation	Position Angle
Number of Obs.	10	9	10	10
Average	25.71''	10.78°	27.14''	13.40°
Standard Deviation	1.43''	2.11°	0.33''	1.89°
Standard Error of the Mean	0.45''	0.70°	0.11''	0.60°

Table 3: STF 2007AB, observed on B2013.503. Past observations from the WDS were made between 1998.8 and 2012.491.

	Our Data		Past Data from the WDS	
	Separation	Position Angle	Separation	Position Angle
Number of Obs.	10	10	10	10
Average	38.63''	320.30°	38.00''	322.19°
Standard Deviation	1.92''	4.21°	0.39''	0.33°
Standard Error of the Mean	0.61''	1.33°	0.13''	0.10°

Table 4: STFA 48AB, observed on B2013.514. Past observations from the WDS were made between 1993.31 and 2012.588.

	Our Data		Past Data from the WDS	
	Separation	Position Angle	Separation	Position Angle
Number of Obs.	10	10	10	10
Average	42.87''	147.10°	42.26''	147.30°
Standard Deviation	2.52''	1.73°	0.56''	0.66°
Standard Error of the Mean	0.80''	0.55°	0.18''	0.21°

where Epoch is the Besselian date of the observation, and *r* is either Cartesian coordinate, *x* or *y*. These coordinates are then converted back into θ and ρ. For the Epoch of our observations we found STF 2007AB to have ρ = 38.275" and θ = 321.93°, and STF 2010AB to have ρ = 27.103" and θ = 13.439°.

When comparing our values of Δ and Δ/σ in Tables 5 and 6 to the values in Table 7, one can see that our results are much closer to the ephemerides from the *Catalog of Rectilinear Elements* than to the averages of the last ten observations reported to the WDS. This is not surprising. However, it does not make sense to draw conclusions about the accuracy of our measurements using the data in Table 7, because the system STF 48AB does not have published rectilinear or orbital elements. The strongest statement that can be made is that, for published rectilinear systems with large numbers of past observations (STF 2010AB has 191 past observations, and STF 2007AB has 77), using the rectilinear elements published by the WDS will probably be closer to observed measurements.

While we did not measure enough stars to make an accurate or informative least squares model, we can still see that, universally, the closeness of measurements to the past ten observations from the WDS (Δ) did improve when we increased the separation of our target star. Interestingly, this trend does not hold for the precision of our data. The standard deviation (σ) of our separation measurements increases with the separation of the target system, and the standard deviation of our position angle measurements has no correlation to separation. We speculate that the increasing uncertainty of the separation measurements is due to the difficulty to count the ticks between wider pairs when using an astrometric eyepiece.

Table 5: Separation measurements; precision and accuracy.

	STF 2010AB	STF 2007AB	STFA 48AB
WDS Separation (ρ)	27.14"	38.00"	42.26"
$\lvert\rho_{ours} - \rho_{WDS}\rvert$ (Δ)	1.43"	0.63"	0.61"
Std. Dev., our data, (σ)	1.43"	1.92"	2.52"
Δ/σ	1.00	0.33	0.24

Table 6: Position Angle; precision and accuracy.

	STF 2010AB	STF 2007AB	STFA 48AB
WDS Separation (ρ)	27.14"	38.00"	42.26"
$\lvert P.A._{ours} - P.A._{WDS}\rvert$ (Δ)	2.62°	1.89°	0.2°
Std. Dev., our data, (σ)	2.11°	4.21°	1.73°
Δ/σ	1.24	0.45	0.12

Table 7: Comparing our measurements to the ephemerides calculated from the Catalog of Rectilinear Elements.

	STF 2010AB		STF 2007AB	
	Position Angle	Separation	Position Angle	Separation
Our Measurement	10.78°	25.71"	320.30°	38.63"
Standard Dev. (σ)	2.11°	1.43"	4.21°	1.92"
Calculated Ephem.	13.44°	27.10"	321.93°	38.28"
|Ours - Ephem.| (Δ)	1.66°	1.39"	1.63°	0.35"
Δ/σ	0.7867	0.97	0.3872	0.1823

Conclusion

We started our research project with two goals: to contribute to the growth of scientific knowledge of double stars, and to demonstrate that research is accessible and beneficial to students of many experience levels. During our project, we encountered problems such as undesirable weather and errors in our observing techniques. Despite these setbacks, we continued to work and eventually solved the issues we came up against.

Acknowledgments

We thank the Orion Observatory and Russell Genet for providing all necessary equipment and facilities for collecting data. In addition, we thank Ryan Gelston, David Ho, and Russell Genet for providing guest observations. This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory. Brian Mason provided specific data regarding the observed stars. Finally, we thank Russ Genet, Vera Wallen, Tom Smith, Bobby Johnson, Ryan Gelston, and Nate Kleinsassar for reviewing our paper.

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Lunar Occultation Observations of Double Stars – Report #4

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Abstract: Reports are presented of lunar occultations of close double stars observed using video including cases where a determination of the position angle and separation of the pair can be made and other cases where no duplicity has been observed. A number of double stars discovered as a result of an occultation are included together with the light curves for the events.

Lunar Occultation Observations of Double Stars – Report #4

This paper continues the series of reports of double star measurements made during lunar occultations. The principle and general method of calculation are explained in Herald (2009) and Loader (2010).

All occultations presented in this paper have been observed using video cameras, with either 25 frames, 50 fields per second (Australasia and Europe) or 30 frames, 60 fields per second (USA and Japan). The start and end times of each field were inserted on the videos to milli-second accuracy. The limit of timing accuracy is usually about ±0.02 seconds where analysis has been carried out using video frame measures and ±0.01 seconds using field measures. An error of 0.01 seconds in time will typically translate to an angular error of 4 milliarcseconds.

All events have been analyzed using the Limovie program developed by K. Miyashita and a light curve of the occultation has been generated. From this analysis an estimate of both the time interval between the occultations of the pair of stars and the relative brightness of the stars has been obtained.

Occultations of double stars result in a stepped light curve, see Herald (2009). The relative size of the step enables an estimate of the magnitude difference of the two stars to be made. Observations are normally made with an unfiltered camera.

Normally, the separate occultations of the two stars of a pair will take place at slightly different points on the moon's limb. An angular separation of 1" at the mean distance of the moon is about 1.86 km. The heights of the moon's limb at the two points of occultation may differ. Any difference will have an effect on the interval between the two events.

For each observation an estimate of the effective slope of the moon's limb between the two points of occultation is therefore needed for calculations of the position angle and separation angle of a pair of stars. For this paper, use has been made of the Kaguya satellite data. While this gives a more detailed view of the moon's limb than the Watt's corrections, some uncertainty remains. An estimate of these has been built into the uncertainty of the resulting PA and separation.

The Observations Reported

Table 1 continues the series of measures of known double stars for which occultations have been observed from more than one locality. In most cases the occultation observations have been made on different dates, with an interval between them sufficiently short for any change in relative position of the pair of stars to be small. An estimate of the change, derived from WDS data, is given in the notes.

Table 2 presents details of previously unknown double stars discovered as a result of stepped lunar occultations. In each case only one occultation observation of the star is available. As a result only a vector separation for the pair of stars can be determined along with an estimate of magnitude difference.

Only cases where the resulting light curve shows a clearly defined step have been included. Light curves are presented for the events except those which have been previously recorded in the JDSO.

Table 3 presents observations of stars which have been reported as possibly double as a result of earlier visual occultation observations. More recent video observations of occultations of the star listed have shown no sign of a stepped event, that is no indication that it is double. Only cases with two or more observations with event PAs (the vector angle) separated by at least 10° have been included. The stars in Table 3 all have an entry in the Interferometric Catalog, but are not listed in the WDS.

While the most likely reason for the failure to detect a companion star is simply that the star is in fact single, other possible reasons are:

- the vector separations were too small so that the interval between the two events were too short to detect. This possibility is largely eliminated by the two or more observations of the star at different vector;
- the magnitude difference of the two component stars is too large for the circumstances of the event.

Names of observers are listed at the head of this paper and are referred to by the two letter code in the tables.

XZ refers to the XZ80 catalog originally published by the USNO. It includes all stars to magnitude 12.5 within 6°40' of the ecliptic, that is all stars which can be occulted by the moon.

Acknowledgements

This research made use of the Washington Double Star Catalog (WDS) and the Interferometric Catalog both maintained by the United States Naval Observatory, Washington.

References

Herald, D. "SAO97883 – a new double star", JDSO, Vol 5, No 4, 2009.

Loader B. "Lunar Occultations of Known Double Stars – Report #1", JDSO, Vol 6, No 3, 2010.

Loader B. "Lunar Occultations of Double Stars – Report #2", JDSO, Vol 7, No 3, July 2011.

Loader B. "Lunar Occultations of Double Stars – Report #3", JDSO, Vol 8 No 4, October 2012.

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Herald D. "Two New Double Stars from Lunar Occultations, SAO 117948 and TYC 1310-16-1", JDSO Vol 9, No 4, October 2013.

Loader B. "A Possible New Double Star from Lunar Occultation, SAO 163677, JDSO Vol 10, No 1 January 2014.

Gault D. "A New Double Star Observed During Lunar Occultation, HIP 18473", JDSO Vol 10, No 1 January 2014.

The program "Limovie" by K. Miyashita can be downloaded from:

http://astro-limovie.info/limovie/limovie_en.html

Table 1: Known double stars: PA and separation measured

WDS name	XZ	Position RA Dec	Measured PA °	Measured Separation "	Mag. diff.	Date	Observers	Note
BU 1058	8487	06105+2300	229.36 ± 3.2	0.104 ± 0.006	0.07	2010.823 2011.347	JM DG	1
HDS 910	9439	06375+2435	223.75 ± 2.65	0.701 ± 0.045	2.8	2009.626 2009.702	JM SM	2
HO 238	9774	06463+1812	174.38 ± 1.20	0.330 ± 0.010	1.2	2013.666 2014.114	RS, SM TG	3
STT 156	9812	06474+1812	152.25 ± 1.90	0.192 ± 0.007	~0.1	2013.666 2014.115	RS, SM TG	4
A 2525	10701	07138+1756	103.54 ± 1.54	0.972 ± 0.023	1.6	2012.696 2013.818	VP, JM BL	5
J 77	13791	09051+1029	135.58 ± 0.42	0.925 ± 0.006	0.4	2012.403 2013.300 2013.300	EE AP EE	6
STT1356	14350	09285+0903	100.34 ± 2.07	0.818 ± 0.035	1.6 0.8	2012.778 2013.003	JM, EE JM	7
RST4495	18232	12159-0610	120.25 ± 5.72	0.393 ± 0.006	1.7 1.	2013.086 2013.461	MI HW	8
RST3829	19226	13149-1122	159.66 ± 1.62	0.540 ± 0.012	1.5	2012.341 2012.491	DG JT, BL	9
CHR 236	25279	18262-1832	116.0 ± 10.0	0.143 ± 0.006		2013.851	DG, JB	10
FEN 30	156863	18268-1813	45.13 ± 0.34	3.294 ± 0.014		2013.852	JB,BL	11
HDS2809	27514	19462-1520	70.35 ± 2.40	0.283 ± 0.006	2.2	2013.781	DH, JB, BL	12
HDS3060	29765	21315-0845	223.80 ± 2.75	0.366 ± 0.017	0.9	2011.990 2013.861	DH JQ	13

Notes

1. BU 1058 = 4 Geminorum, expected change in PA over ca 6 months -0.3°, change in separation < 0.01". The observed intervals between the occultations of the two stars were less than expected, leading to a smaller separation than predicted.
2. HDS 910. Both the intervals between the occultations of the two stars were greater than expected leading to a larger separation than predicted.
3. HO 238. No change expected in PA or separation between August 2013 and February 2014.
4. STT 156. From the published orbit the expected changes between August 2013 and February 2014 are: PA -1.91°, Sepn -0.001".
5. A 2525. The rates of change expected in the PA and separation are low. The PA and separation determined from the observations are close to that expected.
6. J 77 The rates of change expected in the PA and separation are low. The PA and separation determined from the observations are close to that expected.
7. STT1356: The determined PA and separation are in agreement with the published orbit. Expected change in separation in time between two observations was +0.052" and +6.8° in PA,
8. RST 4495: The determined separation, 0.393" is close to recent interferometric measures. The position angle 120.25° differs from recent measures by ca 154°. At both events the secondary star was occulted after the primary, indicating an easterly PA. This order is the reverse of that expected from the interferometric data. The step intervals were similar in magnitude to those expected from previous measures, but opposite in sign. Although this suggests that the relative positions of the stars have been reversed, this would lead to a PA difference of 180°.
9. RST 3829: The solutions for the PA and separation are in agreement with recent interferometric measures.
10. CHR 236: The solutions for the PA and separation are in agreement with recent interferometric measures.
11. FEN 30: A wider double than usual for occultation measures. The solution agrees with expected PA and separation
12. HDS2809: There is only one previous observation of this double in 1991.
13. HDS3060: The two occultations observations used are nearly 2 years apart. There is only one previous measure of the star in 1991 so the rates of change in the PA and separation are unknown.

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Table 2: Occultation Discoveries: Vector separation only measured

Star name	XZ	RA Dec	Vector Angle	Vector Sep.	Mag. diff.	Date	Observer	Figure or Note
SAO 92800	2918	02069+1437	222.4°	0.042″	0.0	2012.604	MI	Fig 1
SAO 92925	3246	02246+1541	232.6°	0.035″	0.5	2012.603	JM	Fig 2
SAO 93681	5140	03569+2005	223.9°	0.083″	0.2	2013.209	DG	14
TYC 1308-00332-1	74543	05275+2041	96.7°	0.085″	0.2	2012.690	JM	Fig 3
SAO 77232	7067	05319+2046	282.4°	0.021″	0.7	2012.691	JM	Fig 4
TYC 1310-00016-1	76885	05424+2051	259.8°	0.233″	0.5	2013.214	DH	15
TYC 1335-00114-1	93450	06487+1804	279.1°	0.055″	2.2	2013.666	SM	Fig 5
SAO 97323	11814	07523+1640	272.5°	0.235″	0.1	2013.670	BL	Fig 6
SAO 98057	13225	08423+1322	283.6°	0.083″	0.8	2013.299	DG	Fig 7
SAO 117948	14860	09515+0830	249.7°	0.088″	0.9	2013.228	DH	15
TYC 6206-00728-1	136228	16205-1840	40.7°	0.086″	0.3	2013.623	DG	Fig 8
SAO 185402	23533	17267-2128	129.4°	0.054″	2.2	2012.502	JT	Fig 9
TYC 6272-00394-1	43586	18150-1912	101.2°	0.067″	1.3	2013.627	DG	Fig 10
TYC 6273-00185-1	153948	18168-1858	234.2°	0.069″	0.6	2013.628	DG,DH	Fig 11
TYC 6273-00351-1	43711	18186-1906	272.8°	0.220″	0.5	2013.628	DG	Fig 12
SAO 161721	25680	18412-1928	90.7°	0.151″	2.6	2013.703	SM	Fig 13
TYC 6299-00250-1	46481	19372-1634	210.5°	0.043″	0.5	2012.733	DH	Fig 14
SAO 162971	27531	19467-1503	45.7°	0.040″	0.7	2013.781	BL	Fig 15
SAO 163469	28273	20207-1340	305.2°	0.021″	0.2	2013.259	BL	Fig 16
SAO 163677	28583	20335-1333	220.5°	0.052″	0.9	2012.361	BL	16
SAO 145613	29992	21431-0919	22.1°	0.128″	0.3	2012.365	JM	Fig 17 17
SAO 128459	32060	23546+0503	45.0°	0.090″	1.1	2012.971	BL	Fig 18 18

Notes

14. See JDSO Vol 10 No 1, January 1, 2014. D. Gault: "A New Double Star Observed During Lunar Occultation, HIP 18473"
15. See JDSO Vol 9 No 4, October 1, 2013. D. Herald: "Two New Double Stars from Lunar Occultations: SAO 117948 and TYC 1310-16-1.
16. See JDSO Vol 10 No 1, January 1, 2014. B. Loader A Possible New Double Star from Lunar Occultation: SAO 163677.
17. SAO 145613: The star was reported as a double as a result of an occultation observation by M. Takahashi, Japan, 1995 November 28.
18. SAO 128459: Previous occultation observations which have reported this star as double were made 1992 January 11 by Z. Kawai, Japan and by R. James, USA, 2011 February 7.

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Light Curves: The figures show light curves for lunar occultations of double stars. The horizontal axes, effectively time, show the frame number of the video. The vertical axes show the measured light intensity of the star in arbitrary units. Measures have been made of the light intensity for each frame of the video recording, unless otherwise stated.

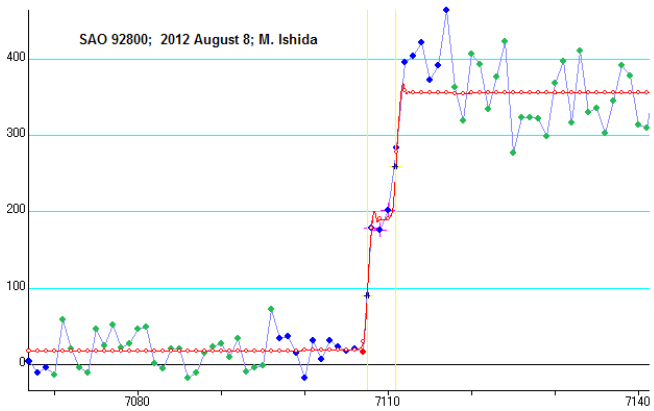

Figure 1: Light curve for the occultation reappearance of SAO 92800 obtained by M. Ishida.. The step lasts 0.12 second, between 3 and 4 frames. The vertical height of the steps suggests the two components have close to the same magnitude. The marginally brighter star was the first to reappear from occultation.

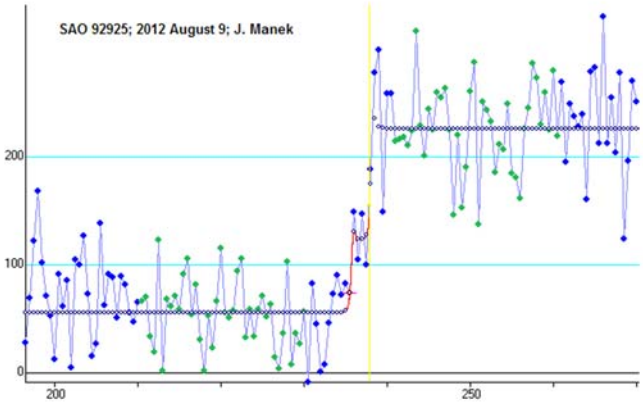

Figure 2: Light curve for the occultation reappearance of SAO 92925 obtained by J. Mánek. Light intensity measures have been made for each field, 50 per second. The step lasts 0.10 second, about 5 fields. The height of the steps suggests a 0.5 difference in magnitude, with the fainter stars reappearing first.

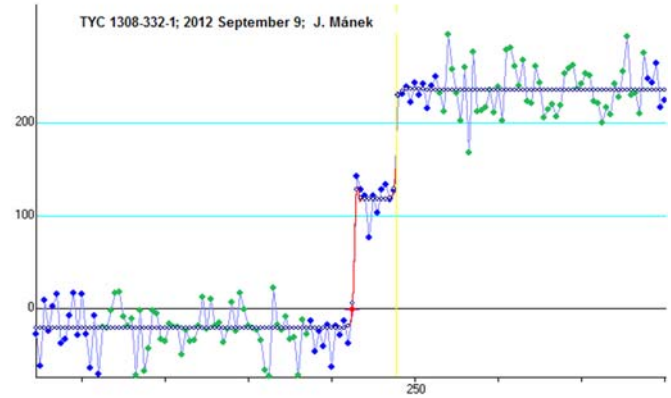

Figure 3: Light curve for the occultation reappearance of TYC 1308-332-1 obtained by J. Mánek. Light intensity measures have been made for each field, 50 per second. The step lasts just over 0.20 seconds, that is 10 fields. The height of the steps suggests a 0.2 difference in magnitude, with the brighter stars reappearing first.

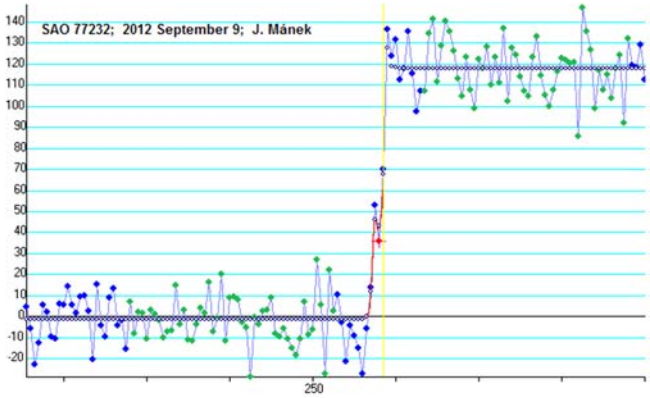

Figure 4: Light curve for the occultation reappearance of SAO 77232 obtained by J. Manek. Light intensity measures have been made for each field, 50 per second. The step lasts for 0.06 seconds, 3 fields and equates to a minimum separation of 21 arcmilliseconds for the pair. The magnitude difference is 0.6 with the fainter component reappearing first.

Lunar Occultation Observations of Double Stars – Report #4

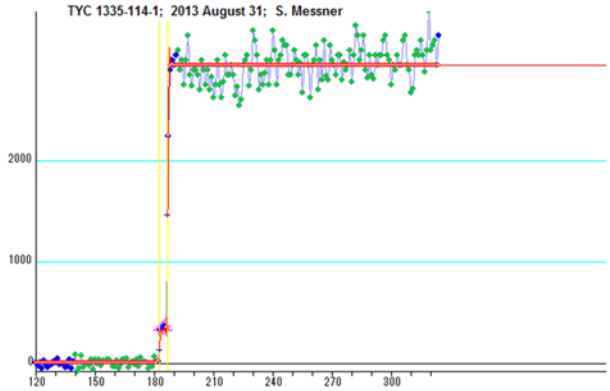

Figure 5: Light curve for the occultation reappearance of TYC 1335-114-1 obtained by S. Messner. The 0.14 second step equates to a minimum separation of 55 arc-milliseconds for the pair. The height of the step suggests a magnitude difference of 2.2, with the fainter component clearly being the first to reappear.

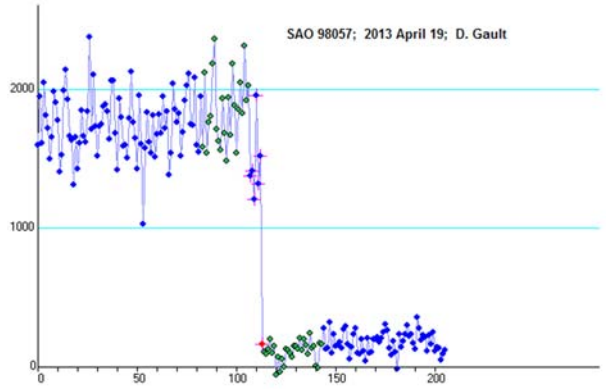

Figure 7: Light curve for the occultation disappearance of SAO 98057 obtained by D. Gault. The 0.24 second step is equivalent to a minimum separation of 83 arc-milliseconds. The step height suggests a 0.8 magnitude difference between the component stars.

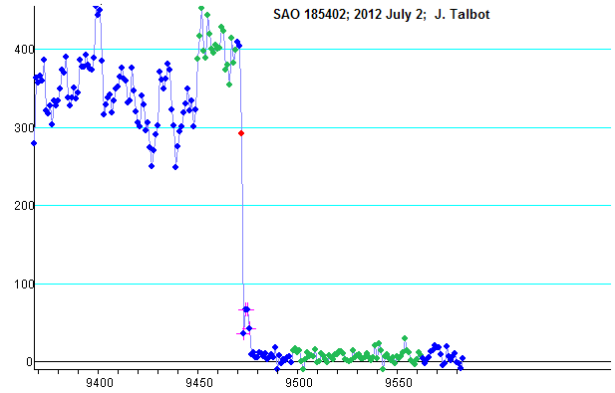

Figure 9: Light curve for the occultation disappearance of SAO 185402 observed by J. Talbot. The light curve suggests a step duration of 0.16 seconds, equivalent to a minimum separation of 54 arc-milliseconds for the pair. Clearly the fainter star was the second to disappear, the magnitude difference of the components is estimated at 2.2.

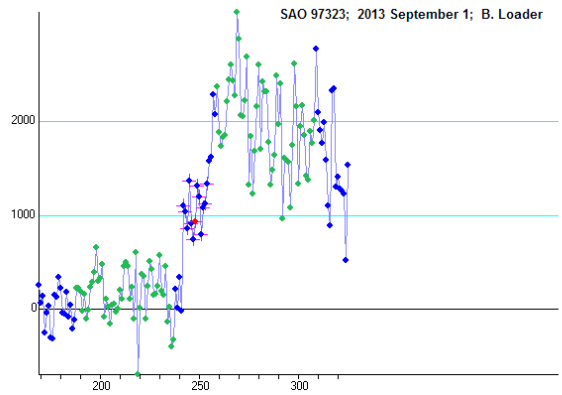

Figure 6: Light curve for the occultation disappearance of SAO 97323 obtained by B. Loader. Light intensity measures have been made for each field, 50 per second. The 0.59 second step is equivalent to a minimum separation of 235 arc-milliseconds. The step height suggests a small, 0.05 magnitude difference between the component stars. The star was at a low altitude, the poor seeing resulting in noisy data.

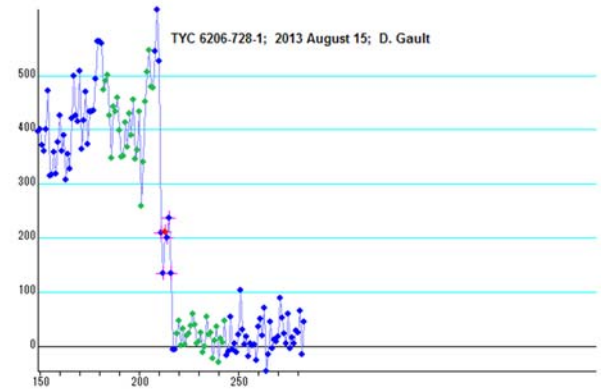

Figure 8: Light curve for the occultation disappearance of TYC 6206-728-1 obtained by D. Gault.. The 0.24 second step equates to a minimum separation of 86 arc-millisecond for the pair. The step height suggests a magnitude difference of about 0.3 between the components with the fainter star being occulted second.

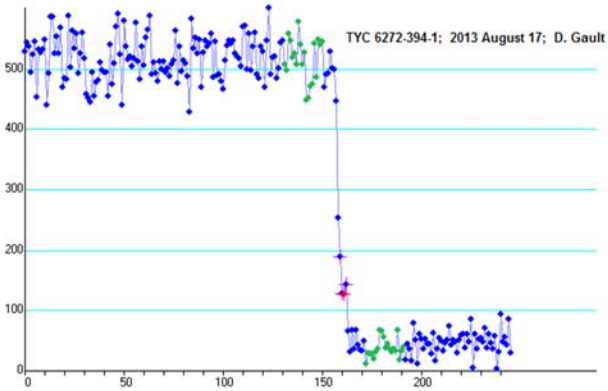

Figure 10: Light curve for the occultation disappearance of TYC 6272-00394-1 obtained by D. Gault. The step lasts for 0.16 second, equivalent to a minimum separation of 67 arc-milliseconds. The low height of the secondary step suggests a 1.3 magnitude difference between the components.

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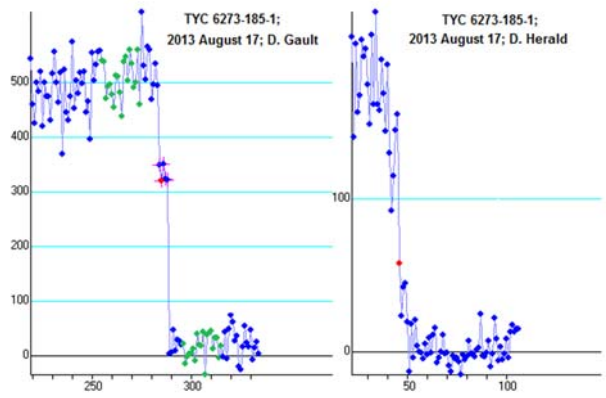

Figure 11: Light curves for the occultation disappearance of TYC 6273-00185-1 obtained by D. Gault and by D. Herald. Gault's step lasts for 0.20 second, equivalent to a minimum separation of 69 arc-milliseconds. The small initial step shows the fainter star was the first to be occulted, and suggests a 0.6 magnitude difference between the components. Herald's observation was 5 minutes earlier, the step lasts for 0.12 second, minimum separation 44 arc-miiliseconds, with the fainter star being the second to disappear. The reversal of order is despite the PAs on the lunar limb of the two events differing by only 5.3°. With two observations the PA of the secondary star can be estimated as 148±3°, but it is not possible to make a reliable estimate of the separation due to the closeness of the limb PAs.

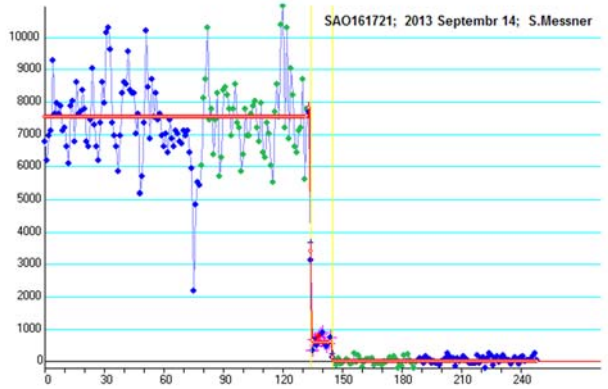

Figure 13: Light curve for the occultation disappearance of SAO 161721 obtained by S. Messner. The step lasts for 0.36 second which is equivalent to a minimum separation of 151 arc -milliseconds. The height of the step suggests a 2.6 magnitude difference between the component stars.

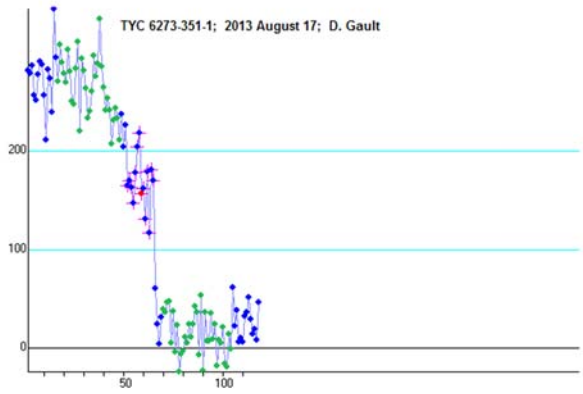

Figure 12: Light curve for the occultation disappearance of TYC 6273-00351-1 obtained by D. Gault. The 0.56 second step is equivalent to a minimum separation of 220 arc-milliseconds. The difference in magnitude of the two components is probably about 0.5.

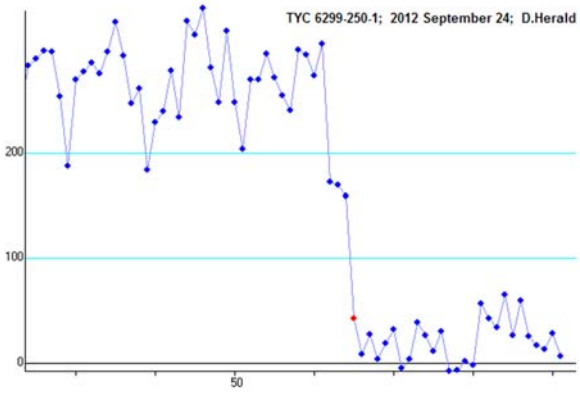

Figure 14: *Light curve for the occultation disappearance of TYC 6299-250-1 obtained by D. Herald. The step lasts 0.12 second which equates to a minimum separation of 43 arc-milliseconds. The magnitude difference suggested by the height of the step is 0.5.*

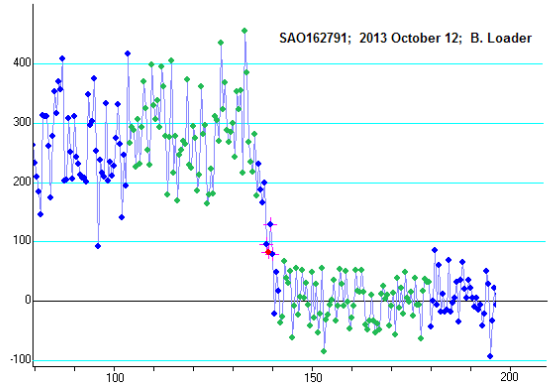

Figure 15: Light curve for the occultation disappearance of SAO 162971 obtained by B. Loader. Light intensity measures have been made for each field, 50 per second. The step lasts 0.08 second which equates to a minimum separation of 40 arc-milliseconds. The magnitude difference of the component stars suggested by the height of the step is 0.7.

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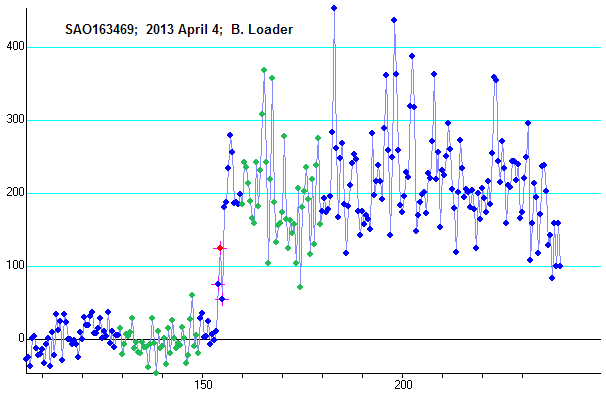

Figure 16: Light curve for the occultation reappearance of SAO 163469 obtained by B. Loader. Light intensity measures have been made for each field, 50 per second. The brief 3 field step last for only 0.06 second, equating to a minimum separation of 21 arc-milliseconds. The magnitude difference of the component stars suggested by the height of the step is about 0.2.

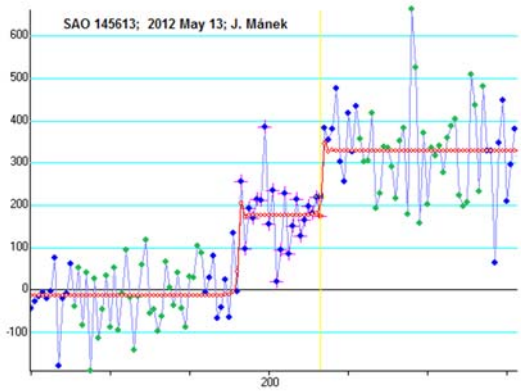

Figure 17: Light curve for the occultation disappearance of SAO 145613 obtained by J. Mánek. Light intensity measures have been made for each field, 50 per second. The step lasts 0.42 second which equates to a minimum separation of 128 arc-milliseconds. The magnitude difference suggested by the height of the step is 0.3.

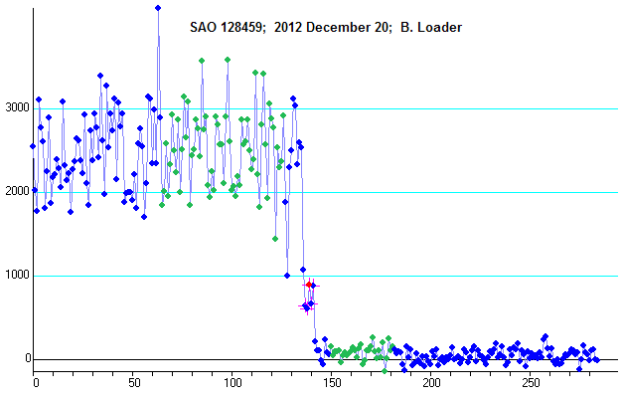

Figure 18: Light curve for the occultation disappearance of SAO 128459 obtained by B. Loader. The step lasts 0.24 second which equates to a minimum separation of 90 arc-milliseconds. The magnitude difference suggested by the height of the step is 1.1.

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Table 3: Companion not observed (possible double star, listed in Interferometric Catalog.)

Star name	OCC #	XZ	RA Dec	Vector angle	Resolution limit	Limiting Mag. diff.	Date	Observer
HD 907	875	214	00135+0628	260.9° 124.5°	0.021″ 0.014″	2.4 2.4	2010.655 2012.897	HK DH
HD 14887	1185	3245	02245+1531	193.6° 109.4° 109.6°	0.016″ 0.018″ 0.018″	2.5 2.5 2.3	2012.581 2012.978 2012.978	JM MI HW
HD 19374	395	4085	03074+1753	279.7° 30.6° 31.6°	0.026″ 0.020″ 0.020″	3.0 3.3 2.3	2012.758 2012.9981 2012.981	MI MI HW
HD 19549	292	4123	03093+2046	35.9° 351.0°	0.020″ 0.003″	1.9 2.1	2011.188 2011.188	KK HT
HD 31071	315	6274	04537+2333	116.1° 86.3°	0.023″ 0.024″	3.1 3.1	2011.119 2011.194	SM KK
HD 31267	685	6315	04553+2340	87.2° 46.1°	0.026″ 0.017″	3.0 2.0	2011.119 2011.194	SM KK
HD 32482	652	6483	05044+2117	79.1° 108.0°	0.038″ 0.025″	3.0 1.8	2012.241 2013137	TH BL
HD 40207	839	7978	05584+2309	117.9° 270.3°	0.029″ 0.027″	2.4 2.5	2011.122 2011.720	EI DG
HD 44253	404	8870	06216+1954	313.2° 57.4°	0.018″ 0.015″	3.3 2.0	2012.843 2013.037	MI HW
HD 83822	306	14639	09412+0860	145.6° 116.5°	0.027″ 0.030″	2.9 3.3	2011.208 2013.452	KK BL
HD 85748	287	14925	09541+0804	106.1° 285.8° 78.7° 86.1°	0.035″ 0.032″ 0.022″ 0.024″	2.8 1.5 3.3 3.3	2011.358 2013.038 2013.228 2013.228	JB DG DG DH
HD 91256	225	15790	10323+0439	71.5° 61.1°	0.019″ 0.015″	3.0 2.7	2013.455 2013.455	DH DG
HD 106384	445	18205	12143-0543	322.5° 44.8° 51.5° 352.0°	0.032″ 0.008″ 0.017″ 0.017″	3.1 2.3 3.0 2.8	2012.188 2012.338 2012.563 2013.086	DH DH DH MI
HD 110299	393	18683	12411-0915	306.8° 43.7° 78.8° 85.6°	0.037″ 0.012″ 0.029″ 0.031″	3.2 2.3 3.0 3.3	2010.992 2011.367 2011.590 2011.590	BL DH DG DH
HD 131337	896	20727	14537-1958	130.3° 236.4°	0.027″ 0.016″	3.0 3.0	2011.521 2012.019	SK MI
HD 150259	49	22507	16406-2025	88.0° 33.4° 31.9°	0.050″ 0.015″ 0.014″	2.3 2.4 2.0	2012.725 2013.549 2013.549	DG TI MI
HD 159160	1504	23668	17340-2302	304.1° 106.1°	0.036″ 0.028″	2.9 3.0	2011.230 2011.604	DH DG
HD 171856	33	25608	18379-2124	67.3° 83.7°	0.030″ 0.030″	3.0 3.3	2011.607 3011.607	DL DG
HD 175453	964	26119	18562-1843	37.1° 119.9°	0.030″ 0.028″	3.1 2.7	2012.656 2012880	DH DG
HD 176124	590	26207	18594-1917	265.4° 224.7°	0.032″ 0.027″	3.3 3.1	2012.281 2012.282	DG BL
HD 184253	971	27204	19342-1719	140.8° 111.2°	0.009″ 0.022″	3.0 2.7	2012.732 2012.732	DG JB
HD 194121	476	28365	20242-1407	277.7° 85.8°	0.036″ 0.029″	2.3 3.0	2012.360 2012.735	BL MF

Table 3 concludes on next page.

Lunar Occultation Observations of Double Stars – Report #4

Table 3 (conclusion): Companion not observed (possible double star, listed in Interferometric Catalog.)

Star name	OCC #	XZ	RA Dec	Vector angle	Resolution limit	Limiting Mag. diff.	Date	Observer
HD200212	914	29204	21024-1227	57.5°	0.029″	2.1	2011.914	HW
				114.6°	0.018″	2.2	2013.710	HW
				113.4°	0.018″	2.0	2013.710	HA
HD203160	946	29578	21208-1121	135.6°	0.006″	2.4	2011.840	HW
				111.5°	0.016″	2.5	2011.840	HY
HD209447	869	30327	22035-0728	24.5°	0.022″	2.3	2010.871	HK
				19.4°	0.021″	2.3	2010.871	KM
				20.7°	0.021″	2.3	2010.871	MI
				202.1°	0.020″	2.7	2013.338	MI
				99.0°	0.024″	2.3	2013.713	HA
HD214376	342	30851	22378-0414	62.0°	0.025″	2.9	2010.724	MI
				170.7°	0.008″	2.0	2011.471	MI
				258.8°	0.030″	3.0	2013.415	MI
HD215708	421	30981	22472-0243	26.4°	0.021″	2.5	2010.874	MI
				356.6°	0.011″	2.8	2012.817	MI
HD216061	355	31022	22497-0222	40.9°	0.026″	2.2	2010.874	MI
				9.3°	0.016″	2.4	2012.817	MI
HD220796	222	31581	23267+0229	276.7°	0.020″	3.0	2010.652	BL
				37.4°	0.030″	2.5	2012.894	DH
HD220858	1641	31588	23272+0107	330.4°	0.004″	2.3	2012.520	JM
				244.4°	0.027″	2.5	2012.670	MI
				72.8°	0.030″	3.0	2013.792	DH

[The 'Resolution limit' is set at no less than two frame intervals [0.080s (PAL) or 0.067s (NTSC)] times the vector rate of motion.]

Apple Valley Double Star Workshop

Mark Brewer[1,5], Eric Weise[2], Reed Estrada[6], Chris Estrada[3,6], William Buehlman[4], Rick Wasson[7], Anthony Rogers[5], and Megan Camunas[4]

1. California State University, San Bernardino, 2. San Diego State University, 3. California State University, Los Angeles, 4. Victor Valley College, 5. High Desert Astronomical Society, 6. Central Coast Astronomical Society, 7. Orange County Astronomers

Abstract: A three-day double star workshop was held at the Lewis Center for Educational Research in Apple Valley, California. Participants gathered from California, Arizona, and Utah to teach and learn about various methods of double star measurements and analysis, and were given the opportunity to do hands-on research with the end goal of publishing their results. The participants learned to operate several telescopes equipped with either an astrometric eyepiece, video camera, Lyot double image micrometer, or a CCD camera. The participants learned how drift analysis, separation, and position angle could help describe a double star. All four teams successfully gathered data on their target stars and will be publishing their results.

The International Association of Double Star Observers (IADSO) and the High Desert Astronomical Society (HiDAS) held a three-day, two-night double star workshop on June 13 – 15, 2013. The workshop was held at the Lewis Center for Educational Research (LCER) (Thunderbird campus) in Apple Valley, California. This was the second annual double star workshop held by the HiDAS taking place in Southern California.

The first day of the workshop, the participants arrived at the Courtyard Marriott Hotel in Hesperia, CA. Afterward the participants went to Las Brisas Restaurant, serving authentic Mexican food, located in Apple Valley, for a meet and greet. After lunch, the participants gathered at the Lewis Center for Educational Research, where they listened to several power-point presentations.

The presentations were designed to help the participants understand double stars and the equipment used for measurements of separation and position angle. Reed and Chris Estrada explained what a double star is and how to use an astrometric eyepiece. In their presentation, they described the functions of the linear scale and the two outer protractors in their Meade eyepiece, and explained how raw data is used to find the separation and position angle of a double star. Eric Weise presented a description of the Lyot double image micrometer. He explained how the crystal inside the micrometer splits the image of the double star into two images. Eric also described the method of using the micrometer by aligning two separate images and applying two equations to measure the separation and position angle of a

Figure 1: A group photo of all participants. Notice Anthony Rogers posing in the slit of the observatory's dome.

Apple Valley Double Star Workshop

Figure 2: From left to right: Eric and Nancy Nelson, Megan Camunas, Mark Brewer, Anthony Rogers, and Deanna Zapata at Las Brisas Mexican restaurant.

Figure 3: Before heading over to the Lewis Center for Educational Research, Russ Genet, Eric Weise, Ryan Gelston, Bobby Johnson, and Vera Wallen take a group photo outside Las Brisas Mexican restaurant.

double star. Rick Wasson explained what a standard monochrome video camera is. He explained how a drift analysis could measure the separation and position angle of a double star. Rick also described the different software and cables needed for data transfer and analysis. Mark Brewer gave a presentation on what a CCD camera is. He explained how a two-dimensional chip gathers electrons from photons to display an object. He also described the software and equations needed to determine the separation and position angle of a double star. After the presentations finished, everyone gathered for dinner at Mama Carpino's Italian restaurant located in Apple Valley.

After dinner, the participants traveled back to Lewis Center for Educational Research. The participants were then split into four different teams. Experience in astronomy and research determined which participants were assigned a particular team. Beginner astronomers and researchers were placed on the astrometric eyepiece team or the Lyot double image micrometer team. Moderate to advance participants were placed on the Video Drift team or the CCD Imaging team.

Six participants were assigned to the astrometric eyepiece team, where they learned the methods of double star measurements with a 22-inch Alt/Az Dobsonian telescope equipped with a modified Meade 12.5mm Micro Guide astrometric eyepiece that had an attached high definition camera. Eight participants were assigned to the Lyot double image micrometer team, where they learned the methods of double star measurements with a

Figure 4: Eric Weise presenting on the Lyot double image micrometer. Notice how he scared everyone out of the first row!

Figure 5: Mark Brewer and Megan Camunas enjoying themselves before dinner arrived.

Apple Valley Double Star Workshop

Figure 6: Eric Weise (left) and Russ Genet (right) inside the Luz observatory.

Figure 7: Anthony Rogers (middle) giving some insight on his Alt/Az Dobsonian telescopes to Earl Wilson (left) and Rick Wasson (right).

14-inch Meade Schmidt Cassegrain telescope equipped with this rare and historic instrument, crafted in the mid twentieth century. Four participants were assigned to the video drift team, where they learned the methods of double star measurements with a 12-inch Alt/Az Dobsonian telescope equipped with a standard monochrome video camera. Seven participants were assigned to the CCD imaging team, where they learned the methods of double star measurements with an 8-inch Meade Schmidt Cassegrain telescope and a 14-inch Meade Schmidt Cassegrain telescope equipped with an SBIG ST8 CCD camera.

The second day of the workshop was focused on data reduction. Several presentations were given describing various methods of reduction, including some time tested, relatively standard procedures as well as methods being developed by participants of the workshop. After the presentations were complete, the participants left for an informal lunch. Once lunch was finished, each team continued reducing and analyzing their data. Before preparation for the second night of observations began, everyone gathered for dinner at Siam Thai Cuisine Restaurant located in Apple Valley. After dinner the participants reconvened at the Lewis Center for Educational Research for their second night of observations.

On the final day of the workshop, the participants met in the lobby of the Courtyard Marriott Hotel where they started structuring the first draft of their scientific research papers for publication in the Journal of Double Star Observations (JDSO). After a first draft was under way, the participants gathered for lunch at the Golden Corral located in Hesperia. This was the last meal of the workshop before the participants headed back to their

Figure 8: William Buehlman (left) and Mark Brewer (right) initializing the SBIG ST8 CCD camera to a MAC computer.

Figure 9: From left to right: Sean Gillette, Reed Estrada, Nancy Nelson, with Vera Wallen taking a measurement. The 22-inch telescope was built by Reed and Chris Estrada.

Figure 10: Eric Weise, Bobby Johnson, Ryan Gelston, and Vera Wallen collaborating on the first draft of their scientific research papers.

Figure 11: Dinner at Siam Thai Cuisine Restaurant.

homes.

Astrometric Eyepiece Team

Workshop participants on the Astrometric Eyepiece Team were Reed Estrada, Chris Estrada, Vera Wallen, Paul Wren, Eric Nelson, and Nancy Nelson. The astrometric team used a 22-inch "push-me pull-me" Dobsonian telescope with a modified Celestron 12.5mm Micro Guide astrometric eyepiece equipped with a Bell and Howell DNV16HDZ 46mm f/2.8-3.5 high definition video camera.

Following Reed and Chris' own method, the team played back their observations with Adobe Photoshop Pro CC software. Both nights, the team measured the drift time, separation, and position angle of double star STFA 58AC, which has a reported separation of about 40.6 arc seconds.

Lyot Double Image Micrometer Team

Workshop participants on the Lyot double image micrometer team were Eric Weise, Russ Genet, Bobby Johnson, Ryan Gelston, Leah Ginsky, Kelsey Dodge, Michael Silva, and Anthony Rogers. The Lyot double image micrometer team used a Meade 14-inch Schmidt Cassegrain telescope with Genet's newly acquired Lyot double image micrometer.

The first night of the workshop yielded the first successful double star measurements using this instrument. The star observed was STF 1744AB (Mizar), which has a reported separation of about 14 arc seconds.

On the second night, the team observed STF 2264, which has a reported separation of about 6 arc seconds. This star and Mizar were both measured 12 times to give the team a reliable standard deviation, and these results will be reported in their paper. For the rest of the night, the team performed a survey of four stars with decreasing separations. Four survey observations were made each of STF 2162AB, STF 2603, and STF 2289, which have a reported separation of 1.3, 3.1, and 1.2 arc seconds, respectively. The purpose of the survey was to find the lower limit of separation that the Lyot double image micrometer could observe. Each system was observed four times to reduce bias for statistical analysis and the report for a scientific paper.

Video Drift Team

Workshop participants on the Video Drift team were Rick Wasson, Earl Wilson, and William Buehlman. In addition, Eric & Nancy Nelson and Deanna Zapata joined the team after the workshop, learning data reduction software techniques and contributing to the paper.

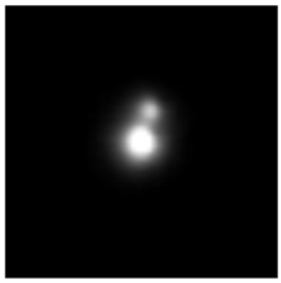
The Video Drift Team used a portable Orion 12-inch f/4.9 Dobsonian telescope, with a video camera in place of a 1¼" eyepiece. A "Kiwi" GPS time inserter, originally intended for accurate timing of asteroid occultations, added a GPS time display to each video frame. A Canon camcorder recorded the digital video stream on cassette tape.

Since the Dobsonian telescope field continuously rotates, the stars were allowed to drift across the video field with the tracking motors off, forming an east-to-west sequence at the sidereal rate. Several "drift times" are typically recorded to the nearest 0.01 seconds. Analysis with specialized freeware programs "VidPro" and "Reduc" produced accurate calibration of field rotation angle and plate scale (arc-seconds per pixel). These programs were then used to measure double star separation and position angle.

The two bright but challengingly close pairs of Epsilon Lyrae (magnitudes 5 to 6, separations < 2.5") were

observed the first night, with a 3x Barlow and a 13% neutral density "moon" filter. No color filter was used. The second night, several faint but wide pairs (magnitudes 10 to 13, separations 6" to 30") were observed, with no Barlow or filter. Unfortunately, on that night, the telescope was not well collimated, the seeing was poor due to hot, windy conditions, and the target stars were quite low in the south. Therefore, the quality of those observations was not as good as typically achieved with the video drift method.

Shown below are typical images of the two Epsilon Lyrae pairs, created using the "Shift & Add" technique of the Reduc program.



Epsilon Lyrae North-West Pair, STF2382AB. Best 118 of 472 Video Frames, Drift "a".

Epsilon Lyrae South-East Pair, STF2383CD. Best 248 of 500 Video Frames, Drift "a".

CCD Imaging Team

Workshop participants on the CCD imaging team were Mark Brewer, William Buehlman, Sean Gillette, Megan Camunas, Alana Brown, Deanna Zapata, Heath Rhoades, and Travis Gillette. The team used an 8-inch Meade Schmidt-Cassegrain telescope with a German Equatorial mount equipped with a SBIG ST8 CCD camera. CCDOps were used for data acquisition and Astrometrica was used for data analysis.

The first night of observations, the CCD Imaging team experienced issues initializing the SBIG ST8 CCD camera to CCDOps. A driver failure was likely the problem. The rest of the night consisted of trouble-shooting without any observations recorded.

On the second day of the workshop, Mark Brewer, William Buehlman, and Megan Camunas spent their lunch solving the CCD initialization problem. They determined that the problem from the first night of observations was due to a PC failure to download some of CCDOps' drivers and install them in the correct sequence. Sean Gillette loaned the team his MAC Pro, which had no complications with CCDOps.

On the second night of observations, the CCD imaging team was up and running. They had issues finding a tight focus, however the data gained was sufficient. They were able to use displacement vectors from the two-dimensional CCD chip to measure the separation and position angle of double star STF 2806AB, which has a reported separation of about 14.8 arc seconds.

Lessons Learned

The first lesson learned was of time. The schedule was prepared so several presentations and breaks were available for the participants, though there were times that presentations fell short of the time allotted. Lesson 2 learned was again related to time. The first scheduled dinner took longer than expected, and those team leaders that needed more time with telescope setup were left setting-up in the dark. Another lesson learned was the lack of images taken of the workshop. Lesson 4 learned was having the participants create a lab notebook of their observations/experiments. The final lesson learned was the problem of not recording which double star(s) each team observed. Of course, email afterwards was enough to get that information, but it would have been much more convenient to have those at the time of the event.

Conclusion

The second annual Apple Valley Double Star Workshop was successful. Preparing and executing the workshop was a rich and rewarding experience for Mark Brewer. Outreach was delivered to a local middle school called Vanguard Preparatory School, and an interstate audience was present from Arizona and Utah. A discussion was held between the participants and the CCD imaging team to decide and develop new methods and ideas for reducing the data through the use of their software. The workshop helped Rick Wasson, Reed Estrada, and Chris Estrada gain more experience with using their techniques to measure double stars. The people that were brought together intend to continue working together on other research projects. The workshop has demonstrated that even a modest gathering of people can produce amazing results through partnerships that will last well beyond the end of the workshop. We enjoyed the second annual workshop and hope the participants will be available to join in for the third annual Apple Valley Double Star workshop.

Acknowledgements

A special thanks goes out to the Lewis Center for Educational Research for opening their facility. We would like to thank Russ Genet for all his expertise during the workshop. We would like to thank the external reviewers, Tom Frey, Bob Bucheim, and Vera Wallen. We also would like to thank the High Desert Astronomical Society and the Central Coast Astronomical Society for all their support.

Small Telescopes and Astronomical Research

(STAR III Conference)

Lander University, Greenwood, South Carolina
June 6-7, 2014
http://www.lander.edu/goto/star

Conference Organizers
Lisa Brodhacker, Lander University, lbrodhacker@lander.edu, (864) 388-8187
Russell Genet, California Polytechnic State University, russmgenet@aol.com, (805) 438-3305

The STAR Conference Series

Large telescopes excel in the detailed study of faint objects at the edge of the observable universe, while small telescopes continue their valuable role in astronomical research through time series, networked, and other observations that only large numbers of small telescopes can provide—tasks which are cost prohibitive for large telescopes. Small telescopes also continue to play a vital role in recruiting and training the next generation of astronomers and instrumentalists, and serve as test beds for developments of novel instruments and experimental methods. Finally, small telescopes provide research opportunities for amateur astronomers—the citizen scientists whose research is often of full professional quality.

The Lander Small Telescopes and Astronomical Research (STAR) Conference will explore the many areas of scientific research where small telescopes excel. The workshop will also consider the development of smaller telescopes and their instruments. Finally, the workshop will consider how astronomical research by undergraduate students—even high school students—provides, simultaneously, a unique scientific education, a career boost, and modest contributions to the advancement of science.

In the age of giant telescopes, are small telescopes still useful? Bruce Weaver pointed out that

"Both quantitative and qualitative arguments demonstrate the continuing importance of small telescopes to the astronomical endeavor. The quantitative arguments show that it is significantly less expensive per citation to use the smallest telescope that will accomplish the research. Both the quantitative and qualitative arguments show that the research accomplished by small telescopes is of continuing and lasting significance to the discipline as witnessed by their non-diminishing contribution to astronomy over the last century and the persistence of their citation histories. Astronomy has a history of an essential synergy between small and large telescopes. This synergy can be maintained only if there is a reasonable number of well-maintained, well-instrumented smaller-sized telescopes."

In a similar vein, F. A. Ringwald suggested that "Small telescopes can hold their own with larger instruments since more time is available on them. This makes possible monitoring campaigns, aerial surveys, and time-resolved campaigns, particularly if the telescopes are networked or automated—all difficult to carry out with larger telescopes, for which even small amounts of telescope time are in great demand."

The 2007 report of the Committee for Renewing Small Telescopes for Astronomical Research (ReSTAR) concluded that "The science to be done with small and mid-size telescopes remains compelling and competitive in the era of big telescopes. Small and mid-size telescopes continue to produce innovative science in themselves, and to provide precursor and follow up observations that enhance the scientific productivity of larger telescopes. Small and mid-size telescopes also enable scientific investigations that are not possible on larger telescopes." The ReSTAR report went on to state that "Small and mid-size telescopes contribute additionally to the discipline through their training and educational functions and as test beds for innovative new instrumentation and techniques."

The first Small Telescopes and Astronomical Research conference (STAR I), was held in San Luis Obispo, California, June 19-22, 2008, and was attended by some 60 professional astronomers, amateur astronomers, students, and educators. The conference proceedings remain available as a book, *Small Telescopes and Astronomical Research* (Genet, Johnson, and Wallen 2008) available from both Amazon and the book's publisher, the Collins Foundation Press.

The second Small Telescope and Astronomical Research conference (STAR II) was held in Hawaii on January 1-3, 2009. It was given the special name, *Galileo's Legacy,* in honor of the 400th anniversary of Galileo's

first telescopic observations. Papers from this conference were included in the book, *The Alt-Az Initiative: Telescopes, Mirror, and Instrument Developments* (Genet, Johnson, and Wallen 2010). The conference was held at the Makaha Resort on the leeward side of Oahu. Post conference, many of the participants joined a special "insider's tour" of the Big Island and telescopes on Mauna Kea.

The STAR III Conference at Lander University will highlight successful small-telescope research conducted during the five years since the last STAR conference. It will cover recent telescope, mirror, and instrumental developments. Finally it will describe the expanding programs of undergraduate and even high-school student astronomical scientific research and engineering development at many schools.

STAR I was held in San Luis Obispo, California, and was an eclectic mixof professional and amateur astronomers, and students and educators.

STAR II, given the special name "Galileo's Legacy" was held in Hawaii and featured a post conference insider's tour of large telescopes on Mauna Kea including the 8-meter Gemini North.

Conference Agenda

Thursday evening, June 5th

7:00-8:00 Public talk on binary stars (Russ Genet)
8:00-10:00 Preconference dinner and discussions at O'Charley's Restaurant

Friday, June 6th, Scientific Research Programs and Instruments

9:00-9:15 Welcome by Lander University President, Dr. Dan Ball
9:15-9:30 Introductions to the conference (Brodhacker & Genet)
9:30-10:30 Double star astrometry
10:30-11:00 Break
11:00-12:00 Asteroid and lunar occultations high-speed observations
12:00-1:30 Lunch
1:30-2:30 Variable star and exoplanet transit photometry
2:30-3:00 Break
3:00-4:00 Spectroscopy and polarimetry
4:00-4:30 Tour of the Lander Mirror Laboratory
6:00-9:00 Social hour and dinner at Fin & Filet Restaurant

Saturday, June 7th, Engineering Developments and Education

9:00-10:00 Optics (especially mirrors)
10:00-10:30 Break
10:30-11:30 Telescopes
11:30-1:00 Lunch
1:00-2:00 Observatories, automation, and networking
2:00-2:30 Break
2:30-3:30 Student education and amateur outreach
3:30-4:00 Roundtable discussion
6:00-9:00 Banquet at Cambridge House and special speaker

Conference Logistics

Talks and Posters

Attendee PowerPoint talks and posters are strongly encouraged. Talks are strictly 20 minutes in length, including any preliminaries or questions. PowerPoint slides and talks (audio added to the slides) will be posted on line after the conference so those that were unable to attend can benefit. There will be a limited number of call-in talks on critical topics not covered by the attendees.

Registration

While there is no registration fee, registration is still required. Please send an email to both of the conference organizers, Lisa Brodhacker and Russ Genet, with the following information:

** Name, institution, email address, and phone number
** Please let us know if you are planning on a PowerPoint presentation or poster and its title (please keep titles short so we can easily include them in the final agenda).
** Let us know, roughly, your planned arrival and departure times.
** Will you be going to the dinners on Thursday, Friday, and/or Saturday night? We'll need a head count in advance.

Refreshments and Meals

Breakfasts are complimentary at the suggested motels.

Refreshments for the breaks during the conference will be provided by Lander University.
Lunches will be ordered during the morning break and brought in by student helpers. Please have some cash with you to pay for lunches which will run about $10.00.
No host dinners on Thursday and Friday night will be at local restaurants. We will ask for separate checks.
The closing banquet on Saturday evening at Cambridge Hall will be $30.00 per attendee, and can be paid for by cash either or check.

Suggested Motels (All have complimentary breakfasts)

Recommended where most attendees will stay
Holiday Inn Express (rates from $85)
110 Birchtree Dr.
Greenwood SC 29649
1.2 miles to Lander University

Fairfield Inn & Suites (rates from $101)
527 By-pass 72 NW
Greenwood SC 29649
2.6 miles to Lander University

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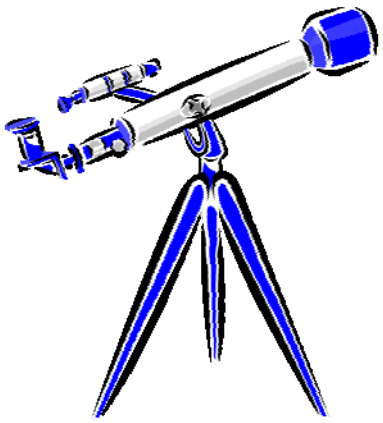
Questions, comments, or submissions may be directed to rclark@southalabama.edu or to rmollise@bellsouth.net

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

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

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

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



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