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Measurements of Neglected Double Stars: November 2014 Report

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Abstract: This article presents measurements of 30 neglected double stars. The stars were selected from the Washington Double Star Catalog published by the United States Naval Observatory. The photographs were taken by a remote telescope. The measurements were done by the author.

Methodology

The photographs were taken using a telescope located in the Canary Islands near the west coast of Africa. The telescope is located at an elevation of 2,300 meters. The instrument has a focal length of 3,910mm, an aperture of 356mm, and is a Celestron unit of Schmidt-Cassegrain design. The observatory, which is called SLOOH, is a part of the Institute of Astrophysics. The methods used to calibrate the instruments of the SLOOH Observatory are unknown to this author.

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

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

After accumulating the photographs, averages were calculated for the position angles and separations. All of the star patterns were compared with the data from ALADIN (part of the SIMBAD site) or with the SKY X program, to insure correctness.

After measuring each star and calculating the results, comparisons were made with the published data. The results are listed in the table. The numbers in the table represent averages of measurements, or, in the case of a single measurement, the actual value.

Report

The following information was reported for each star: the WDS code with components, the discoverer code, the constellation, the position angle, the separation, the date of the first observation, and, under measures by the author, the results of other authors. The number of measurements for WDS values was the number of past observations reported in the WDS prior to these current observations.

The column headings are: number of the Washington Double Star and components, DC = Discovery Code, PA = position angle, Sep = Separation, Mts = number of measurements, Con = Constellation, and the first observation date.

Acknowledgements

Grateful appreciation is extended to Russell Genet for his guidance and to Thomas Smith for his support.

This research made use of the SIMBAD database operated at CDS, Strasbourg, France, and the Washington Double Star Catalog maintained by the United States Naval Observatory.

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WDS number/Comp	D.C.	P.A.	Sep	Mts	Con	Date
00313+6321 AB	**BU 107**	***354.2***	***5.7***	**1**	**CAS**	**2014.641**
WDS		0	2.0			1873
WDS		354	5.8	25		2012
00313+6321 AC	**BU 107**	***336.8***	***46.8***	**1**		**2014.641**
WDS		336	46.9			1898
WDS		337	46.9	14		2012
00313+6321 AD	**BU 107**	***145.2***	***51.7***	**1**		**2014.641**
WDS		146	50.3			1898
WDS		145	51.8	14		2012
00313+6321 AE	**BU 107**	***171.4***	***111.4***	**1**		**2014.641**
WDS		171	113.6			1898
WDS		172	112.4	12		2012
00313+6321 AF	**BU 107**	***114.2***	***154.1***	**1**		**2014.641**
WDS		115	150.5			1898
WDS		115	154.3	13		2012
00313+6321 AG	**LV 13**	***265.3***	***20.8***	**1**		**2014.641**
WDS		267	21.2			1916
WDS		266	21.1	7		2012
00313+6321 AH	**BU 107**	***93.0***	***46.0***	**1**		**2014.641**
WDS		94	45.6			1908
WDS		94	46.3	9		2012
00313+6321 BC	**BU 107**	***334.5***	***41.4***	**1**		**2014.641**
WDS		334	41.5			1898
WDS		335	41.3	14		2012
00313+6321 BD	**BU 107**	***147.9***	***56.7***	**1**		**2014.641**
WDS		149	55.4			1898
WDS		148	57.0	15		2012
00313+6321 CD	**BU 107**	***150.7***	***98.***	**1**		**2014.641**
WDS		151	96.8			1898
WDS		151	98.1	16		2012
00313+6321 CE	**BU 107**	***167.1***	***157.2***	**1**		**2014.641**
WDS		167	159.4			1898
WDS		168	158.1	13		2012
00313+6321 DE	**BU 107**	***190.7***	***69.0***	**1**		**2014.641**
WDS		188	71.3			1898
WDS		191	69.1	13		2012
BD+62 94						

Other identifiers: ADS 423 AB, BD+62 94; CCDM J00313+6320AB; HIC 2460; HIP 2460

Measurements of Double Stars: November 2014 Report

WDS number/Comp	D.C.	P.A.	Sep	Mts	Con	Date
13288+5956 CA	**S 649**	***110.6***	***182.2***	**1**	**UMA**	**2014.422**
JDSO (Arnold)		110.3	181.7			2013
Tycho -2		110.3	182.1			1991
WDS		262	20			1831
WDS		111	181.7	11		2012

Other identifiers: BD+60 1461; CCDM J13286+5956ABC

15511-5503 AB	**DUN 193**	***15.3***	***16.2***	**4**	**NOR**	**2014.515**
O A G (Duque)		13	16.8			1988
Tycho -2		12.7	16.7			1991
Webb (Argyle)		10.1	15.8			2013
Webb (Nicholson)		12.4	16.5			1999
WDS		19	22.5			1836
WDS		10	15.8	24		2013
15511-5503 AC	**ARY 99**	***20.8***	***50.9***	**4**		**2014.515**
WDS		19	50.2	1		2013

Other identifiers: ALS 15016; GSC 08701-00350; HIP 77645; SAO 243044

16057-0617 AC	**STF 2005**	***232.3***	***30.1***	***2***	**OPH**	**2014.370**
WDS		231	20.0			1835
WDS		232	29.0	15		2000
16057-0617 AD	**STF 2005**	***201.5***	***55.3***	***2***		**2014.370**
WDS		185	35.0			1835
WDS		200	55.4	10		2000
16057-0617 AE	**SHY 696**	***270.5***	***260***	***2***		**2014.370**
WDS		271	259.4			1991
WDS		270	259.4	4		2000
16057-0617 CD	**STF 2005**	***175.8***	***34.2***	***2***		**2014.370**
WDS		151	25.4			1835
WDS		174	34.2	9		2000

Other identifiers: ADS 9918 C; BD-05 4324C; CCDM J16057-0617C; CSI-05 4234 2; GEN +1.00144362C; IDS 16004-0601 C; UBV 13628

17211+0127 AB	**STF 2150**	***213.6***	***11.7***	**1**	**OPH**	**2014.625**
WDS		185	8.1			1832
WDS		213	11.6	25		2013

Other identifiers: AG+01 1959; BD+01 3422; GSC 00400-00165; HIP 84919; SAO 122303; TD1 20301; TYC 400-165-11; UBV 14791; YZ 1 2410

Measurements of Double Stars: November 2014 Report

WDS number/Comp	D.C.	P.A.	Sep	Mts	Con	Date
17311+1027 AB	**STF 2176**	***16.8***	***16.8***	**1**	**OPH**	**2014.625**
JDSO (Schlimmer)		17.0	16.7			2013
WDS		9	16.9			1829
WDS		17	17.1	24		2004
17311+1027 AC	**GUI 19**	***71.4***	***89.9***	**1**		**2014.625**
Tycho-2		71.2	89.9			1991
WDS		71	90.5			1908
WDS		71	89.3	17		2013

Other identifiers: AG+10 2067; BD+10 3225; GSC 00996-01492; SAO 102878; TYC 996-1492-1

17344+1310 AB	**STF 2184**	***65.3***	***22.7***	**1**	**OPH**	**2014.625**
JDSO (Schlimmer)		65.7	22.7			2010
JDSO (Schlimmer)		64.9	22.8			2012
WDS		82	15.9			1783
WDS		65	23.7	25		2013

Other identifiers: AG+13 1693; BD+13 3397; GSC 01004-00180; HIP 85979; SAO 102925; TYC 1004-180-1; YZ 13 6159

17344+2520 AB	**HJ 1300**	***263.5***	***12.3***	**3**	**HER**	**2014.608**
JDSO (Arnold)		256.9	13.3			2006
WDS		300	8.0			1828
WDS		264	12.2	13		2013
17344+2520 AC	**SLV 5**	***241.3***	***15.5***	**3**		**2014.608**
WDS		264	13.9			1897
WDS		241	15.4	13		2013
17344+2520 BC	**HJ 1300**	***192.9***	***6.2***	**3**		**2014.608**
WDS		190	2			1828
WDS		193	6.2	9		2002

Other identifiers: ADS 10637; GSC 02079-00082; TYC 2079-82-1; UCAC3 231-130475

18209+0323 AB	**HJ 5495**	***284***	***27.5***	**2**	**OPH**	**2014.625**
Webb (Nicholson)		283.9	27.1			2002
WDS		290	18			1827
WDS		284	27.1	12		2002
18209+0323 AC	**HJ 5495**	***81.4***	***57.9***	**2**		**2014.625**
JDSO (Nicholson)		81.9	58.4			2002
WDS		80	58			1912
WDS		82	58.4	6		2002

Other identifiers: ADS 11271 A; BD+03 3680; GSC 00436-03545; HIP 89918; SAO 123377; TYC 436-3545-1; YZ 3 6199

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WDS number/Comp	D.C.	P.A.	Sep	Mts	Con	Date
18289+3515 AB	**POP 34**	***2.6***	***6.6***	**8**	**CYG**	**2014.405**
WDS		79	2.9			1969
WDS		4	6.4	19		2011

Other identifiers: BD+34 3568; CCDM J19289+3515AB; IDS 19252+3503

19464+3344 AB	**STF 2580**	***68.8***	***26.3***	**4**	**CYG**	**2014.405**
JDSO (Arnold)		69.0	26.2			2010
JDSO (Carro)		68.9	25.5			2011
JDSO (Malwald)		68.2	26.1			2012
JDSO (Schlimmer)		68.1	26.0			2006
WDS		73	25.5			1822
WDS		70	25.6	73		2013

Other identifiers: 17 CYG; ADS 12913; BD+33 3587; HD 187013; HIP 97295; HR 7534; SAO 68827; TYC 2660-04227-1

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A New Visual Binary System in Auriga

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Abstract: A new visual binary system is reported in Auriga, currently not listed in the WDS catalog. The components have been determined to be a pair of G-type main sequence stars that lie close to a least squares negative exponential curve, which places the pair at a distance of some 300 to 500 ly from Earth.

Introduction

I had first noticed this pair on the moonless night of September 24th 2014 whilst sweeping the star fields surrounding the red-tinted carbon star UU Aurigae. My initial reaction was how aesthetically beautiful this pair had seemed, all so neatly presented in the eyepiece with a small Δm and that the components were not too widely spaced apart. It wasn't until October 21st 2014 that I had determined the system was in fact a true CPM binary. That same night of October 21st, once the clouds had shifted, the skies turned out to be pristinely clear with steady seeing conditions and so I set about finding the pair again in my 120mm refractor. They were easy to spot about 2.9° to the lower left of UU Aurigae, as shown in Figure 1.

I then had the pleasure of making a drawing of the field, and this is shown in Figure 2.

The components of this binary have Tycho 2 designations: TYC 2443-146-1 and TYC 2443-337-1, located in the sky at 2000 ICRS: 06 38 48.17 +35 36 29.6 (J2000.0), and they are of UCAC4 apparent visual magnitudes 10.17 and 11.39, respectively.

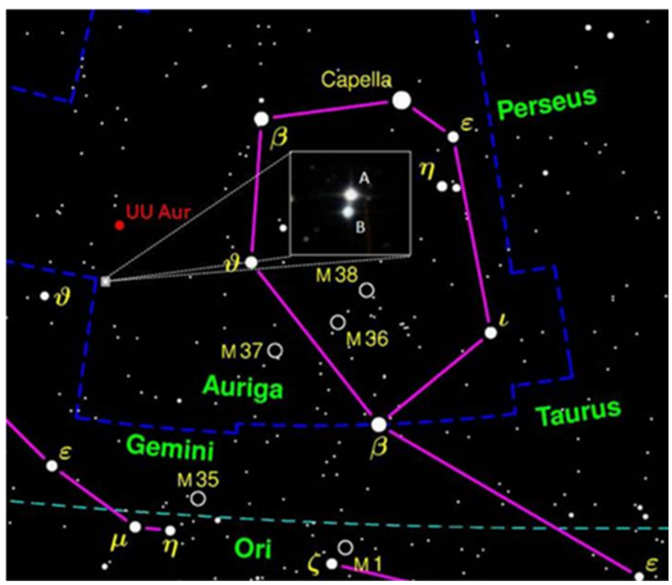

Figure 1: Location of the new binary south of UU Aurigae

Observations and Analysis

The system was later imaged using the 0.61 meter Cassegrain telescope of the Sierra Stars Observatory Network on November 3, 2014, from which the position angle and separation were deduced for epoch 2014.841:

PA: 172.6°
Sep: 15.61″

The UCAC4 catalog [1] revealed the two stars to be sharing virtually identical proper motions, shown in Table 1.

A New Visual Binary System in Auriga

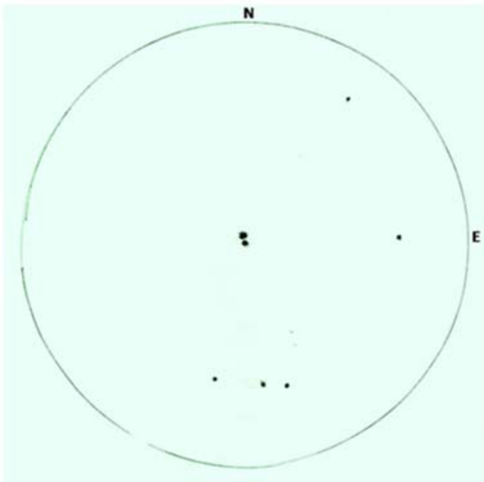

Figure 2: Pencil sketch made with a 120mm (4.75") refractor at a magnification of x159. The FOV is about 10 arcminutes in radius and the faintest stars are of magnitude 12.

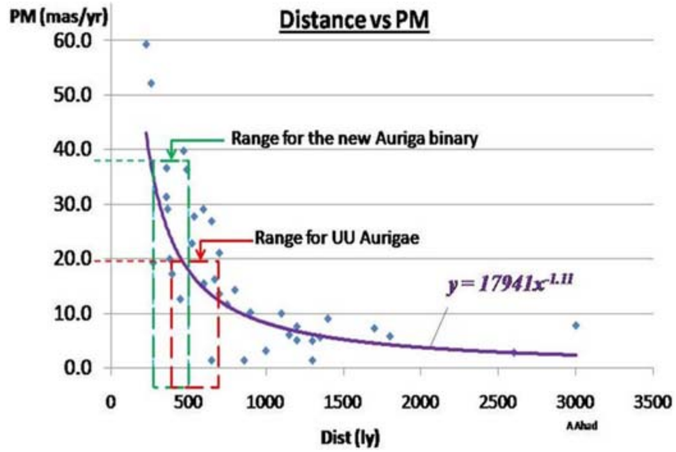

Figure 3: The negative exponential determined by the author to fit a least-squares regression curve, showing statistically significant distance ranges for both the new binary and UU Aurigae.

A total proper motion, $\mu = (\mu_\alpha^2 + \mu_\delta^2)^{1/2} = 37.8$ mas yr^{-1} was computed for the pair. Referring back to my earlier work, the use of the inverse correlation between distance and proper motion which I had first postulated in 2011 (Ahad 2011, Webb Society DSSC 19, page 48, Table 1) to be a predictive tool for gauging astrophysical characteristics of wide double stars, was further expanded over a larger sample of stars and then fine-tuned to both a tabular, as well as a graphical, form. The latter is shown in Figure 3.

Through successive iterations and some trial and error, I derived a least-squares negative exponential to fit the centreline:

$$y = 17941\ x^{-1.11}$$

where x is the distance in light-years and y the total annual proper motion in milliarcseconds. It will be seen from the chart that a total PM of 37.8 mas yr^{-1} places this new Auriga binary at a distance range of some 300 to 500 light-years (90 to 150 parsecs) from Earth. The curve in Figure 3 can, in fact, be used as a general reference tool to ascertain a more statistically rigorous distance estimate for both single and multiple stellar systems in cases where trigonometrical parallaxes have either not been determined at all, or have been poorly determined. Whereas trigonometrical parallaxes can be highly uncertain for stellar systems going into great distances exceeding of the order of 1000 light-years or more, it is the author's personal experience that the proper motion errors can often be much more manageable way beyond such distance thresholds. The carbon star UU Aurigae is a good candidate case to illustrate this point. UU Aurigae is in its own right a 'Washington Double Star' (WDS 06365+3827), though not a binary, attended by a wide unrelated companion of magnitude 11.77. Distance estimates for UU Aurigae A tend to be highly uncertain in the literature. Values typically range from 1600 to 1800 light-years, with a ±800 light-year error margin. The measured parallax of UU Aurigae is 1.80 mas, with a high uncertainty of ±0.81 mas (45% error), whereas the proper motion of this star is stated as 20 mas yr^{-1}, with an uncertainty of ±1.0 mas yr^{-1} (just 5% error). In these circumstances, it would make more sense to use the proper motion to estimate the distance of UU Aurigae rather than its unreliable parallax. Hence, a more reasonable estimate for the distance of UU Aurigae would perhaps be in the 400 to 700 light-year distance range, as shown by the red dotted line in Figure 3.

Table 1: Proper Motion of Components

	μ_α mas yr^{-1}	Error mas yr^{-1}	μ_δ mas yr^{-1}	Error mas yr^{-1}
Primary	+7.7	±1.0	-36.9	±0.9
Companion	+7.8	±0.8	-37.1	±1.1

From the 2MASS catalog [2] we find J and K magnitudes, color indices (J-K), and likely spectral types [3] for the components of this new CPM binary as shown in Table 2.

Fitting the apparent visual magnitudes of the components of 10.17 and 11.39 to average absolute magnitudes for a pair of G1V + G8V stars in the distance modulus equations, we project spectral distances of 405

Table 2: 2MASS photometry, color indices, and spectral types

	J-mag	K-mag	Color Index (J-K)	Spec Type
Primary	9.157	8.836	+0.32	G1V
Companion	10.229	9.859	+0.37	G8V

ly and 428 ly, respectively, for the A and B components of this Auriga binary. These distances are close enough to one another and fit well within the 300 to 500 ly distance range derived earlier from proper motions, hence the whole scenario proves this to be a visual binary system with gravitationally connected components.

References

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

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

Double Star Measurements for 2011 Part 2

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Abstract: I report 65 measurements of binary systems from 2011.772 to 2011.774. The observations were conducted with the T11 robotic telescope located at the iTelescope Observatory, Mayhill, NM, USA . Discussion includes notes on a number of the observed doubles. Information about instrumentation and methodology and results are included.

Introduction and Instrumentation

I have been imaging double stars for a number of years using the equipment at iTelescopes remote observatory.

The program of measuring the visual doubles used the T11 telescope in Mayhill, NM. The instrument is a Planewave 20 in Dall-Kirkham Astrograph with a focal length of approximately 2280 mm. The CCD camera is a FLI ProLine PL11002M with 9um square pixels. The field of view is 36.2 X 54.3 arc-mins. The OTA is mounted on a Planewave Ascension 200HR.

The instrument is capable of quickly and accurately slewing to a selected double star. The system takes about one minute to cycle through an exposure and save the resulting image in a FITS format. Taking 5 to 6 exposures per double star allows 6 doubles to be imaged per hour. The relatively short focal length of this system restricts measurements of doubles to pairs > 10 arc-seconds in most cases.

Methods

Imaging was done by entering the coordinates of the double into the robotic telescope's web interface. A test exposure was done and checked for centering and proper exposure. If all was well, an exposure run of 5 to 7 images through a clear filter was done for each pair. Exposures typically ran about 10-15 seconds for 10-13 magnitude doubles. After the observing session was completed, the images were retrieved from an ftp site provided by the iTelescope observatory.

Each image in the exposure sequence was examined and any trailed or sub-par images were discarded. MOP Canopus (Warner, 2006) was used to reduce the images. Any image for which the software could not reach a plate solution was also discarded. Canopus produces an astrometric solution to the image based on the UCAC2.0 catalog (Zacharias et all.,2004) or the MSOSC catalog (USNO and Tycho data) in areas not covered by UCAC2.0. The software measures double stars using a subroutine built into Canopus. It also produces a great amount of information about the astrometric solution. All images were copied to archival CD -ROM material and are available by request from the author. Each starting and ending image was blinked—just in case.

Results

Table 1 shows the results for the 65 doubles measured.

Double Star Measurements for 2011 Part 2

Table 1: Measures of Double Stars

WDS ID	Discoverer	PA	SEP	EPOCH	No.	PAsd	SEPsd	Notes
19293+0223	J 2176 AB	359.6	31.47	2011.772	4	0.07	0.03	
19297+2453	POU3860	75.9	10.21	2011.774	5	0.18	0.04	
19298+2123	LDS1023	268.4	227.64	2011.772	5	0.01	0.03	1
19298+0239	BAL1994	297.6	10.52	2011.772	4	0.49	0.08	
19299+2440	POU3862	171.6	16.20	2011.774	5	0.22	0.05	
19306+2450	POU3874	80.9	16.83	2011.774	5	0.14	0.02	
19314+2437	POU3876	185.0	15.57	2011.774	5	0.11	0.01	
19316+2441	POU3879	37.7	12.67	2011.774	5	0.15	0.03	
19317+2432	POU3880	137.0	15.92	2011.774	5	0.09	0.02	
19319+2420	POU3882	111.7	11.04	2011.774	5	0.10	0.05	
19321+2441	POU3885	208.4	9.64	2011.774	5	0.25	0.06	
19328+2444	POU3895	211.0	9.06	2011.774	5	0.49	0.08	
19329+2443	POU3897	312.7	16.54	2011.774	5	0.16	0.04	
19355+3019	SLE 639	11.0	11.36	2011.772	5	0.14	0.03	
19376+3030	LDS1026	138.3	17.91	2011.772	5	0.08	0.02	
19386+3026	SLE 653	338.3	11.49	2011.772	5	0.19	0.04	
19537+3442	SEI 716	110.2	23.18	2011.772	5	0.04	0.03	
19547+3453	SEI 723 AB	41.2	12.41	2011.772	5	0.04	0.01	
19547+3453	TOB 162 AC	253.4	24.17	2011.772	5	0.07	0.02	2
19557+3443	HLM 33 AB	76.7	11.73	2011.772	5	0.11	0.02	
19557+3443	HLM 33 AC	291.4	14.76	2011.772	5	0.11	0.02	
19537+3442	HLM 33 AD	129.7	13.36	2011.772	5	0.10	0.03	
19561+3457	HLM 34	12.6	9.80	2011.772	5	0.13	0.04	
19564+3448	SEI 737	67.5	25.77	2011.772	6	0.10	0.03	
20041+2347	POU4198	247.6	18.44	2011.774	5	0.09	0.01	
20057+2336	POU4208	169.3	19.18	2011.774	5	0.08	0.03	
20057+2336	POU4211	12.8	14.21	2011.774	4	0.18	0.02	
20065+2338	POU4216	300.8	13.30	2011.774	5	0.10	0.02	
20067+2358	POU4217	210.5	14.36	2011.774	5	0.21	0.02	
20120+2328	POU4264	353.0	16.47	2011.774	5	0.14	0.03	
20126+2326	POU4272 AB	31.8	13.56	2011.774	5	0.10	0.05	
20128+2331	POU4275	83.0	10.31	2011.774	4	0.25	0.06	
20130+2346	POU4278	15.7	11.42	2011.774	5	0.25	0.10	
20132+2342	POU4281	348.7	5.53	2011.774	5	0.76	0.40	
20133+2345	POU4283	173.1	9.90	2011.774	5	0.24	0.06	
20135+2325	POU4284	342.7	14.51	2011.774	6	0.19	0.03	
20136+2334	POU4287	63.3	15.41	2011.774	6	0.15	0.02	
20137+2333	POU4288	104.5	14.58	2011.774	3	0.06	0.01	
20138+2334	BKO 807 AB	170.9	9.91	2011.774	4	0.22	0.03	
20138+2340	POU4289	80.0	8.84	2011.774	6	0.25	0.08	3
20140+2335	POU4292	348.4	12.00	2011.774	4	0.13	0.06	
20142+2340	POU4294	155.1	13.11	2011.774	5	0.21	0.05	
20143+2328	POU4296	80.6	15.41	2011.774	5	0.10	0.03	

Table concludes on next page.

Double Star Measurements for 2011 Part 2

Table 1 (conclusion): Measures of Double Stars

WDS ID	Discoverer	PA	SEP	EPOCH	No.	PAsd	SEPsd	Notes
20143+2343	POU4297	296.3	13.64	2011.774	5	0.13	0.01	
20309+2339	POU4545	254.0	11.81	2011.774	5	0.31	0.06	
20310+2323	POU4548	8.0	14.18	2011.774	5	0.11	0.04	
20313+2330	POU4556	335.3	7.10	2011.774	5	0.36	0.14	
20315+2336	POU4560	343.6	10.19	2011.774	5	0.28	0.06	
20326+2325	POU4594	214.8	18.97	2011.774	5	0.09	0.03	
20327+2327	POU4602	11.5	8.31	2011.774	5	0.24	0.12	
20322+2330	POU4622	349.4	8.52	2011.774	6	0.31	0.09	
20322+2335	POU4625	42.4	10.39	2011.774	5	0.21	0.04	
20333+2341	POU4633	177.4	11.56	2011.774	5	0.17	0.08	
20337+2316	POU4647	206.8	11.09	2011.774	5	0.30	0.04	
20338+2329	POU4651	226.9	22.30	2011.774	5	0.14	0.02	
20340+2330	POU4654	154.0	15.76	2011.774	5	0.11	0.04	
21586+0931	HJ 3077	36.0	35.63	2011.772	5	0.05	0.02	
22306+3706	HJ 1774 AB	53.0	15.94	2011.772	5	0.10	0.04	
22306+3706	HJ 1774 AB	322.0	29.15	2011.772	4	0.13	0.04	
22308+3708	ALI 456	212.2	14.66	2011.772	5	0.09	0.05	
22322+3659	LDS1057	353.8	57.83	2011.772	5	0.02	0.03	
22441+4029	LDS1064	270.8	18.84	2011.772	5	0.09	0.03	4

Table 1 Notes:

1. LDS 1023. This seems to be a cpm pair. “A” is TYC 1613 561, proper motion PA -64 dec -130. “B” is TYC 1613 520, proper motion PA -57 dec -128.
2. TOB 162 BC. This seems to be a cpm pair. “B” TYC 2677 967, proper motion, PA -62 dec -43. “C” is 4UC625-087839, proper motion PA -60.9 dec -39.8.
3. POU 4289. “B” star is much brighter in CCD image. POU stars are often reversed in visual and CCD brightness as the original plates were blue sensitive. “A” star is 2MASS 20134816+2340206 listed mag is 12.384. “B” star is 2MASS 20134881+2340221 listed mag is 10.262.
4. LDS 1064. This seems to be a cpm pair. “A” is TYC 3218 905 proper motion PA -75 dec -119. “B” is TYC 3218 907 proper motion RA -74 dec -121.

Acknowledgments

As usual, “thanks” to B. Mason and W. Hartkopf for being willing to work with amateurs and for answering numerous data requests. Special “thanks' to my sister Gail Smith for proofreading this article.

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

This research made use of the VizieR Catalog Access Tool, CDS, Strasbourg, France. The original description of the VizieR service was published in A&AS 143,2.

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A New Double Star in Cepheus

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Reprinted from http://mainsequence.org/html/wds/tvb7/tvb_7.html

Abstract: A new double star has been found in Cepheus, at 21:55:22.8 +65:01:40.8, J2000. A measurement made with the Aladin tool[1] of the new double gives 15.6 arc seconds of separation and a position angle of 27°. The APASS[2] visual magnitudes, as reported by the UCAC4[3] are 11.1 and 11.35. Historical data from the stars are listed, as are distance estimates to the pair.

A new double star has been found in Cepheus at R.A. = 21:55:22.8, dec. = +65:01:40.8, J2000.The pair was found while observing STT 457, WDS ID: 21555+6519. Using the Aladin tool, UCAC4 listed the proper motions (in milliarcseconds per year) of the pair as:

Primary pmRA: -0.5, pmDec: -5.8.
Secondary pmRa: -0.8, pmDec: -8.2.

This was reported to William Hartkopf[4] of the USNO[5], who has included it in the WDS[6] as TVB 7.

The primary's UCAC4 id is 569-000097, and the secondary's UCAC4 id is 569-000094.

Dr. Hartkopf researched the new pair and emailed me his results:

"I extracted Tycho[7], UCAC4, and 2MASS[9] measures, as well as two photographic measures from 1895 and 1903 - so 5 astrometry measures spanning over a century, plus 5 additional photometry measures."

These results are shown in Table 1. Column headings in the table are defined as follows:

- Date is the date of the observation.
- Rho is the separation angle, in arc seconds.
- Errors in rho are also in arc seconds.
- Theta is the position angle, in degrees.
- Errors in theta are also in degrees.
- A mag is the magnitude of the primary.
- B mag is the magnitude of the secondary.
- FEW: Filter effective wavelength, in nanometers.
- FWHM: Full width at half maximum, in nanometers.
    - Note: A "B" designates a blue magnitude, where the filter information was not accurately known.
- Aperture: Telescope aperture, in meters.
- Obs ct: Number of observations used to generate the data.
- Sources (With publication year appended):
    - WFC: From the Washington Fundamental Catalog[10]
    - TYC: From the Tycho catalog.
    - TMA: From the 2MASS catalog.
- Type: The observation's data type.
    - Pa: Photographic technique with an astrograph.
    - Ht: Tycho data from the Hipparcos satellite.
    - E2: 2MASS data.
    - Eu: UCAC data.

Based on the Wikipedia H-R diagram[9] and UCAC4 blue and visual magnitudes, the primary appears to have a spectral class of A8, and the secondary F9. Assuming these stars to be main sequence dwarves, this gives them approximate absolute magnitudes of +4 and +6. Using the well known distance modulus equation:

$$M - m = 5(\log_{10}(d)) - 5$$

where M is the absolute magnitude, m the apparent magnitude, and d is the distance in parsecs. Solving for d gives:

$$d = 10^{((m - M + 5) / 5)}.$$

Distances of 250 and 120 parsecs result from the abso-

Table 1. Historic Measurements of the New Double Star Extracted by W. Hartkopf

Date	Rho	Error in rho	Theta	Error in theta	A mag	Error in A mag	B mag	Error in B mag	FEW	FWHM	Aperture	Obs ct	Source	Type
1895.88	23.9	_	15.857	_	-	-	-	-	-	B	0.3	1	WFC1998	Pa
1903.73	26.7	_	15.780	_	-	-	-	-	-	B	0.3	1	WFC1998	Pa
1991.66	26.8	_	15.908	_	11.096	0.077	11.353	0.093	530	100	1.4	1	TY-C2000b	Ht
1991.66	_	-	-	-	11.526	0.072	12.130	0.136	430	90	1.4	1	TY-C2000b	Ht
1999.74	27.1	_	15.71	_	10.062	0.026	10.413	0.026	1256	245	1.3	1	TMA2003	E2
1999.74	_	-	-	-	9.822	0.030	0.174	0.028	1633	160	1.3	1	TMA2003	E2
1999.74	_	-	-	-	9.795	0.021	0.157	0.019	2210	300	1.3	1	TMA2003	E2
2003.702	27.0	0.1	15.746	0.029	10.95	0.03	11.33	0.05	609	70	0.2	4	UC_2013a	Eu

lute magnitudes of +4 and +6, respectively. If they are both subgiants, however, the absolute magnitudes are both close to +3, giving a distance of about 400 parsecs.

Figure 1 is a photo of the new binary from the DSS as rendered by the Aladin Sky Atlas tool.

Note that the proper motions associated with these stars are fairly small, although rho and theta have shown little change from when the pair was first measured. It is hoped that observations from the recent Gaia mission and other subsequent measurements will establish that this pair, and many like it, are physical.

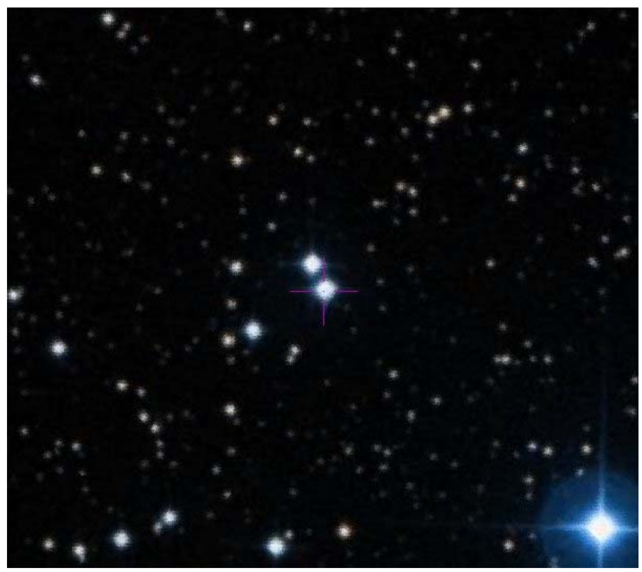

Figure 1. DSS image of the new double star.

Acknowledgements

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

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9) Wikipedia H-R diagram, http://upload.wikimedia.org/wikipedia/commons/6/6b/HRDiagram.png

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A New Visual Binary System in Aquarius

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Abstract: In this paper, a new common proper motion pair is reported in Aquarius, currently not listed in the WDS catalog. From a combination of B, V, J, and K-band photometry, proper motion, and radial velocity observations, the components are shown to be part of a gravitationally connected binary system.

Introduction

A DSS image of this pair, located at ICRS: 20 59 15.95, -08 11 57.6 (J2000.0), is shown in Figure 1.

The primary bears the designations HD199726 and BD-08 5534, and is of V-mag 9.78. The secondary is of an estimated V-mag of ~11.8. The pair was visually sighted and sketched with a Skywatcher Evostar 120mm refractor at 00:25 UT on August 1, 2014 as shown in Figure 2.

Figure 1: Digitized sky survey image of the new binary in Aquarius

It must be stressed, however, the faint companion was only just barely glimpsed through dark adapted

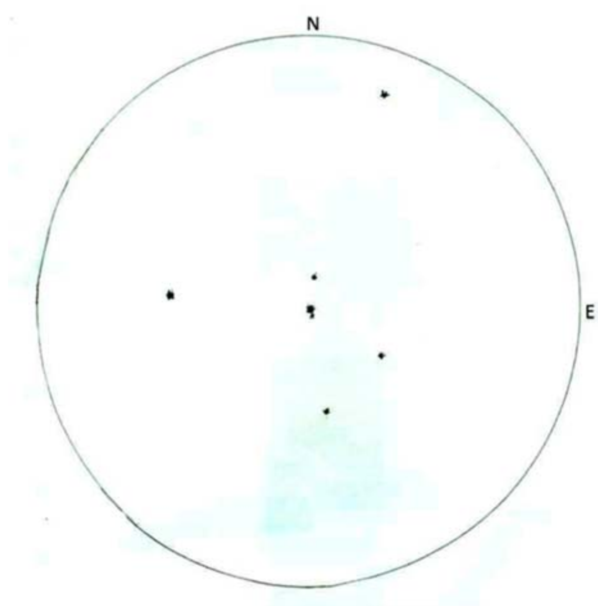

Figure 2: The new binary visually sketched at a magnification of x159.

A New Visual Binary System in Aquarius

Table 1: Proper Motions and Radial Velocities of the Components

	μ_α mas yr^{-1}	Error mas yr^{-1}	μ_δ mas yr^{-1}	Error mas yr^{-1}	Radial Velocity km sec^{-1}	Error km sec^{-1}
Primary	+15.7	±1.6	+2.5	±3.4	+7.98	±1.8
Companion	+16.7	±1.6	+0.0	±1.9	+6.66	±1.9

eyes and using averted vision. The system was later imaged to a greater resolution using the 0.61-meter Cassegrain telescope of the Sierra Stars Observatory Network[1] on 2014 September 4th, which enabled approximate measurements to be taken:

Position Angle: 161.1°

Separation: 10.58″

Proper Motions and Radial Velocities

As mentioned in earlier papers[2], the components of a dynamically associated binary system would, in addition to displaying common proper motions, be expected to have very similar radial velocities. The primary in this Aquarius pair has a measured radial velocity of +7.98 km/sec. Radial velocities of stars as faint as this are generally not so abundantly available, however. In recent years, efforts have been initiated to extend radial velocity measurements across broader regions of the sky and going down to fainter limiting magnitudes.

The Radial Velocity Experiment (RAVE)[3], in particular, is a multi-fiber spectroscopic astronomical survey of stars in the Milky Way using the 1.2-meter UK Schmidt Telescope of the Anglo-Australian Observatory (AAO). From this survey, it has been possible to obtain a radial velocity measurement of the faint companion in this new Aquarius pair. This, along with UCAC4 [4] proper motions for both stars are summarized in Table 1.

We note that the PM vectors and radial velocities of both components are closely aligned, considering the small error margins in each. This is strongly indicative of a binary association between the two stars.

From Table 1, a total proper motion, μ, of 16.3 mas yr^{-1} was computed for the pair, suggesting a distance in the region of about 400 to 700 ly from Earth [5].

Photometry and Distance Calibration

A summary of photometric data, taken from the UCAC4 and 2MASS[6] catalogs, along with spectral classifications are shown in Table 2.

We note that the primary component already has a spectroscopically determined classification of F8V in the catalogs. The K0V classification for the secondary has been determined in this paper as follows: the "K0" part is derived from its 2MASS (J-K) color index of +0.39[7] and the "V" part (main-sequence dwarf) from its apparent visual brightness and estimated distance in the region of 400 to 700 ly, inferred from proper motions[5]. This K0V classification for the secondary is consistent in relation to the primary's already known F8V classification, considering that the two stars have a Δm of 2.0 and share very similar PMs. Now F8V stars generally tend to be of absolute magnitudes of around 4.0 and K0V stars are generally of absolute magnitudes around 5.9[8]. Projecting spectral distances of both components on these assumptions using the distance modulus, we arrive at distances of 467 ly and 494 ly from Earth, respectively, for the A and B components.

These distances are close enough to one another and fit comfortably within the 400 to 700 ly distance range projected earlier from proper motions, again suggesting a true binary system.

Conclusions

On consideration of the astrophysical parameters of this pair discussed in this paper, and the manner in which they all fit together, we conclude that this is a proven gravitationally-connected binary system.

References

1. Sierra Stars Observatory Network (SSON), website: http://www.sierrastars.com

Table 2: B, V, J, and K-band Photometry and Spectral Types

	B	V	J	K	Color Index (B-V)	Color Index (J-K)	Spec Type
Primary	10.202	9.778	9.046	8.824	+0.42	+0.22	F8V
Companion	...	~11.8	10.643	10.250	...	+0.39	K0V

A New Visual Binary System in Aquarius

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Double Star Measurements at the Southern Sky with a 50 cm Reflector and a Fast CCD Camera in 2014

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Abstract: A Ritchey-Chrétien reflector with 50 cm aperture was used in Namibia for recordings of double stars with a fast CCD camera and a notebook computer. From superposition of "lucky images", measurements of 91 pairings in 79 double and multiple systems were obtained and compared with literature data. Occasional deviations are discussed. Some images of noteworthy systems are also presented.

Introduction

As in earlier work, the technique of "lucky imaging" was applied to reduce seeing effects in recordings of double star images by using short exposure times. With only the best frames being registered and stacked, the resolution can approach the theoretical limit of the telescope, and the accuracy of position measurements can even be better than this by about one order of magnitude. More details of the technique are, for example, described in reference [1]. In this paper, measurements on double and multiple systems, made in March/April 2014 in Namibia, are reported. Some are well documented in the literature, such that extrapolations are reasonable and can be used for calibration. For many others, however, only few data exist, and often with large scatter. The present results may help to improve the statistics.

Instrumental

Recordings were made with a 50 cm telescope of Ritchey-Chrétien type (*Alluna*, Germany) at the *Internationale Amateur-Sternwarte* (IAS) in Namibia, which I had already used in 2012 [2, 3]. The focal length is 4.1 m. Imaging was done with a b/w-CCD camera of type "Chameleon" (*Point Grey*). Its small pixel size of 3.75 µm square results in a nominal resolution of 0.19 arcseconds per pixel. This was about halved with a Barlow lens, with only one exception (Acrux). A more exact scaling factor was obtained with calibration stars (see Table 1 and discussion below).

Recordings were made with red or near-infrared filters to reduce seeing effects and the atmospheric spectrum, and especially when using the Barlow lens, to reduce chromatic aberration. Exposure times were varied between 0.1 msec and 350 msec, depending on the brightness and on the seeing conditions. The best frames, typically several tens up to more than one hundred, were later selected and stacked, as described earlier.

Position angles were obtained as usual by recording trails in an east-west direction, while the telescope drive was temporarily switched off.

Results

All measurements are listed in Table 1, which is followed by individual notes. Numbering of the notes (last column at right) is with R.A. values. Names, position, and magnitude data are adopted from the *WDS* [4]. N is the total number of recordings. Shaded lines denote systems which were used for calibration of the image scale (see below). The residuals, delta P.A. and delta rho, refer to the trends of literature data, if sufficiently available, or for binaries, to the currently assumed ephemeris, if not otherwise stated. Main sources are the *Fourth Catalog of Interferometric Measurements of Binary Stars ("speckle catalog")* [5], and the *Sixth*

(Continued on page 87)

Table 1: List of 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. Notes with asterisks refer to figures shown below.

PAIR	RA + DEC	MAGS	P.A. meas.	ρ meas.	DATE	N	ΔP.A.	Δrho	NOTES
STT 517 AB	05 13.5 +01 58	6.79 6.99	243.1	0.69	2014.243	1	1.6	0.01	05135
STF 668 A,BC	05 14.5 -08 12	0.3 6.8	202.0	9.52	2014.243	2	-	-	05145
DUN 23	06 04.8 -48 28	7.30 7.69	127.1	2.59	2014.248	1	0.2	-0.01	06048
R 65 AB	06 29.8 -50 14	5.97 6.15	256.9	0.46	2014.248	1	0.8	-0.01	06298
DUN 30 AC		5.97 7.98	311.1	12.03	2014.248	1	-	-	
HDO 195 CD		7.98 8.73	184.2	0.37	2014.248	1	4.2	-0.02	
DUN 32	06 42.3 -38 24	6.59 7.73	277.1	7.95	2014.249	1	0.1	0.02	06423
HU 112	07 01.8 -11 18	7.03 7.70	197.3	0.62	2014.249	2	-1.3	-0.01	07018
I 7	07 17.5 -46 59	7.10 8.35	202.0	0.68	2014.246	2	-0.8	-0.01	07175
STF1104 AB	07 29.4 -15 00	6.39 7.60	36.3	1.79	2014.246	2	-0.7	-0.02	07294
HU 710	07 43.0 -17 04	7.00 7.95	62.7	0.48	2014.243	1	0.7	0.01	07430
STF1146	07 47.9 -12 12	5.73 7.32	341.0	1.07	2014.244	1	0.3	-0.03	07479
HJ 4087	08 22.1 -40 69	7.58 7.98	254.4	1.47	2014.247	1	1.0	0.02	08221
SLR 8	08 32.1 -53 13	6.13 7.08	281.3	0.81	2014.255	1	0	0.01	08321*
BU 205	08 33.1 -24 36	7.14 6.84	290.2	0.54	2014.247	1	2.8	-0.05	08331*
BU 208	08 39.1 -22 40	5.37 6.81	41.8	0.91	2014.247	1	-6.5	+0.18	08391*
I 314	08 39.4 -36 36	6.4 7.9	242.6	0.82	2014.248	2	0.4	0.02	08394
HJ 4188 AB	09 12.5 -43 37	5.96 6.76	281.0	2.88	2014.255	1	0.5	0	09125
COP 1	09 30.7 -40 28	3.91 5.12	115.2	0.99	2014.251	2	-2.6	-0.10	09307*
R 123	09 33.3 -57 58	7.50 7.61	32.7	1.87	2014.256	1	-0.5	-0.01	09333
SEE 115	09 37.2 -53 40	6.12 6.28	9.9	0.68	2014.255	1	0	-0.03	09372
HRG 47	10 03.6 -61 53	6.34 7.93	353.4	1.14	2014.256	1	0.9	-0.02	10036
I 173	10 06.2 -47 22	5.32 7.10	9.3	0.96	2014.251	2	0.6	-0.01	10062*
DUN 89 AB	10 33.3 -55 23	6.79 7.76	31.0	25.93	2014.256	1	-	-	10333
HLD 106 BC		7.76 8.14	255.1	1.41	2014.256	1	-	-	
BU 411	10 36.1 -26 41	6.68 7.77	305.5	1.33	2014.247	1	0.3	0	10361
SEE 119	10 37.3 -48 14	4.13 5.76	259.8	0.46	2014.251	2	2.8	0.03	10373*
R 155 μ Vel	10 46.8 -49 25	2.82 5.65	56.8	2.32	2014.250	2	0.7	-0.04	10468
HJ 4383	10 53.7 -70 43	6.38 7.09	288.6	1.55	2014.256	1	0	0.04	10537
HJ 4432	11 23.4 -64 57	5.37 6.56	309.8	2.53	2014.256	1	-	-	11234
BSO 5	11 24.7 -61 39	7.68 8.76	248.3	7.49	2014.245	1	0.4	0.02	11247
I 885 Aa,Ab	11 28.6 -45 08	7.98 9.90	146.3	0.58	2014.245	1	5.1	0.06	11286
HJ 4455 AB	11 36.6 -33 34	6.01 7.77	241.1	3.49	2014.256	1	-	-	11366
HLD 114	11 55.0 -56 06	7.36 7.81	169.2	3.82	2014.245	1	1.1	0.74	11550
SEE 143	12 03.6 -39 01	7.05 7.65	25.0	0.49	2014.248	2	0.7	0.01	12036*
DUN 117 AB	12 04.8 -62 00	7.40 7.83	149.4	23.56	2014.232	2	-	-	12048*
DUN 117 AC		7.40 10.0	18.5	25.67	2014.232	2	-	-	
DUN 117 AX		7.40 13?	115.5	3.24	2014.232	1	-	-	
BU 920	12 15.8 -23 21	6.86 8.22	306.3	1.91	2014.244	1	-0.7	0.01	12158
BSO 8	12 24.9 -58 07	7.84 7.98	334.5	5.42	2014.232	1	-	-	12249

Table 1 continues on next page.

Table 1 (continued): List of 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. Notes with asterisks refer to figures shown below.

PAIR	RA + DEC	MAGS	P.A. meas.	ρ meas.	DATE	N	ΔP.A.	Δrho	NOTES
BU 606	12 26.0 -14 57	7.42 9.39	289.3	0.54	2014.244	1	1.0	-0.03	12260
DUN 252 AB	12 26.6 -63 06 1	1.25 1.55	112.3	4.00	2014.232	1	-	-	12266
DUN 252 AC		1.25 4.80	202.0	91.8	2014.240	2	-	-	
ANT 1 AG		1.25 10?	145.3	58.7	2014.268	2	-	-	
CPO 12 A,BC	12 28.3 -61 46	7.32 8.24	187.6	2.08	2014.240	1	-1.2	-0.03	12283
R 207	12 46.3 -68 07	3.52 3.98	51.4	0.98	2014.237	3	-6.4	0.08	12463
I 83	12 56.7 -47 41	7.39 7.68	235.6	0.85	2014.248	2	0.3	-0.01	12567
BU 341	13 03.8 -20 35	6.25 6.51	131.7	0.47	2014.246	2	-0.3	0.01	13038
I 917	13 06.6 -46 02	8.13 8.37	277.5	1.39	2014.251	1	1.5	0.03	13066
R 213	13 07.4 -59 52	6.59 7.04	21.5	0.66	2014.251	1	0	-0.01	13074
RST3829	13 14.9 -11 22	7.35 9.14	154.8	0.53	2014.246	2	-1.2	-0.03	13149
I 298	13 32.5 -69 14	7.36 8.54	150.5	0.53	2014.245	1	-1.8	-0.03	13325
HWE 95 AB	13 43.8 -40 11	7.51 7.85	185.1	0.89	2014.256	1	0	-0.03	13438
BU 343	13 52.0 -31 37	6.26 8.91	202.4	0.66	2014.246	2	1.7	-0.03	13520
HWE 28 AB	13 53.5 -35 40	6.27 6.38	314.2	1.00	2014.242	3	0.3	0.06	13535*
SLR 19	14 07.7 -49 52	7.14 7.38	326.7	1.12	2014.243	3	-0.1	-0.03	14077
HJ 4672	14 20.2 -43 04	5.77 7.94	300.8	3.46	2014.256	1	0	0.05	14202
RHD 1 AB	14 39.6 -60 50	0.14 1.24	279.2	4.33	2014.241	5	0.2	-0.01	14396
NZO 52	14 40.8 -66 57	7.87 8.54	59.5	2.21	2014.256	1	-	-	14408
HJ 4707	14 54.2 -66 25	7.53 8.09	271.2	1.13	2014.245	1	0.1	-0.03	14542
I 227 AB	14 56.5 -34 38	8.06 8.39	99.6	0.44	2014.251	1	0.5	0.01	14565a
HJ 4715	14 56.5 -47 53	5.98 6.82	277.9	2.08	2014.256	1	0	0.01	14565b
HN 28 AB	14 57.5 -21 25	5.88 8.18	306.4	25.69	2014.253	2	-0.4	0.01	14575
BU 239	14 58.7 -27 39	6.17 6.79	12.4	0.47	2014.248	1	-0.8	0	14587*
HJ 4728 AB	15 05.1 -47 03	4.56 4.60	64.4	1.64	2014.256	1	0	-0.03	15051
I 228	15 14.0 -43 48	7.98 8.24	12.0	1.34	2014.269	1	0	0.01	15140
STF3091 AB	15 16.0 -04 54	7.74 8.48	228.5	0.51	2014.256	1	3.1	-0.03	15160
BU 227 AB		7.53 8.64	158.9	1.82	2014.249	1	0	-0.01	
HJ 4757	15 23.4 -59 19	4.94 5.73	179.4	0.79	2014.250	2	2.1	-0.03	15234
CPO 16 AB	15 29.5 -58 21	7.03 7.98	33.9	2.48	2014.269	1	0	0.04	15295
B 2036 AB	15 31.3 -33 49	7.7 7.9	1.6	0.38	2014.250	2	0.5	0	15313*
HWE 78 AC	15 31.3 -33 49	7.7 9.11	119.7	1.46	2014.250	2	0	-0.01	15313*
HJ 4786 AB	15 35.1 -41 10	2.95 4.45	275.9	0.83	2014.242	2	-0.7	0	15351*
BU 36	15 53.6 -25 20	4.69 6.98	267.8	1.98	2014.269	1	0	0.01	15536
I 977	15 55.7 -26 45	7.99 8.48	256.3	0.52	2014.250	1	-1.0	-0.02	15557
PZ 4	15 56.9 -33 58	5.09 5.56	49.3	10.18	2014.233	1	0	0.03	15569
SEE 258 AB	16 03.5 -57 47	5.20 5.76	190.0	0.26	2014.233	1	-0.4	-0.01	16035*
HJ 4825 AB,C		4.64 8.02	242.1	11.04	2014.233	1	0.3	-0.01	
HWE 82	16 03.8 -33 04	7.71 7.86	344.7	2.31	2014.269	1	-	-	16038
STF1998 AB	16 04.4 -11 22	5.16 4.87	3.0	1.05	2014.252	2	0.3	0	16044
STF1998 AC		5.16 7.30	42.0	7.97	2014.252	2	-1.8	0.43	

Table 1 concludes on next page.

Double Star Measurements at the Southern Sky with a 50 cm Reflector ...

Table 1 (conclusion): List of 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. Notes with asterisks refer to figures shown below.

PAIR	RA + DEC	MAGS	P.A. meas.	r meas.	DATE	N	DP.A.	Drho	NOTES
BU 120 AB	16 12.0 -19 28	4.35 5.31	2.0	1.32	2014.251	1	0	-0.01	16120
MTL 2 CD		6.60 7.23	55.5	2.38	2014.251	1	0	0.04	
H 5 6 AC		4.35 6.60	335.6	41.58	2014.251	1	-	-	
GNT 1 AB	16 29.4 -26 26	0.96 5.4	276.6	2.57	2014.251	1	-0.4	-0.03	16294
R 283	16 42.5 -37 05	6.98 7.83	246.9	0.81	2014.251	2	1.6	0	16425
BU 1118 AB	17 10.4 -15 44	3.05 3.27	232.3	0.55	2014.250	1	0	-0.02	17104
SHJ 243 AB	17 15.3 -26 36	5.12 5.12	141.1	5.06	2014.251	1	0	0.05	17153
MLO 4	17 19.0 -34 59	6.37 7.38	152.5	1.23	2014.251	1	-0.9	0.04	17190
HDO 275	17 44.3 -72 13	6.85 8.11	76.5	0.68	2014.251	1	0	-0.04	17443
HJ 5014	18 06.8 -43 25	5.65 5.68	1.8	1.78	2014.233	1	-0.6	0.02	18068

Table Notes:

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

Asterisks in column “notes” refer to figures shown below.

05135: in Orion, binary, P = 312 y, many speckle data.

05145: β Orionis, “Rigel”, measurement difficult, because of large difference in brightness of the components, large scatter of literature data, residuals ambiguous, rho seems to slowly increase.

05308: 32 Orionis, binary in doubt, P = 586 y ?, “motion about rectilinear”, many speckle data.

06048: in Puppis, binary, P = 464 y.

06298: in Puppis, two binaries, AB: P = 52.9 y, many speckle data, CD: P = 101 y. Few data for AB-CD, residuals ambiguous.

06423: in Puppis, few data, residuals refer to last entry in speckle catalog from 1991.

07018: in Canis major, few data with some scatter, PA increasing.

07175: in Puppis, binary, P = 82 y, large excentricity, many speckle data.

07294: in Puppis, binary, P = 729 y ?, “premature orbit”.

07430: in Puppis, binary, P = 138 y, many recent speckle data.

07479: in Puppis, binary, P = 1332 y ?, own measure follows recent speckle data, being close to the recently revised orbit (which much longer period than previously assumed).

08221: in Puppis, binary, P = 880 y ?, few data, only small portion of orbit documented.

08321: in Vela, few data, PA decreasing, rho about constant at least since decades. See fig. 3.

08331: in Pyxis, binary, P = 136 y, apparent orbit almost circular, many speckle data, measured position deviates from ephemeris, but fits better to the trend of recent speckle data. See figs. 3 and 4.

08391: in Pyxis, binary, P = 123 y, orbit highly inclined, many speckle data with only small scatter, but significant deviations from ephemeris. Own measure closely follows trend of recent speckle data. Residuals refer to ephemeris.

08394: in Pyxis, binary, P = 66 y, few data.

09125: in Vela, few data, PA decreasing, rho increasing.

09307: ψ Velorum, binary, P = 34 y, own measure deviates from ephemeris, but follows the trend of recent speckle data. See fig. 6.

09333: in Carina, “neglected”.

09372: in Vela, PA increasing.

10036: in Carina, “neglected”, few data, rho virtually constant since about a hundred years, PA increasing?

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10062: in Vela, binary, P = 232 y, few data. See fig. 3.

10333: in Vela, tripel, too few data, residuals ambiguous, PA(BC) increasing.

10361: in Hydra, binary, P = 210 y, orbit well documented, recent speckle data with only small scatter suggest fairly accurate extrapolation.

10373: in Vela, close and fast binary, P = 16 y, although measurement difficult, because companion on diffraction ring, position seems to deviate from the ephemeris, and to follow the trend of recent speckle measurements. See fig. 3.

10468: mu Velorum, binary, P = 138 y, few data, own measure of rho as well as recent speckle data fit quite well to the recently revised orbit.

10537: in Carina, few data, residuals refer to last entry in speckle catalog from 1991.

11234: in Musca, few data, residuals ambiguous.

11247: in Centaurus, binary, P = 421 y, few speckle data.

11286: in Centaurus, binary, P = 650 y ?, only small portion of orbit covered, own measure follow speckle data, all deviate from ephemeris.

11366: in Hydra, relfix, cpm, few data, residuals ambiguous.

11550: in Centaurus, binary, P = 930 y ?, orbit highly inclined, only small portion documented, measured position is far off from ephemeris.

12036: in Centaurus, binary, P = 109 y, small scatter of recent speckle data, PA and rho rapidly decreasing.

12048: in Crux, relfix, few data, dim companion x near A (~13 mag?) not listed in the WDS. See fig. 10.

12158: in Corvus, binary, P = 873 y ?, orbit is preliminary, but recent speckle data with relatively small scatter let short term extrapolation appear reasonable.

12249: in Crux, few data, residuals ambiguous.

12260: in Corvus, binary, P = 707.6 y ?, orbit ambiguous, highly inclined, few data.

12266: alpha Crucis, AB binary, no closed orbit determined, few data, even fewer for AC, residuals ambiguous. Separations of both AC and AG have increased by 2.2” or 2.3”, respectively, since my last measurements in 2012, while the PA´s were about the same. Imaging of component G was done without Barlow, and of distant C even with a reducer to increase the field of view. The corresponding scaling factors were calculated on the basis of images of AB, taken with Barlow.

12283: in Crux, binary, P = 2520 y ?, orbit preliminary, few data, PA decreasing. BC not resolved.

12463: beta Muscae, binary, P = 383 y, measured position is lying exactly on the orbit, but deviates from the ephemeris. This seems to be shifted by about 5 years. See figs. 5a and 5b.

12567: in Centaurus, binary, P = 294 y, measured position is close to recently revised orbit.

13038: in Virgo, binary, P = 59 y ?, orbit almost directly edge-on.

13066: in Centaurus, “neglected”, PA decreasing, rho slowly increasing.

13074: 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.

13149: in Virgo, binary, orbit revised in 2014, P = 122.7 y, few data.

13325: in Musca, binary, P = 590 y, few data, rho deviates from ephemeris, in accordance with recent speckle data.

13438: in Centaurus, few data, PA and rho decreasing.

13520: in Centaurus, binary, newly revised orbit, P = 280 y, PA decreasing, rho rapidly increasing.

13535: in Centaurus, binary, P = 258 y, few data, measured position deviates from ephemeris, similar to recent speckle data. See figs. 7a and 7b.

14077: in Centaurus, binary, P = 233 y, measured position reasonably fits to recently revised ephemeris.

14202: in Lupus, few data, rho seems to be slowly decreasing, residuals ambiguous.

14396: alpha Centauri, AB binary, P = 79.9 y, well documented.

14408: in Circinus, “neglected”, few data, rho seems to be increasing, residuals ambiguous.

14542: in Circinus, binary, P = 288 y, few data, own measure close to ephemeris.

14565a: in Centaurus, binary, P = 40 y, own measure close to ephemeris.

14565b: 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.

14575: also known as 33 Librae, AB binary, P = 2130 y (?), only a small portion of the orbit is documented, but this is on a long stretch, which can fairly accurately be extrapolated to the near future.

14587: also known as 59 Hydrae, binary, P = 429 y, measured position fits well both the ephemeris and the trend of recent speckle data. See fig. 3.

15051: pi Lupi, PA slowly decreasing.

15140: in Lupus, “neglected”, PA decreasing, while rho about constant.

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15160: in Libra, binary, P = 156 y, large scatter of recent PA (speckle) data.

15192: in Libra, few data, PA decreasing.

15234: gamma Circini, binary, P = 270 y, while the measured PA is close to the newly revised ephemeris, rho is slightly off.

15295: in Circinus, “neglected”, PA increasing.

15313: in Lupus, triple, AB: binary, P = 227.8 y, orbit almost directly edge-on, rho is rapidly increasing. C is orbiting around AB, P = 1258 y ?, few data. See fig. 3.

15351: gamma Lupi, binary, P = 190 y, orbit highly inclined, but reasonably well documented. See fig. 3.

15536: in Scorpius, PA and rho decreasing.

15557: in Scorpius, binary, P = 158 y, two orbits calculated by Scardia [6], own measure seems to better fit to the first one.

15569: xi Lupi, relfix, “splendid”.

16035: jota[1] Normae, triple, all cpm, AB binary, P = 26.9 y, PA and rho rapidly decreasing, AB-C: few data, PA decreasing. See fig 3.

16038: in Lupus, “neglected”, although deemed relfix by Burnham, PA and rho are slowly decreasing.

16044: xi Scorpii, interesting triple, AB: binary, P = 45.8 y, many speckle data. Own measure fits well to both ephemeris and literature data. AC: P = ? y, only small portion of orbit covered. Residuals refer to the ephemeris. PA and rho data exhibit large scatter, possibly due to confusion as to which to refer, A or AB. See fig. 9.

16120: nu Scorpii, “double-double”, but no orbits determined, rho(AB) slowly increasing, PA(CD) slowly increasing.

16294: alpha Scorpii, “Antares”, binary, preliminary orbit, P = 1218 y, only few recent data, own measure close to ephemeris, although difficult because of large difference of brightness of the components.

16425: in Scorpius, binary, “premature orbit”, own measure close to ephemeris.

17104: eta Ophiuchi, binary, P = 88 y, many speckle data with small scatter. See fig. 3.

17153: also known as 36 Ophiuchi, binary, P = 550 y (?),”premature orbit”.

17190: in Scorpius, binary, P = 42.1 y, PA and rho rapidly decreasing.

17443: in Apus, binary, P = 101y, few data, PA decreasing, rho increasing.

18068: in Corona Australis, binary, P = 191 y, own measures deviate from ephemeris, in accordancewith the trend of speckle data.

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Catalog of Orbits of Visual Binary Stars [6]. Data available up to December 2014 are taken into account, as of writing this article. In several cases, larger deviations were found, which often agree with trends of literature data. These will be discussed in more detail below. In other cases, literature data are so scarce and/or exhibit so large a scatter that no reasonable residuals can be given.

Systems used for calibration of the image scale were carefully selected. In Table 1, these are marked with shaded lines. Criterion was a well documented history of literature data, i. e. many data with small scatter, generally from the speckle catalog [5], such that extrapolation to the current date was unambiguous. Statistical analysis with 16 pairs resulted in a calibration factor of 0.0967 arcsec/pixel (with Barlow) with an error margin of +/- 0.3 percent. Maximum error margins for separation measurements are expected to be of the order of +/- 0.02 arcsec for the range of relatively small separations considered here.

Generally, residuals were calculated as differences against extrapolated literature data, mainly from the speckle catalog, and for binaries against ephemeris data [6]. In some cases, no reasonable residuals could be given, because of too few data and/or too large a scatter. Some systems exhibit significant deviations which are discussed in the notes or below. Residuals of PA and rho values are plotted versus the measured separation in Figures 1 and 2, respectively.

As can be seen in Figure 1, several residuals are greater than the error limits. As they are usually calculated with respect to the current ephemeris, deviations may indicate that this should sooner or later be revised. In fact, in many cases, residuals against the trend of recent measurements are found much smaller. Examples are shown in Figures 4 and 6 - 8 below.

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 plot in Fig. 2. However, a number of pairs seem to stand out more than this, in particular binaries with not well known orbits.

Some images of double and multiple systems are presented in the following figures. Fig. 3 is a selection of close binaries with sub-arcsec separations.

Concluding remarks

For many of the doubles investigated here there are only few data found in the literature, and often with

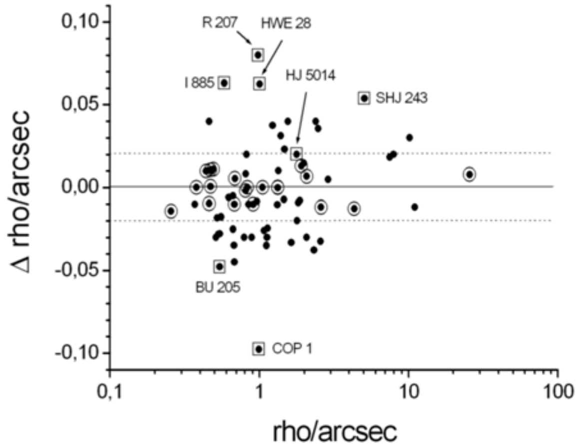


Figure 1. Plot of the residuals of rho versus rho. Semi-logarithmic scale. Pairs used for calibration are marked with superposed open circles. Some systems with large deviations are marked with their names. Symbols with squares denote binaries with significant deviations from ephemeris data. See also notes.

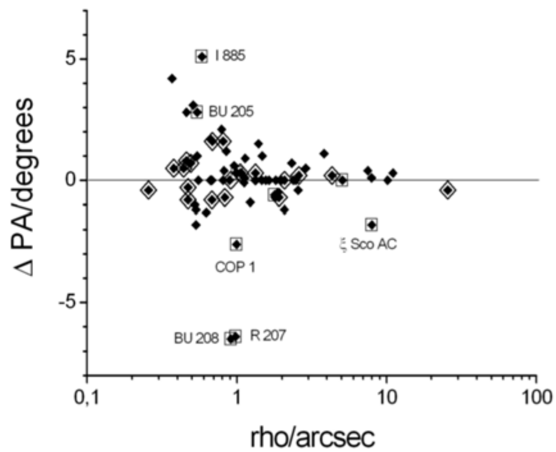


Figure 2. Plot of the residuals of the P.A. versus rho. Semi-logarithmic scale. Pairs used for calibration of the image scale are marked with superposed open rhombs. Some systems with large deviations are marked with their names. See also notes.

(Continued on page 90)

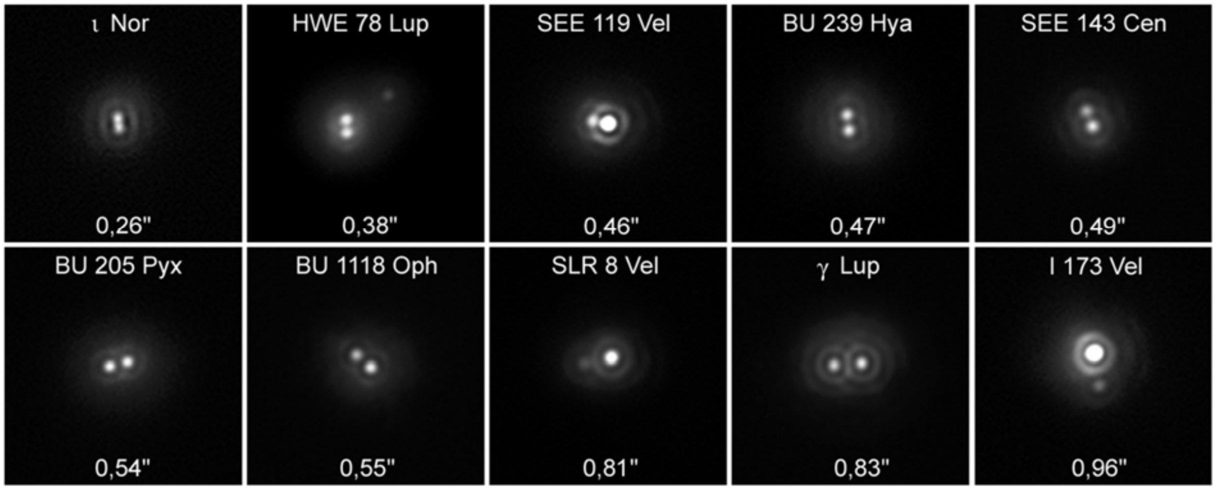


Figure 3. A selection of close binaries. North is down, and east is right, as in all other star images. See also notes 16035, 15313, 10373, 14587, 12036, 08331, 17104, 08321, 15351, 10062, respectively.

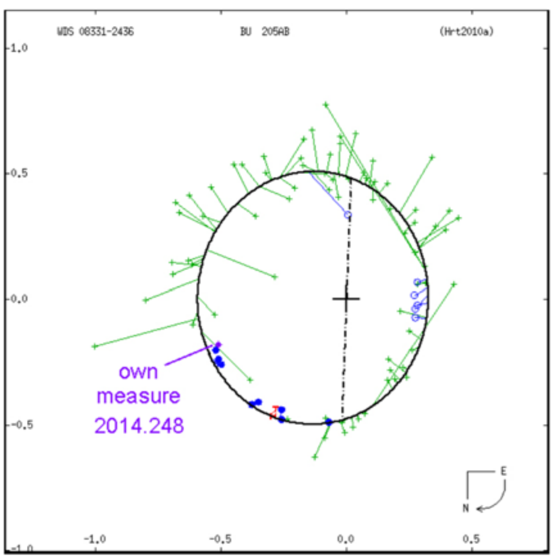
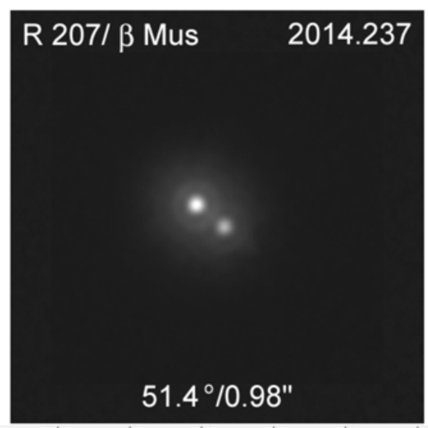


Fig. 4: The orbit of BU 205 AB in Pyxis (WDS 08331-2436). Adopted from reference [6]. Recent speckle data (blue), as well as my own measurement (purple) tend to deviate from the ephemeris. See Fig. 3 and note 08331.



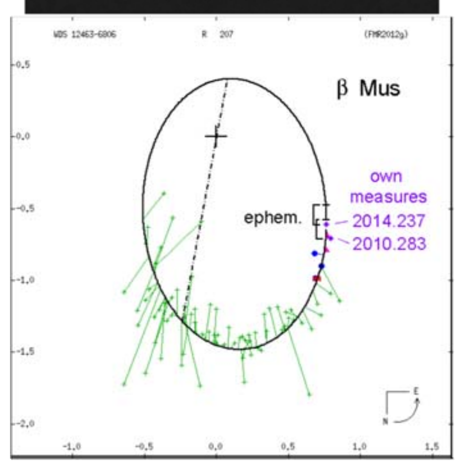


Figure 5a: (Top) The binary R 207/beta Muscae (WDS 12463-6807). Composite of two imaging series recorded on different dates. See also note 12463.

Figure 5b: (Bottom) The orbit of beta Muscae. Adopted from reference [6]. Positions measured in 2012 and 2014 (purple) are on or close to the orbit, but the ephemeris for the respective dates systematically deviate, as indicated. Blue symbols indicate recent speckle data. See also note 12463.

Double Star Measurements at the Southern Sky with a 50 cm Reflector ...

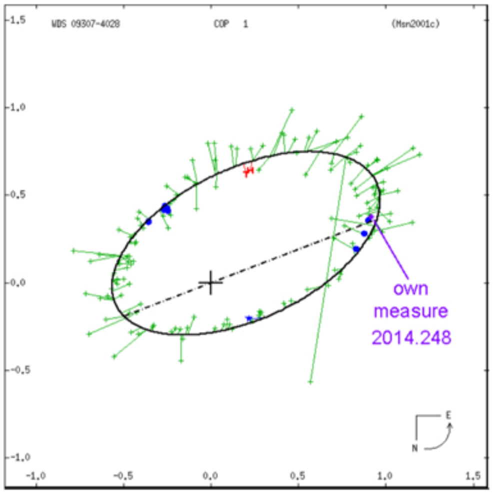


Figure 6. The orbit of COP 1 (WDS 09307-4028, ψ Vel). Adopted from reference [6]. The measured position (purple) deviates from the orbit, but follows the trend of recent speckle data (blue). See also note 09307.

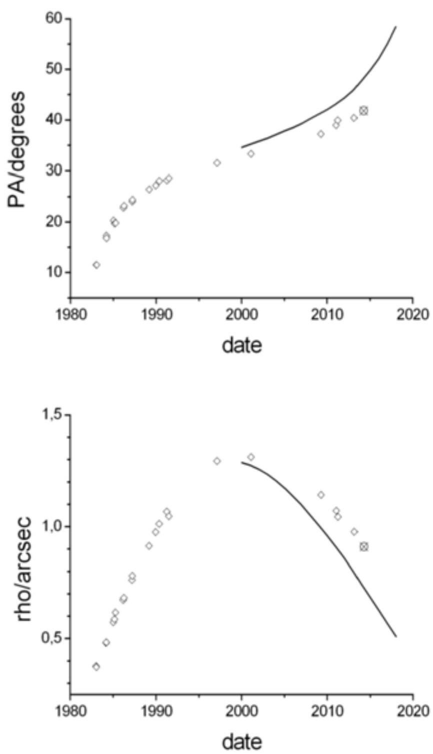


Figure 8a. (Top) Plot of the position angle versus date of the binary of BU 208 AB in Pyxis (WDS 08391-2240). Open squares indicate speckle data [5], the circle with cross is my measurement of 2014. The solid line is the ephemeris (Hei1990c).

Figure 8b. (Bottom) Plot of the separation rho of BU 208 AB versus date. The meaning of the symbols is as above. Deviations from the ephemeris are clearly greater than the error margins of the measurements.

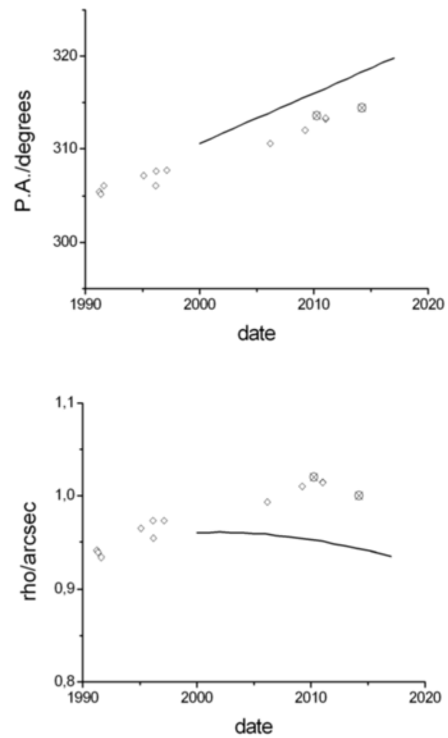


Figure 7a. (Top) Plot of the position angle versus date of the binary of HWE 28 AB in Centaurus (WDS 13535-3540). Open squares are speckle data [5], circles with crosses are own measurements of 2012 and 2014. The solid line is the ephemeris (Lin1998a).

Figure 7b. (Bottom) Plot of the separation ρ of HWE 28 AB versus date. The meaning of the symbols is as in Fig. 7a. Deviations from the ephemeris are clearly greater than the error margins of the measurements.

Double Star Measurements at the Southern Sky with a 50 cm Reflector ...

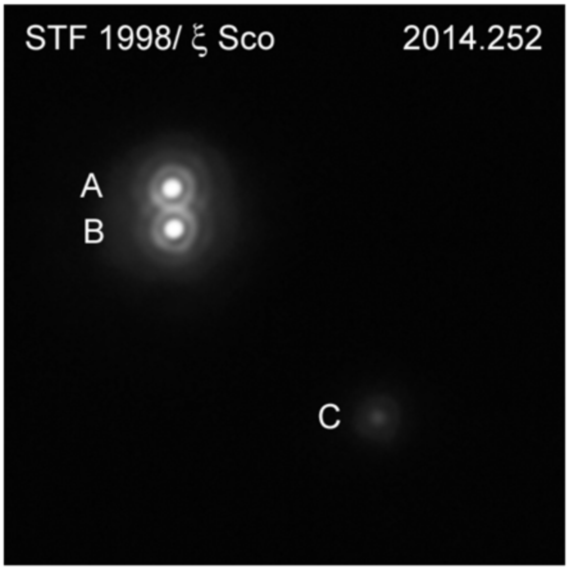


Figure 9. The triple xi Scorpii (STF 1998, WDS 16044-1122). The period of binary AB is about 46 years, while the orbit of C around AB is still not well known. See note 16044.

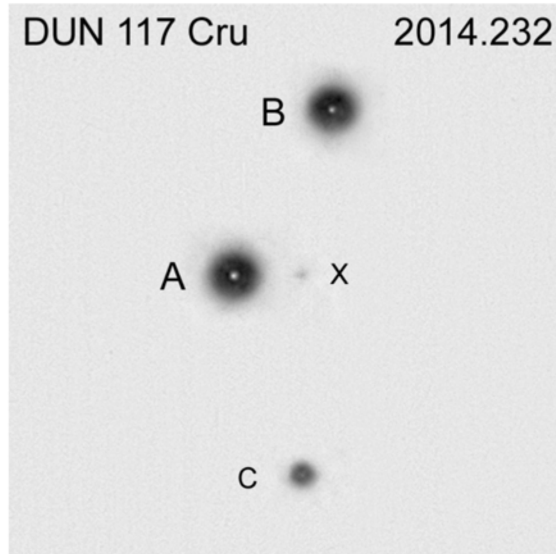


Figure 10. The multiple DUN 117 in Crux (WDS 12048-6200). Composit of a short exposure (specs in the centers of components A, B, and C), and a longer exposure as a negative, in order to show the dim companion x. See note 12048.

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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 frequently been measured. Generally, the scatter is of comparable magnitude. As a result of this work, several double star systems were found, which should more often be measured, in order to improve the knowledge about their status, or of their orbits, respectively. In particular, the following systems seem to be interesting:

WDS Ident.	Name
08331-2436	BU 205 Pyx
08391-2240	BU 208 Pyx
08394-3636	I 314 Pyx
09307-4028	COP 1, ψ Vel
10373-4814	SEE 119 Vel
11286-4508	I 885 Cen
11550-5606	HLD 114 Cen
12463-6807	R 207, β Mus
13325-6914	I 298 Mus
13535-3540	HWE 28 Cen
16044-1122	STF 1998 AC, ξ Sco
18068-4325	HJ 5014 CrA

Acknowledgement

I have made extensive use of the double star catalogs available online at the USNO website. Special thanks are due to Brian Mason for directing my attention to a number of less frequently observed and "neglected" doubles.

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Reaching Magnitude +16 with the Modified Video Drift Method

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Abstract: The video drift method of measuring double stars is a quick and efficient way to obtain position angle and separation measurements. With ordinary video cameras magnitude +12 and deeper double star systems often prove difficult or even impossible to measure without using an image intensifier. A simple modification to the video drift method and corresponding *VidPro* analysis program now makes reaching magnitude +16 a reality for modest amateur equipment.

Introduction

In our previous reports using the video drift method (Nugent and Iverson, 2011 - 2015), we have reported position angle and separation measurements obtained with our respective 14-inch (35 cm) Meade LX-200 Schmidt-Cassegrain telescopes and other, smaller aperture, telescopes. Author Nugent, using a non integrating *Watec 902H2 Ultimate* video camera fitted with a Collins I^3 image intensifier, has measured double stars down to magnitude +15.6 (Nugent and Iverson, 2014). This was accomplished in relatively dry air at his west Texas observatory. Unfortunately the Collins I^3 image intensifier is no longer being manufactured. Author Iverson measures double stars with a cooled variation of the Astrovid *Stella Cam 3* video camera (equivalent to the *Watec 120N+* camera) which can co-add (stack) video frames within the camera (integration). Co-adding 2 frames is the equivalent of doubling the exposure, co-adding 4 frames equates to quadrupling the exposure, and so on. Longer exposure times (with the telescope motor drive on, no drifting) allow reaching fainter stars unattainable with conventional non-integrating video cameras.

Although the Stella Cam 3 video camera is capable of virtually unlimited user-defined integration periods, hardware-defined integration periods extend up to 8.4 seconds (256 frames). Nugent and Iverson (2012) suggested that integration periods longer than 0.198 seconds (using a Stella Cam EX camera) are impractical with the original video drift method. As the integration time increases, the stars drift in increasingly longer jumps which eventually lead to smearing/streaking of the star images, making them unsuitable for measurement. The freeware program *Limovie* (Miyashita, 2006), used to measure the stars' (x,y) position in each video frame, has a difficult time following the longer jumps. When the program cannot keep up it begins to report inaccurate (x,y) coordinate positions and then it eventually loses the ability to track the stars. Due to this limitation and the humid, unstable air over his east Texas observatory, author Iverson has been unable to routinely measure doubles fainter than +12 magnitude.

While investigating the *Reduc* double star analysis program (Losse, 2011) and the combined *Reduc/VidPro* methodology used by Wasson (2014), it was realized that a few simple changes to the video drift method and a corresponding change to the *VidPro* double star analysis program would significantly increase the depth at which ordinary integrating cameras could measure double stars. These changes include (1) recording the double star at an integration level long enough to allow dim components to be easily seen while the telescope mount is tracking and (2) recording several drifts (no tracking) of a bright nearby star at the same declination to determine the scale factor and drift angle.

Methodology

In this study we used our respective equatorial mounted 14-inch (35 cm) Schmidt-Cassegrain telescopes and video recording equipment used in our previous papers (Nugent and Iverson, 2011-2015). At the beginning of an observing session, the video camera's chip was adjusted parallel to the approximate true east-west direction by trial and error rotation of the camera and slewing the telescope. Once aligned, the camera alignment was not changed. The *VidPro* program compensates for any remaining offset from true east-west. Data was only recorded when the target double star was within one hour of the meridian.

The modified video drift method records video when the telescope is tracking the double star (motor drive on) and when the double star is allowed to drift (motor drive off) across the field of view (FOV). The procedure for recording the necessary video is as follows:

1) Locate the target double star and center it in the video camera's FOV.

2) Choose a camera integration level and gain setting where the secondary star is visible but not saturated. Saturating the primary star is usually unavoidable, but this is not a problem as long as the secondary star doesn't merge with the primary.

3) With the telescope motor drive on, record up to 2.5 minutes of video. The stars may move slightly depending on the telescope balance, the telescope mounts ability to track the night sky, and/or accuracy of the polar alignment. This slight movement does not affect the results. Stop the recording.

4) Adjust the integration time to less than 0.132 seconds. Slew the telescope over to the nearest bright star that closely matches the target's declination (see below). If the primary star is visible then use it.

5) Resume recording and position this star at the eastern edge of the FOV. Turn the telescope motor drive off and allow this star to drift across the entire FOV. Repeat this east to west drift at least 3 or 4 times on this same recording. Now stop recording.

By recording a bright star drifting across the FOV, the video drift method and modified video drift method avoid using calibration (also known as reference or standard) doubles that some investigators rely on. Calibration doubles are believed to have stable position angle and separations over long periods, thus they provide a reference coordinate system frame for making new position angle and separation measurements for new targets. If the calibration double position angles and separations have not been updated or have significant errors, then these errors will propagate to the new targets being measured. The modified video drift method described here is completely self-calibrating thus no calibration/reference doubles are needed.

Measurement and Reduction

Once the video is obtained, it's analyzed in two stages. First, the video drifts are analyzed using the freeware programs *Limovie* and *VidPro* as previously described (Nugent and Iverson, 2011-2015) with one exception. It is important that both *Limovie* aperture rings are placed on the drifting star. Since only a single star is used during these drift videos, the *VidPro* program position angle and separation output cells will show meaningless results. This is not an issue since at this stage we are only interested in calculating the scale factor and camera offset from east to west (drift angle). The averaged result for both quantities will be manually entered into *VidPro* again during the second step of the reduction.

The second step uses *Limovie* and *VidPro* again but this time to reduce the tracking video file. *Limovie's* aperture rings are placed over the primary and secondary stars. Recall the target double star was not drifting, so the aperture rings will remain essentially stationary (see step 3 above). Because the stars are not drifting across the FOV, *VidPro* cannot calculate the scale factor or drift angle in this situation. The previously determined scale factor and drift angle from the first step are manually inserted into a modified version of *VidPro*. As before, *Limovie* creates a CSV file of (x,y) coordinates for the centroid of each star covered by an aperture ring for each video frame. The CSV file size should be limited to less than 5000 frames or about 2.5 minutes of video. This file is also manually copied into *VidPro*. When *VidPro* has all 3 inputs (scale factor, drift angle, and the CSV file), it automatically calculates the position angle and separation along with standard deviations.

The acquisition of the videos using this method takes a bit longer than the original drift method due to the extra time needed to make the tracking video. The level of integration used will significantly influence the amount of tracking data recorded. This is because as integration time increases, fewer new images are available in a given time interval. A camera integrating at

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sixteen frames outputs a new image approximately every 0.5 second at the NTSC video frame rate. At 128 frames, a new image will be output approximately every 4.2 seconds. The duplicate images do not affect the final result.

In order to prove that there is no significant difference in the results obtained from the conventional *VidPro* procedures and the modified *VidPro* procedures, 20 well studied double star systems were selected. Both the primary and secondary star needed to be bright enough to allow drift scanning with either no integration or, if used, then less than 0.132 seconds of integration. Each system was first processed using the traditional video drift method (Nugent and Iverson, 2011). The scale factor and drift angle measurements obtained were then averaged for each double star. Next, each double star was reprocessed using the modified video drift method (steps 1-5 above). The averaged scale factor and drift angle measurements obtained from the traditional analysis were inserted into a modified version of the *VidPro* designed for use with tracking data.

Ordinary drift scans are essential for *VidPro* to determine the scale factor and the offset of the camera's video chip from the true east west direction. If a replacement star is used then its declination should be close to the primary star's declination. From Equation 1, below, the cosine of the declination is used in determining the scale factor (Nugent and Iverson, 2011).

$$scalefactor = \frac{(drifttime)15.041068\cos(dec)}{\sqrt{(x_B - x_E)^2 + (y_B - y_E)^2}} \qquad (1)$$

x_B, y_B, x_E, y_E are the beginning and endpoints of the drift, and "dec" is the declination of the primary star or its substitute. *Drifttime*, in seconds, is defined by the number of frames (*x,y* pairs) divided by the camera frame rate. The National Television Standards Committee (NTSC) frame rate is 29.97 frames per second which we round to 30 for convenience.

Reaching fainter double stars with a common integrating video camera is significantly enhanced by using the *AviSynth* "Level" filter (http://avisynth.nl/index.php/Levels). It is a one line addition to the *AviSynth* script (Appendix I) used by *Limovie* to open the video file. This filter can be used to adjust the brightness, contrast, and gamma of the video clip (Appendix II).

In cases where observations were made over multiple nights or more than one observation was obtained in a single night, the position angle and separation values were merged using weighted averaging (Nugent and Iverson, 2013). The scale factor and drift angle measurements from multiple drifts were merged as a simple average. All references to stellar magnitudes have been copied from the online WDS summary catalogue.

Table 3 was compiled using the online WDS summary catalogue. It is intended to be only a rough estimate of the total number of double stars visible from the southern United States over the course of a year. The stars included covered a region of the night sky between 90° north and -30°south declination. Any entry in the WDS catalogue lacking a companion star magnitude was not considered. Double stars with a separation less than 5 arc seconds are probably not measurable by the modified video drift method and have been excluded from the table. Most of the southern hemisphere double stars were also excluded from consideration. Percentages were calculated based on a total of 59,590 double stars visible over the course of a year.

Results

As an initial test of the modified *VidPro* method, a number of doubles were picked at random from the doubles measured as part of our ongoing double star measurement program. The results from both the modified video drift method (tracking) and original video drifting method for these double stars are given in Table 1. The column titled *PA° tracking–drifting* presents the difference between the position angle results obtained by the two methods. The difference in position angle did not deviate by more than 0.1 degrees over the 20 examples. This is insignificant considering the online WDS summary catalogue gives the position angle to the nearest whole degree. The measured separations also varied by an insignificant amount. For the 20 doubles investigated, the separation did not vary by more than 0.04 arc seconds. Again, the WDS summary catalogue reports separation to the nearest tenth of an arc second. The WDS observational data base includes the known measurements for a double star. It typically reports precisions up to 2 decimal places for the position angle and 3 decimal places for the separation. Entries in this data base just mirror the precision reported by other authors in the literature using a variety of methods.

The standard deviations from the tracking data analysis have been included in Table 1. The standard deviations from the drift analysis are not presented, but they are similar to the values reported in our previous papers.

The next step was to determine the faintest double star that could be measured reliably. Table 2 reports position angle and separation measurements obtained

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Table 1. Results of double star measurements using both the Video Drift Method and the Modified Video Drift Method.

WDS	Discover	PA° Track-ing	std. dev. Track-ing	PA° Drift-ing	PA° Track - Drift	Ave Sep" Track-ing	std. dev. Track-ing	Avg Sep" Drift-ing	Sep" Track - Drift	Date	No. Track-ing (x,y) pairs	Mag. Pri.	Mag. Sec.	No. Obs. Tracking	No. Obs. Drifting	No. Nights
00407-0421	HJ 323	285.5	0.30	285.5	0.0	62.84	0.34	62.81	0.03	2014.805	1953	6.01	8.46	1	4	1
14575-2125	H N 28AB	305.6	0.57	305.7	-0.1	25.68	0.28	25.65	0.03	2014.479	1348	5.88	8.18	2	2	1
15041+0530	STF1904	347.9	1.11	347.8	0.1	9.97	0.21	9.96	0.01	2014.479	1408	7.19	7.37	2	2	1
15127+1917	STF1919	10.3	0.48	10.2	0.1	23.06	0.21	23.07	-0.01	2014.479	1338	6.71	7.38	2	2	1
15145-1826	SHJ 195	139.8	0.28	139.8	0.0	46.77	0.27	46.79	-0.02	2014.479	1242	6.79	8.32	2	2	1
15187+1026	STF1931AB	166.5	0.80	166.5	0.0	13.17	0.21	13.18	-0.01	2014.479	1004	7.20	8.07	2	2	1
15201+2937	ENG 53	342.3	0.08	342.3	0.0	142.16	0.19	142.13	0.03	2014.499	3539	5.62	10.46	3	6	1
15202+3042	STF1935	289.0	1.16	289.1	-0.1	8.56	0.15	8.56	0.00	2014.499	5502	9.91	10.19	3	6	1
15282-0921	SHJ 202AB	132.2	0.23	132.2	0.0	52.06	0.24	52.06	0.00	2014.479	1089	6.95	7.61	2	2	1
15288+3101	A 1369AC	258.8	0.17	258.8	0.0	73.31	0.18	73.32	-0.01	2014.499	4113	10.66	10.48	3	6	1
15387-0847	STF1962	189.3	0.82	189.5	-0.1	11.60	0.20	11.60	0.00	2014.479	1079	6.44	6.49	2	2	1
15591-1956	SHJ 213	317.4	0.75	317.4	0.0	17.34	0.25	17.37	-0.03	2014.479	1153	8.11	8.50	2	2	1
16044-1127	STF1999AB	98.4	0.93	98.4	0.0	11.83	0.20	11.83	0.00	2014.479	1159	7.52	8.05	2	2	1
16060+1319	STF2007AB	321.5	0.32	321.5	0.0	38.33	0.23	38.29	0.04	2014.479	1088	6.89	7.98	2	2	1
16401+3038	LAU 3	262.6	0.13	262.6	0.0	80.01	0.16	79.99	0.02	2014.499	4846	9.86	10.52	3	6	1
16457+3000	STF2098AB	144.9	0.78	144.8	0.1	14.17	0.18	14.18	-0.01	2014.499	5588	8.77	9.61	3	6	1
16457+3000	STF2098AC	128.1	0.17	128.1	0.0	65.58	0.18	65.58	0.00	2014.499	5497	8.77	8.81	3	6	1
16534+2925	HEI 13	121.3	1.39	121.2	0.1	7.70	0.18	7.67	0.03	2014.499	5558	10.07	10.24	3	6	1
21576+1157	STTA227	32.6	0.24	32.6	0.0	77.94	0.33	77.96	-0.02	2014.805	1660	7.51	9.03	1	4	1
22451-0240	STF2938A, BC	341.8	0.94	341.8	0.0	19.82	0.36	19.81	0.01	2014.805	1393	9.41	9.55	1	4	1

for 22 doubles where the companion star is too dim or both the primary and companion star are too dim to be measured by the original video drift method. Three of these doubles were observed on multiple nights. The faintest double measured (01325+1417 LDS 1102) has a primary /secondary magnitude of +11.1/+16.9. Since measurements have only been made in the relatively humid, unstable air of east Texas, it is reasonable to expect that even fainter doubles can be measured in a dryer environment with better seeing.

Only 3 of the double stars studied were measured within in the last 5 years and most were measured 15 years ago or longer. Position angle and separation measurements obtained using the modified video drift method (Table 2) in general varied very little from their last historical measurements. In only 4 instances did the position angle change by more than one degree. The average change was 0.66 degrees. Only one double star (01325+1417 LDS 1102) showed a significant change (3.1 degrees). Inspection of the WDS historical data base suggested that this was not unreasonable given the high proper motions of the components. All 22 double stars studied showed very little change in separation from their historical measurements. The maximum change was 0.9 arc seconds while the average change was 0.30 arc seconds. The USNO CCD Astrographic Catalogue project (Hartkopf, W., *et al.*, 2013) derived position angle and separation measurements from the UCAC4 catalogue for 20 of the 22 doubles in Table 2. Inspection of the WDS historical database revealed that in all but 5 cases the most recent measurement was derived from either the 2 MASS catalogue (4 doubles) or the UCAC4 catalogue (13 doubles). The close agreement with the UCAC4 measurements sug-

Table 2. The results of 22 double stars using the Modified Video Drift method and long integration periods. These double stars were too dim to be measured by the original video drift method author Iverson's east Texas observatory.

WDS	Discover	PA°	std. dev.	Ave Sep"	std. dev.	Date	No. of Tracking (x,y) pairs	Mag. Pri.	Mag. Sec.	No. Obs.	Nights
00506-0121	HJ 1998	330.1	0.91	20.7	0.33	2014.871	1970	11.41	14.59	1	1
01285+0940	UC 561	236.6	0.78	18.4	0.31	2014.896	4528	11.50	15.50	1	1
01295-1120	UC 564	236.2	0.45	30.8	0.28	2014.951	7080	10.20	16.30	2	1
01298+0510	BAL2594	220.6	2.09	10.9	0.35	2014.929	6520	10.44	12.20	2	1
01324-0930	LDS2204	238.1	0.86	17.7	0.26	2014.929	8332	10.20	14.50	2	1
01325+1417	LDS1102	2.4	1.32	9.6	0.42	2014.951	4820	11.10	16.90	1	1
01567-0754	LDS5358	97.7	0.32	69.1	0.45	2014.948	4848	13.82	16.26	1	1
02354-0228	GWP 341	99.6	0.40	51.3	0.48	2014.951	4680	8.50	16.30	1	1
02444+1057	PLQ 35AB	315.3	0.82	24.6	0.34	2014.929	9718	11.20	15.20	2	1
02444+1057	SKF 20AC	107.7	0.78	20.7	0.31	2014.929	9924	11.20	15.30	2	1
02444+1057	SKF 20BC	122.8	0.49	43.9	0.43	2014.929	9866	15.20	15.30	2	1
02550-0029	MMA 33	337.1	0.49	17.7	0.20	2014.896	8002	12.00	15.40	2	1
03353+1725	GWP 483	88.4	0.40	23.6	0.19	2014.805	14204	11.50	15.30	3	2
04042+2416	POU 371AB	163.3	1.41	9.6	0.22	2014.948	9396	11.60	14.10	2	1
04042+2416	POU 372AC	227.5	0.68	20.9	0.20	2014.948	9399	13.01	16.25	2	1
04076+2322	POU 402	198.0	0.77	16.0	0.19	2014.805	12106	12.82	15.96	3	2
05136+2304	POU 590	330.7	0.61	11.8	0.15	2014.805	16631	13.30	15.50	4	2
05166-1048	GWP 665	117.2	0.30	49.7	0.27	2014.948	9651	11.52	16.12	2	1
06053+1838	GWP 737	333.1	0.34	46.9	0.25	2014.948	9534	10.60	16.11	2	1
22073-0002	BAL 934	337.7	1.06	14.4	0.29	2014.871	2046	10.84	12.03	1	1
22114+0057	BAL1240	274.4	1.62	10.1	0.32	2014.871	1664	11.89	12.02	1	1
23292+0049	HJ 3195	99.3	1.01	14.9	0.30	2014.871	2043	11.63	12.31	1	1

gest the modified video drift method is a useful method for studying faint double stars.

As demonstrated previously (Nugent and Iverson, 2015), the value for both the position angle and separation can be considerably in error based on the trend line formed by plotting the previously reported values. Considering the double stars in Table 2, the most frequently observed system has only 7 previous measurements. The majority of the double stars have less than 5 measurements. Graphical trend line analysis is not very meaningful in this situation.

Table 3 illustrates the increased accessibility of potentially measureable doubles that a southern United States observer might have using the modified video drift method. Using the limits established for author Iverson's observatory as an example, on a night with average seeing (magnitude +11), it is estimated that about 29 percent of the available double stars could be measured. On a night with good seeing (magnitude +12), this number increases to about 46 percent. However, using the modified video drift method, over 87 percent of the double star systems listed in the WDS

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Table 3. The estimated number, by magnitude, and the relative percentage of double stars from 90° north down to -30° south declination. This estimate was compiled using the WDS online summary catalogue. See text for an explanation.

Magnitude	Number of Double Stars < magnitude	Percent of total
18.99	57225	96.0
17.99	54917	92.2
16.99	52248	87.7
15.99	48727	81.8
14.99	43590	73.1
13.99	36997	62.1
12.99	27582	46.3
11.99	17017	28.6
10.99	8495	14.3
9.99	3580	6.0

catalog should be within reach. Considerations such as locating the double star at its published coordinates, camera sensitivity to a star's spectral type, and the very slow drift rates at high declinations will limit the actual number of double stars that can be studied with a video camera.

Conclusions

We have demonstrated that with a 14-inch telescope, the position angle and separation of double stars down to at least magnitude +16 can be easily measured using the modified video drift method. It is a reasonable assumption that smaller telescopes might see a 3-4 magnitude gain and a corresponding increase in the number of double star systems that can be reached. Both the video drift method and modified video drift method are fast and efficient tools. Traditional CCD cameras which are often very expensive are no longer the only tool capable of measuring dim double star systems. With an integrating video camera, the time involved to collect and analyze the data can be a bit more involved, especially when working at fainter magnitudes. Unfortunately the Stella Cam 3 is now out of production but the principles presented apply equally to other integrating camera brands.

The Image Source line of video cameras may prove useful in double star work. Although they lack the high sensitivity normally found in an astronomical video camera, they are capable of very long exposure times and reduced output frame rates. Additional changes to the modified video drift method may be needed to accommodate these cameras. This type of camera offers two important advantages. First, unlike analog video cameras, the CCD chip uses square pixels, and second, the video signal is digitized inside the camera instead of an external frame grabber. The result is that an aspect correction does not need to be applied to make the recorded image closely match the night sky (Nugent and Iverson, 2014).

Acknowledgements

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

Appendix I

The *AviSynth* script is used to define the aspect ratio and set the image brightness. See Nugent and Iverson (2015) for an explanation of why the aspect ratio needs to be adjusted to fit the observed night sky for each system.

```
#########################################################
#
#   AviSyth script used by Limovie to open a video file.
#
#########################################################

ClipMain = ("insert the video file path")
DirectShowSource(ClipMain)

LanczosResize(640,480)    #sets the image size used by
                          #Limovie to 640x480.  Adjust this
                          #value to match the observed sky.

Noise =25     #below this pixel value will be pure black
              #(the noise floor)

IH = 60       #above this pixel value will be pure white

Levels(Noise,1,IH,0,255-Noise,coring=false)

#########################################################
```

Appendix II

The *AviSynth* "Level" filter is used to adjust the brightness, contrast and gamma of the video clip. See the web page: http://avisynth.nl/index.php/Levels for a complete description.

The *AviSynth* script file syntax is:

Levels(I_L, *G*, I_H, O_L, O_H, *coring*)

I_L is the input pixel value that will be set to black and I_H is the input pixel value that will be set to white.

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Gamma (G) controls the degree of nonlinearity in the conversion and should be set to 1 for black and white cameras. Making gamma less than 1 will brighten dim stars but it also has the negative effect of increasing the background noise. O_L is the output pixel value that will be set to black and O_H is the output pixel value that will be set to white. Increasing the input-low parameter (I_L) effectively raises the noise floor and increases contrast. This reduces the amount of noise seen in the *Limovie* 3D window. Settings up to 30 were common in our analysis. The input-high parameter (I_H) essentially acts as an inverse gain control. As the value decreases from 255, fainter star images become brighter and therefore easier for *Limovie* to follow. Settings as low as 50 were used. Changing the output pixel settings reduces the dynamic gray scale range of the image and should be avoided.

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Measuring Double Stars with Position Circle and Filar Micrometer Screw: Report #2

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Abstract: I present a list of 54 binaries observed in late 2012. Some remarks on changes against recently measured pairs are given. Also a short discussion about causes and consequences of diverging results obtained.

In *JDSO* Vol.10 n.3 [1] I presented the method and equipment which I have been using for more than 7 years to measure separation and position angle of binaries.

Here are a further 54 double stars, selected from Washington Double Star Catalog (WDS) and observed and measured in late 2012. The measurements are given in Table 1. The criteria for my choices, just like the equipment and the method, have not been changed and are subject to two factors. The first factor is the limits given by the equipment: pairs with a separation of more than 10” and a magnitude brighter than 9. Second, I was looking for objects that showed significant changes in rho and/or theta in the past.

The evaluation of the following list and comparison of the results obtained, against the published measures from other observers in the WDS, gave occasion to investigate whether the divergences found showed some systematic scheme. Therefore I have attempted a graphic evaluation (Figure 1) to show the portion of diverging results over the 13 observing sessions that contributed to the list reported.

Two facts are quite significant. First, most divergences concern the distances, while angle measures are less affected. Second, the later the time of year, the more the quota of divergences increases.

So, I investigated further in the rho-measures; Figure 2 shows the ratio between consistent and diverging rho-measures over the distances, these split in 5 categories of 50” steps.

Figure 2 shows very clearly that the portion of

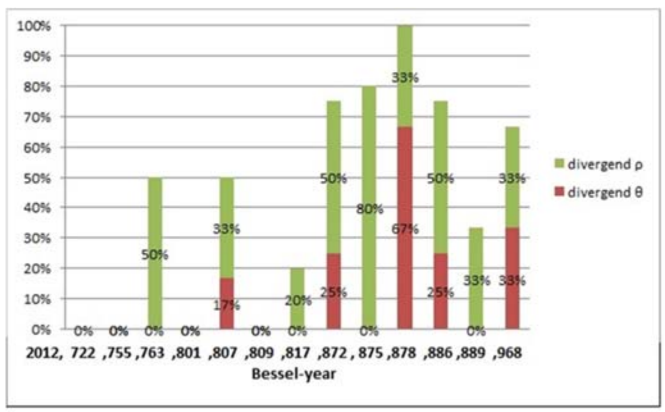

Figure 1: Quota of diverging measures in rho and theta over 13 sessions reported .

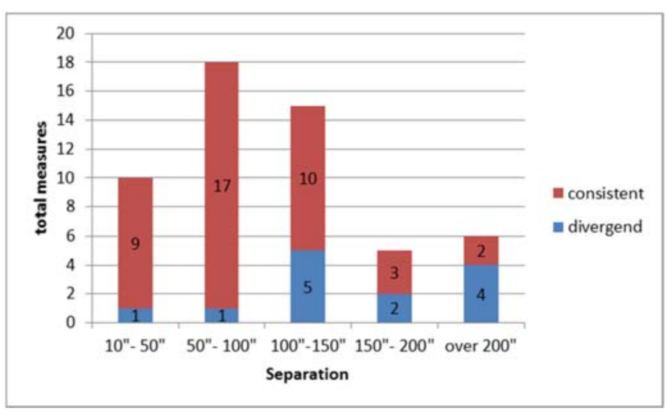

Figure 2: Ratio between consistent to deviating measures in rho over separation.

Measuring Double Stars with Position Circle and Filar Micrometer Screw: Report #2

Table 1. Measurements of Double Stars Measured in 2012.

Name	RA	Dec	mag 1/2	rho	theta	Date	N	Remarks
S 838 AD	00h 04.2	62° 17	5.9/8.2	244"	197°	2012,807	2	No change against v.r.
STTA256 AB	00h 08.0	31° 23	7.1/7.3	110"	113.5°	2012,755	2	Measures consistent, θ↓ with trend
BU 483 AC	00h 09.1	40° 51	7.0/7.7	158.2"	269°	2012.755	2	Measures consistent, θ↑with trend
BU 484 AC	00h 09.7	52° 02	7.6/8.5	81.8"	51°	2012.801	2	No change
ARY 7 AB	00h 10.4	58° 31	7.8/8.3	122.7"	1°	2012.801	2	No change
ARY 9	00h 11.6	58° 13	7.1/8.6	135.1"	81.5°	2012.801	2	θ no change; ρ↓. Con- sistent
HJ 1944	00h 13.2	-17° 11	7.7/9.0	65.3"	335°	2012.801	2	ρ↑, θ↓ consistent
STF 30 AB	00h 27.2	49° 59	7.0/8.9	14.2"	313°	2012.807	2	ρ matches v.r. Θ 2° un- der v.r.
STT 10 AC	00h 27.5	16° 02	6.5/9.5	272.5"	156°	2012.968	2	Θ No change ρ 2" under v.r., but with the trend
HJ 1968 AB	00h 27.7	-16° 25	7.3/10.0	36.92"	232.5°	2012.807	2	ρ 1" over, θ 1.5° under v.r. Both with trend
HJ 1981 A-BC	00h 31.0	-10° 05	6.9/8.4	78.7"	90°	2012.968	2	P no change, θ 2° over v.r. But matches trend
HJ 323	00h 40.7	-04° 21	6.0/8.5	62.2"	285.5°	2012.801	2	No change
H 5 82 AB	00h 47.4	51° 06	8.0/8.4	56"	75.5°	2012.809	2	No change
STTA 9AB	00h 49.9	30° 27	7.8/8.8	120.9"	243.5°	2012.763	2	Θ No change. ρ 4" (!) over v.r. Measurements show no error; =0".
HJ 629 AC	00h 55.6	34° 33	9.3/8.9	65.8"	257.5°	2012.968	2	Consistent with trend: θ↑, ρ↓
STTA 11 AB, C	01h 07.2	38° 39	7.6/8.8	60.5"	163.3°	2012.763	2	No change
S 397	01h 21.1	64° 39	6.3/8.6	56.5"	339.5°	2012.878	2	P no change; θ 2° under v.r., but matches ↓ trend
STTA 17 AC	01h 24.5	39° 02	8.0/8.5	134.7"	345°	2012.878	2	P 2" under 2007 measure, confirming ↓ trend. Θ slightly under v.r.
HJ 2052	01h 31.6	-19° 01	6.9/7.5	80.5"	114°	2012.807	2	no change
STF 142 AB	01h 39.9	13° 15	8.9/9.2	21.3"	65°	2012.807	2	P slightly under v.r., confirming ↓ trend; θ 2° under v.r., but with↓ trend
KPR 1 AC	01h 44.3	09° 29	7.9/8.4	189.8"	285°	2012.807	2	no change
STFA 4 AB	01h 56.2	37° 15	5.8/6.1	207.1"	298°	2012.809	2	no change
ARN 90 AB	01h 56.8	38° 02	9.0/9.2	36.9"	194.5°	2012.809	2	no change
H 6 69 AC	02h 09.4	25° 56	5.0/8.0	104"	277°	2012.878	2	P no change; θ 2° under v.r.
BUP 30 AC	02h 22.8	41° 24	5.8/7.4	302.2"	9.5°	2012,817	2	No change
WAL 20 AC	03h 02.3	41° 24	8.0/8.9	96.5"	211°	2012,817	2	No change
ENG 11	03h 07.7	36° 37	7.5/9.2	132.5"	260°	2012,817	2	See text
STFA 6	03h 09.2	07° 28	7.7/7.8	80.9"	164°	2012,817	2	No change

Table 1 concludes on next page.

Measuring Double Stars with Position Circle and Filar Micrometer Screw: Report #2

Table 1 (conclusion). Measurements of Double Stars Measured in 2012.

Name	RA	Dec	mag 1/2	rho	theta	Date	N	Remarks
ENG 12AB	03h 10.9	-11° 08	7.3/8.6	143.1"	50.5°	2012.875	2	**P~1" under v.r. θ↓confirming trend**
ENG 13AB-C	03h 15.1	16° 18	8.9/8.5	172.2"	185°	2012.875	2	P 1.5" under v.r. matches ↓ trend. Θ 1° under v.r. against trend.
STT 557AB	03h 19.4	03° 22	4.9/8.9	263.6"	164.5°	2012.875	2	Θ consistent; ρ3" under v.r., but matches ↓ trend
STT 54AB	03h 32.0	67° 35	7.7/9.0	20.9"	1°	2012.872	2	Θ no change; ρ 1" under v.r., matches ↓trend
BU 1231AC	03h 43.7	65° 59	7.9/8.8	87.6"	260.5°	2012.872	2	P no change;θ increased 1.5° against 2003 measure, confirming trend
STTA 38AB	03h 44.6	27° 54	6.8/6.9	134.7"	52°	2012.875	2	Θ no change; ρ 1.5" under v.r.
S 437AB-C	03h 46.3	24° 11	8.1/7.7	38.2"	308°	2012.875	2	Quite consistent
BUP 45AC	03h 55.6	42° 53	7.5/8.0	176.7"	90°	2012.872	2	Θ no change; ρ 2" under v.r., but consistent with ↓trend
BUP 49	04h 00.8	18° 12	5.9/9.1	174.7"	275.5°	2012.872	2	Θ 1.5° under v.r; ρ no change
S 738AB	20h 10.6	33° 38	7.8/8.4	41.8"	104°	2012.886	2	P no change; θ 2° under v.r.
ENG 72AB	20h 14.5	36° 48	5.0/6.7	213.4"	155°	2012.886	2	Θ no change; ρ 2" under v.r., against ↑trend
STF2708AB	20h 38.7	38° 38	6.8/8.7	56.5"	323°	2012.886	2	No change
ENG 77AC	20h 56.8	42° 54	7.3/9.1	125.8"	17°	2012.889	2	P increased 2.2" against 2003 measure, θ increased 2°. Both with ↑trends.
STF2758AB	21h 06.9	38° 45	5.4/6.1	31.6"	151°	2012.889	2	Quite no change
ARN 78	21h 31.4	48° 29	7.6/8.8	51.6"	99°	2012.889	2	Θ no change; ρ ~2" over v.r., but matches ↑trend
S 799AB	21h 43.4	38° 17	5.7/7.0	147.9"	60°	2012.886	2	Θ no change; ρ 2" under v.r., matches ↓trend
ARN 24AC	22h 25.8	-20° 14	6.7/8.0	127.7"	89.5°	2012.801	2	No change
WEB 10AB	23h 38.6	44° 41	8.3/8.8	128"	304°	2012.722	2	No change
STF3041AC	23h 47.9	17° 03	8.4/9.2	60.7"	358.5°	2012.722	2	No change
STF3041AB	23h 47.9	17° 03	8.4/9.1	57"	358.5°	2012.722	2	No change
STF3044	23h 53.0	11° 55	7.3/7.9	20"	283.2°	2012.722	2	No change
STTA251AB	23h 53.6	51° 31	6.9/9.1	48"	209.5°	2012.722	2	P no change; θ 1.5° over v.r,, matches ↑trend
HO 205AD	23h 54.1	39° 17	6.7/9.4	122.7"	215.5°	2012.722	2	No change
ARY 33	23h 59.2	50° 32	7.3/8.1	99.6"	140°	2012.722	2	No change

Measuring Double Stars with Position Circle and Filar Micrometer Screw: Report #2

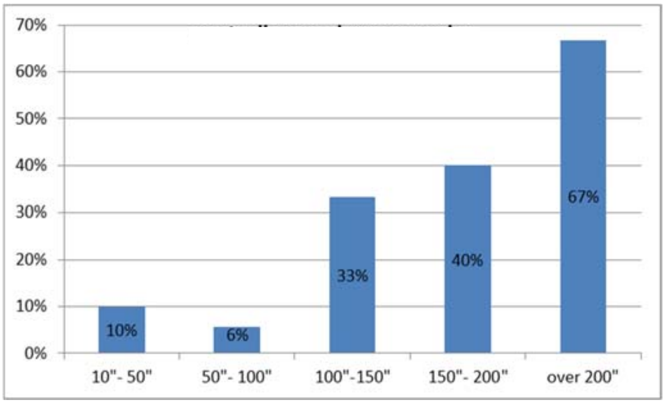

Figure 3. Dependence between separation and quota diverging measures of rho.

diverging results increases as distance grows. Figure 3 shows the percent of "divergers" and more clearly shows the connection.

Taking into account all these considerations, I came to the conclusion that the reason for the discrepancies in separation measurements is not a subjective one, but has its cause in the action of the micrometer screw. With typical low harvest and winter-season temperatures here on the mountain-sides, the mechanics become slow reacting, almost as if they have to "go a longer way". In my opinion, decreasing viscosity of lubrication plays a major role in this. This corresponds also with the fact that the deviations manifest in most cases in lower results than to be expected. I will keep an eye on this in the future.

As concerns the qualitative aspect of the issue discussed, I must say that the typical difference between my results and the presumably correct values ranges in general around 2". With respect to the fact that the deviations are to be found mostly in the measures of distances >150", one must consider that these discrepancies give an erroneous ratio of almost 2%. This makes the results obtained usable, but one should consider the fact. Furthermore, it seems remarkable that the relative results in most cases are reported if they adhere to the reported trend; results that go against the reported trend are hard to find.

Some words on ENG11 at 03h07.7+36°37: I observed this pair October 25, 2012 and found it with a separation of 132.5" (σ = 0.9") and position angle 260°. The latter diverged from the WDS value by more than 9°! I tended to believe this to be an erroneous measure on my part, because the sigma was negligibly small, and because the other measures that night were quite in the range of given values to be expected. Then, I found in the JDSO an article by R. Nugent and E. Iverson[2] in which their result on ENG11 - obtained with better and more sophisticated methods than my own - was consistent with my PA measure from 2012 and suggests that the entry in the WDS is erroneous.

Acknowledgements:

Gianluca Sordiglioni maintains a useful tool with his website: http://stelledoppie.goaction.it, that gives fast and complex information on double stars. Thanks for that!

This project has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory.

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Double Star Observations with a 150mm Refractor in 2014

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Abstract: In the following article, 166 observations of 84 doubles made with a 150mm refractor in 2014 are presented. Residuals were calculated for selected pairs.

For all observations in 2014, a 150 mm folded refractor with filter 11 (yellow – green) was used. Cameras used were the Imaging Source DMK 21 and the Phillips SPC 900 NC (NC in Table 1). As in previous years, teleconverters 1,4 (TK1,4 in Table 1) and 2x (TK2 in Table 1) were used for pairs with smaller separations. Wider pairs were observed at direct focus (f in Table 1). The observing technique was the same as described in Maiwald (2013) and Maiwald (2014).

The image scales with the DMK 21 are:

f: 0.384 a.s. per pixel
TK 1.4: 0.297322 a.s. per pixel
TK 2: 0.19876 a.s. per pixel

For the SPC 900 NC with TK2, the image scale was determined to be 0.2091 a.s. per pixel.

For some of the measured pairs, weighted averages were calculated and compared with the ephemeris. Calculation was done with *Binary Star Calculator* (Workman, 2013) using data from the "Sixth Catalog of Orbits of Visual Binary Stars". The residuals are listed in Table 2.

As exemplified by the measurements of STF 73, STF 1196 AB, and STF 1338 (see remarks 1, 4, and 5 to Table 2 and Maiwald, 2014, p. 191), the error in θ for small distances can be rather large. A detailed discussion of the errors in double star measurements with *Reduc* can be found in Napier–Munn and Jenkinson (2014).

Acknowledgements

This paper made extensive use of the Washington Double Star Catalog and the Sixth Catalog of Orbits of Visual Binary Stars, both maintained at the U.S. Naval Observatory. Noncommercial software used was: *Binary Star Calculator* by Brian Workman; *Reduc 3.88* by Florent Losse, *Registax 4* by Cor Berrevoets and *SharpCap* by Robin Glover.

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(Continued on page 107)

Table 1. Double star observations in 2014

Designation	WDS ident	θ	ρ	Date	No	Name	Notes
STF 60AB	00491+5749	324.3 324 324.3 324.3	13.25 12.78 12.9 12.78	2014.751 2014.757 2014.784 2014.834	43 35 26 32	η Cas	TK2; NC TK2 TK2 TK2
STF 73AB	00550+2338	326.3 327.5 328.9	1.1 1.08 0.96	2014.836 2014.861 2014.869	41 66 82	36 And	TK2 TK2 TK2
H 5 12AB	01579+2336	47.5	37.41	2014.007	44	λ Ari	TK1,4
STF 262AB	02291+6724	229.7 228.6	2.67 2.69	2014.773 2014.784	35 41	ι Cas	TK2 TK2
STF 262AC	02291+6724	115.5 115.9	6.99 7.02	2014.773 2014.784	32 31	ι Cas	TK2 TK2
STF 299	02433+0314	298.2 299	2.04 1.91	2014.910 2014.954	98 127	γ Cet	TK2 TK2
STF 559	04335+1801	277.6 277.2	2.99 3.11	2014.157 2014.165	31 27		TK2 TK1,4
STF 572AB	04385+2656	8.6	4.35	2014.097	36		TK1,4
STF 616	04593+3753	4.6	4.75	2014.061	36	ω Aur	TK1,4
STF 644AB	05103+3718	222.6	1.47	2014.012	25		TK1,4
STF 653AC	05154+3421	224.6	14.23	2014.012	39	14 Aur	TK1,4
STF 698AB	05252+3451	347.2	31.26	2014.968	29		f
STF 716AB	05293+2509	208.9 208.7	4.77 4.76	2014.081 2014.097	36 37	118 Tau	TK1,4
STF 742	05364+2200	273.8 272.7	4.18 3.94	2014.097 2014.157	34 18		TK1,4 TK2
STF 845	06116+4843	358.3	7.56	2014.061	36	41 Aur	TK1,4
STF 958AB	06482+5542	256.6	4.55	2014.226	16		TK1,4
STF 982AB	06546+1311	143.2 143.5	7.38 7.33	2014.13 2014.144	41 35	38 Gem	TK1,4
STF1062AB	07229+5517	315.8	14.97	2014.226	47	19 Lyn	TK1,4
STF1083	07256+2030	45.5	6.76	2014.13	32		TK1,4
STF1110AB	07346+3153	55.2 55 55.2	5.03 5.02 5	2014.13 2014.144 2014.152	36 45 39	α Gem	TK1,4 TK1,4 TK1,4
STF1196AB	08122+1739	25 24 25.7 22.1	1.06 1.08 1.05 1.1	2014.168 2014.171 2014.176 2014.179	39 53 38 38	ζ Cnc	TK2 TK2 TK2 TK2
STF1196AC	08122+1739	62.6 62.7 62.6 62.6	6.29 6.28 6.27 6.26	2014.168 2014.171 2014.176 2014.179	42 72 38 32	ζ Cnc	TK2 TK2 TK2 TK2
STF1223	08268+2656	218.4	5.24	2014.179	31	Φ^2 Cnc	f
STF1268	08467+2846	307.6	30.55	2014.168	36	ι Cnc	f
STF1282	08508+3504	279.9	3.55	2014.223	25		TK1,4
STF1291	08542+3035	310.1 312.4	1.46 1.45	2014.176 2014.179	32 28	57 Cnc	TK2 TK2
STF1333	09184+3522	50.4 50	1.88 1.86	2014.231 2014.291	30 11		TK2 TK2

Table 1 continues on the next page.

Double Star Observations with a 150mm Refractor in 2014

Table 1 (continued). Double star observations in 2014

Designation	WDS ident	θ	ρ	Date	No	Name	Notes
STF1334AB	09188+3648	223.8 223.6	2.52 2.54	2014.231 2014.291	37 39		TK2 TK2
STF1338AB	09219+3811	310.5 308.2 309.9 306.7 309	1 1.07 1.1 1.06 1.05	2014.226 2014.231 2014.283 2014.291 2014.338	27 43 11 41 44		TK2 TK2 TK2 TK2 TK2
STF1424AB	10200+1950	127.1 125.8 126.1	4.8 4.79 4.72	2014.223 2014.239 2014.242	30 35 78	γ Leo	TK1,4 TK1,4 TK1,4
STF1487	10556+2445	112.3	6.62	2014.25	45	54 Leo	TK1,4
STFA 19	11279+0251	181.7	88.49	2014.3	16	τ Leo	f
STF1523AB	11182+3132	179.3 179.3	1.69 1.68	2014.365 2014.376	82 38	ξ Uma	TK2 TK2
STF1670AB	12417-0127	8.6 7.5 6.7	2.08 2.07 2.07	2014.338 2014.365 2014.373	36 47 62	γ Vir	TK2 TK2 TK2
STT 261	13120+3205	337.8 337.6	2.56 2.53	2014.382 2014.393	36 33		TK2 TK2
STF1768AB	13375+3618	95.2 95.6 95.2	1.7 1.67 1.67	2014.379 2014.382 2014.393	46 42 53	25 CVn	TK2 TK2 TK2
STF1864AB	14407+1625	111.2 111.1	5.31 5.34	2014.412 2014.417	37 43	π Boo	TK2 TK2
STF1877AB	14450+2704	343.1 343.4	2.76 2.9	2014.42 2014.428	57 28	ε Boo	TK2 TK2
STF1888AB	14514+1906	303.1 303.7	5.59 5.58	2014.395 2014.412	43 43	ξ Boo	TK2 TK2
STT 288	14534+1542	159.1 159.7	1 0.98	2014.412 2014.417	36 43		TK2 TK2
STF1909	15038+4739	65.7 66.2 65.4 64.9	1.04 1.01 1.03 1.11	2014.393 2014.395 2014.412 2014.42	84 60 32 77	44 Boo	TK2 TK2 TK2 TK2
STF1919	15127+1917	10.5	23.22	2014.445	41		f
STF1932AB	15183+2650	264.1 264	1.59 1.56	2014.431 2014.437	26 25		TK2 TK2
STF1938BC	15245+3723	4.4 3.9	2.18 2.17	2014.42 2014.428	44 45	μ Boo	TK2 TK2
STF2032AB	16147+3352	238.1 238.3	6.98 6.96	2014.431 2014.437	34 36	σ CrB	TK2 TK2
STF2054AB	16238+6142	350.7 350.1	0.92 1.01	2014.448 2014.456	80 92		TK2
STF2118AB	16564+6502	64.6 66.5	0.94 0.91	2014.475 2014.478	24 81	20 Dra	TK2
STF2130AB	17053+5428	5.7 3.8 4.1 3.8	2.41 2.43 2.44 2.42	2014.475 2014.478 2014.483 2014.486	65 60 28 69	μ Dra	TK2
STF2140	17146+1423	103.6 103.2	4.64 4.61	2014.500 2014.505	44 38	α Her	TK2
STF2161AB	17237+3709	320.4 320.2	3.95 3.94	2014.500 2014.505	44 32	ρ Her	TK2

Table 1 concludes on the next page.

Double Star Observations with a 150mm Refractor in 2014

Table 1 (conclusion). Double star observations in 2014

Designation	WDS ident	θ	ρ	Date	No	Name	Notes
STFA 34AB	17346+0935	190.2	41.23	2014.546	42	53 Oph	f
STF2194AB	17411+2431	6.8	16.26	2014.546	36		f
STF2272AB	18055+0230	126.4 126.4	6.04 6.09	2014.535 2014.541	72 73	70 Oph	TK2
STF2276AB	18057+1200	265.7	6.94	2014.56	39		TK1,4
STF2289	18101+1629	224.2 223.6	1.19 1.2	2014.500 2014.505	43 52		TK2
STT 358AB	18359+1659	149.1 148.9	1.6 1.59	2014.541 2014.543	61 29		TK2
STF2382AB	18443+3940	347.5 346.8	2.25 2.21	2014.464 2014.483	38 41	ε Lyr	TK2
STF2383CD	18443+3940	76.2 77	2.35 2.33	2014.464 2014.483	37 41	5 Lyr	TK2
STFA 39AB	18501+3332	148.3 148.3	45.8 45.72	2014.543 2014.557	36 26	β Lyr	f
STF2404	18508+1059	181.9	3.56	2014.56	46		TK1,4
STTA178	19153+1505	266.9	89.84	2014.565	37		f
STTA182AB	19268+5009	297	73.22	2014.557	37		f
STT 384AB	19438+3819	193.5 195.5 198	1 0.94 1.07	2014.568 2014.582 2014.601	33 30 35		TK2 TK2 TK2
STF2579AB	19450+4508	220 217.9 217.5	2.6 2.64 2.63	2014.568 2014.582 2014.601	57 67 65	δ Cyg	TK2 TK2 TK2
STF2583AB	1948+1149	101.5 101.3	1.3 1.37	2014.535 2014.543	39 39	π Aql	TK2
STF2628	20078+0924	338.4	2.96	2014.565	44		TK1,4
STFA 50AC	20136+4644	172.7 172.7	106.86 106.81	2014.557 2014.587	40 33	31 Cyg	f
STF2758AB	21069+3845	152.1 152.2	31.58 31.58	2014.587 2014.645	44 44	61 Cyg	f
STF2822AB	21441+2845	317.4 317.9	1.61 1.58	2014.645 2014.647	36 42	μ Cyg	TK2
STF2822AD	21441+2845	43.4	197.09	2014.647	22	μ Cyg	f
S 799AB	21434+3817	59.8	149.52	2014.645	40	79 Cyg	f
STF2840	21520+5548	196.1	17.72	2014.688	40		f
STF2873	21582+8252	65.7	13.88	2014.688	33		f
STF2872AB	22086+5917	315.6	21.61	2014.697	29		f
STF2893	22129+7318	346.7	28.79	2014.697	38		f
STFA 58AC	22292+5825	191.2	40.65	2014.688	44	δ Cep	f
STF2947AB	22490+6834	55.5 55.3	4.51 4.52	2014.71 2014.727	29 27		TK2
STTA238AB	22527+6759	280.3 280.2	66.74 66.73	2014.71 2014.727	37 23		TK2 TK2
STF2950AB	22514+6142	274.7 276.1 275.3	1.18 1.25 1.23	2014.71 2014.727 2014.748	44 20 30		TK2 TK2 TK2
STF2909	22288-0001	164.5 164.5	2.23 2.05	2014.822 2014.825	98 49	ζ Aqr	TK2
STF2978	23075+3250	144.7	8.04	2014.748	36		TK2
STF3042	23519+3753	86.9	5.47	2014.861	19		TK2
STF3049AB	23590+5545	325.9 326.2	3.17 3.07	2014.751 2014.757	46 35	σ Cas	TK2; NC TK2
STF3050AB	23595+3343	338.4 338.8	2.28 2.31	2014.836 2014.861	37 33		TK2 TK2

Double Star Observations with a 150mm Refractor in 2014

Table 2. Residuals for double stars in 2014

Designation	WDS	Name	Date	θ	ρ	Δθ	Δρ	Ref.; Notes
STF 60 AB	00491+5749	η Cas	2014.8	324.2	12.95	0.6	-0.39	Str1969a
STF 73 AB	00550+2338	36 And	2014.9	327.8	1.03	-1.3	-0.09	Mut2010b; 1
STF 262 AB	02291+6724	ι Cas	2014.8	229.1	2.68	1	0.06	Hei1996b
STF 742	05364+2200		2014.1	273.4	4.1	-2	-0.04	Hop1973b; 2
STF 958 AB	06482+5542		2014.2	256.6	4.55	-0.4 0.1	0.01 0.08	Kis2009 Kis2009
STF 982 AB	06546+1311	38 Gem	2014.1	143.3	7.36	2	0.14	Hop1952; 3
STF 1110 AB	07346+3153	α Gem	2014.1	55.1	5.02	-0.2 0.3	0.03 0.07	Hei1988a Doc1985c
STF 1196 AB	08122+1739	ζ Cnc	2014.2	24.2	1.07	1.4	-0.04	WSI2006b; 4
STF 1338	09219+3811		2014.2	308.5	1.05	-3.2	0.04	Sca2002b; 5
STF 1424 AB	10200+1950	γ Leo	2014.2	126.2	4.75	0.1	0.29	Rab1958
STF 1523 AB	11182+3132	ξ Uma	2014.4	179.3	1.69	-1.3	-0.05	Msn1995
STF 1670 AB	12417-0127	γ Vir	2014.4	7.4	2.07	0	-0.11	Sca2007c
STT 261	13120+3205		2014.4	337.7	2.55	-0.8	-0.03	Kis2012
STF 1768 AB	13375+3618	25 CVn	2014.4	95.3	1.68	0	-0.02	Sod1999
STF 1888 AB	14514+1906	ξ Boo	2014.4	303.4	5.59	-0.2	-0.1	Sod1999
STT 288	14534+1542		2014.4	159.4	0.99	0.4	-0.03	Hei1998
STF 1909	15038+4739	44 Boo	2014.4	65.5	1.05	0 0.2	0.05 -0.07	Sod1999 Zirm 2010
STF 1932 AB	15183+2650		2014.4	264.1	1.58	-1.1 -0.9	0.06 -0.04	Hei1965c Sca2013b
STF 1938 BC	15245+3723	μ Boo	2014.4	4.2	2.17	0.2 0.4	-0.05 -0.07	Sca2013a Sod1999
STF 2032 AB	16147+3352	σ CrB	2014.4	238.2	6.97	0.1 0.1	-0.21 -0.3	Rag2009 Sca1979
STF 2118 AB	16564+6502	20 Dra	2014.5	66.1	0.92	-0.8	-0.23	Sca2002d
STF 2130 AB	17053+5428	μ Dra	2014.5	4.4	2.42	0.9	-0.07	Pru2012
STF 2140 AB	17146+1423	α Her	2014.5	103.4	4.63	0.3	-0.01	Baz1978
STF 2272 AB	18055+0230	70 Oph	2014.5	126.4	6.07	0.5	-0.19	Pxb2000b
STF 2289	18101+1629		2014.5	223.9	1.2	8	-0.04	Hop1964b; 6
STT 358AB	18359+1659		2014.5	149	1.6	2.2	0.09	Hei1995; 7
STF 2382 AB	18443+3940	ε Lyr	2014.5	347.1	2.23	0.9 0.9	-0.05 -0.12	Nov 2006e WSI2004b
STF 2383 CD	18443+3940	5 Lyr	2014.5	76.6	2.34	0.2	-0.04	Doc1984b
STF 2579 AB	19450+4508	δ Cyg	2014.6	218.4	2.62	0.8	-0.1	Sca2012c
STF 2758 AB	21069+3845	61 Cyg	2014.6	152.2	31.58	-0.6 -0.2	0.05 -0.02	Pko2006b Kis1997
STF 2822 AB	21441+2845	μ Cyg	2014.6	317.7	1.59	-3.0	0.03	Hei1995; 8
STF 2909	22288-0001	ζ Aqr	2014.8	164.5	2.17	-1.5 -0.7	-0.19 -0.07	Hei 1984c; 9 Sca 2010c
STF 3050AB	23595+3343		2014.8	338.6	2.29	-0.8	-0.07	Hrt2011a

Table Notes.

1. The large variations in Δθ show the difficulties in measuring θ for small separations. See Table 3.
2. Residuals for 2009.186 (Courtot, 2010, p.7): Δθ –0,8 and Δρ - 0,12 and for 2008.08 (Alzner, 2008, p. 12): Δθ –0.7 and Δρ - 0.09.
3. Argyle (2013, p. 3) Δθ + 4.3 and Δρ + 0.03 for 2012.216; Argyle (2008, p. 5) Δθ + 3.1 and Δρ + 0.01 for 2006.244; Courtot (2010, p. 7) Δθ + 1.6 and Δρ + 0.04 for 2009.21.
4. Measurements from 2010 to 2012 were published in Maiwald (2013) and for 2013 in Maiwald (2014). The great variation in Δθ shows that the separation of the star is rather small for my telescope and location. See Table 4.
5. Residuals for my own measurements from 2010.3 to 2013.2 (Δθ all negative) can be found in (Maiwald, 2014, p. 191). (Argyle, 2014, p. 4): Δθ – 3.0 and Δρ + 0.09 for 2013.345.
6. In (Maiwald, 2014, p.190f.) Δθ 6.3 for 2013.5 was reported.
7. Data for 2012 from Maiwald (2013, p. 193), for 2013 from Maiwald (2014, p. 190). Argyle (2013, p. 4): Δθ + 4.4 and Δρ + 0.07 for 2012.683. See Table 5.
8. Star is known for deviations from ephemeris. Residuals from 2010.6 to 2013.8 in Maiwald (2014, p. 191). Argyle (2014): Δθ – 3.4 and Δρ + 0.18 for 2013.538.
9. Residuals from 2010.8 to 2013.8 in Maiwald (2014, p. 191). Argyle (2014, p. 4): Δθ – 2.4 and Δρ + 0.26 for 2013.864 for the newer orbit.

Double Star Observations with a 150mm Refractor in 2014

Table 3: Residuals for STF 73 from 2012.9 to 2014.9

Designation	WDS	Nights	Date	θ	ρ	Δθ	Δρ	Ref.
STF 73 AB	00550+2338	4	2012.9	326.5	1.13	-0.3	0.04	Mut2010b
		4	2013.9	328.4	1.01	0.5	-0.09	
		3	2014.9	327.8	1.03	-1.3	-0.09	

Table 4: Residuals for STF 1196 from 2010.2 to 2014.2

Designation	WDS	Nights	Date	θ	ρ	Δθ	Δρ	Ref.
STF 1196 AB	08122+1739	4	2010.2	38.3	1	1.3	-0.06	WSI2006b
		2	2011.2	37.3	0.99	4	-0.09	
		1	2012.2	32.4	1.04	2.6	-0.05	
		2	2013.2	26.9	1.04	0.6	-0.06	
		4	2014.2	24.2	1.07	1.4	-0.04	

Table 5: Residuals for STT 358 AB from 2012.6 to 2013.5

Designation	WDS	Nights	Date	θ	ρ	Δθ	Δρ	Ref.
STT 358 AB	18359+1659	4	2012.6	150.2	1.63	2.3	0.11	Hei1995
		2	2013.5	149.1	1.6	1.7	0.08	
		2	2014.5	149	1.6	2.2	0.09	

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Searching for New Double Stars with a Computer

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Reprinted from http://mainsequence.org/html/wds/newPairs/FindingUnlistedDoubleStars.html

Abstract: The advent of computers with large amounts of RAM memory and fast processors, as well as easy internet access to large online astronomical databases, has made computer searches based on astrometric data practicable for most researchers. This paper describes one such search that has uncovered hitherto unrecognized double stars.

Introduction

Recently, four previously unlisted double stars were added to the Washington Double Star Catalog (WDS)[1] as a result of the process to be described in this article. They are shown in Table 1.

These pairs were located by a computer search of the fourth USNO CCD Astrographic Catalog[2] (UCAC4). Using the CD provided by the United States Naval Observatory[3] (USNO), a suite of programs written in Perl and C was used to search the UCAC4 for candidate binary pairs that were not in the WDS.

Pairs that passed this test were then placed into a list for manual verification, using the Aladin[4] tool.

Using Aladin, the candidate pair was manually examined. Pairs that seemed to be associated with nearby clusters were eliminated, as were pairs enmeshed in nebulosity to the point that they could not be accurately measured with Aladin. Pairs that passed these tests were then measured for position angle and separation, using Aladin's UCAC4 template on the DSS plate, and placed in a final list of candidates.

The four entries from this final list of pairs were chosen based on their visibility in the summer sky from 39° north latitude, brightness, separation, and a large proper motion. These stars were observed from the Little Tycho Observatory, and then submitted to William Hartkopf[5] of the USNO.

Search for Unlisted Double Stars from the UCAC4 Data

The instructions given below have been shown to work in a Linux development environment. While they can be replicated in other environments, e.g, an Apple Mac, or the Cygwin environment on a Windows PC, they have not been tested in these environments.

Obtain a copy of the UCAC4 data.

You'll need to send an email to brenda.hicks@navy.mil with "UCAC4" in subject and your full name and postal mailing address in the body of

Table 1: Double stars recently found by computer search and added to the WDS.

RA + Dec: J2000	UCAC4 Designation	Primary mv	Secondary mv
16:39:17.31 +26:27:28.92	583-54539	10.15	11.325
17:16:01.38 +25:16:05.87	577-56486	10.652	12.202
19:50:41.95 +20:18:29.21	552-99070	9.22	10.5
20:43:31.93 +52:16:35.77	712-76210	9.51	10.96

your e-mail.

A CD of the data will be sent to your address. When it arrives, mount the CD(s) in your computer's CD drive and download the 900 UCAC4 declination zones to a directory on your computer.

Obtain a copy of the WDS data.

On a computer equipped with the wget program and connected to the internet, the following command should do the trick:

```
cd /DirectoryWhereYouWantToStoreTheData/
wget -r -O wdsData http://ad.usno.navy.mil/wds/Webtextfiles/wdsweb_summ.txt
```

The file wdsData should now be downloaded to your current working directory:

```
DirectoryWhereYouWantToStoreTheData.
```

Getting the code

It is assumed that the reader is somewhat familiar with programming and the C and Perl languages in particular in this section.

Code can be obtained from GitHub, or the author's web site, http://www.mainsequence.org/html/wds/newPairs.

In downloading code from the author's web site, you can list the program by left-clicking on the link below, and download it by right-clicking (Ctl-click on a Mac)

The WDS is listed in order of its positional Ids, a low precision J2000 coordinate designation, as opposed to a pair's precise coordinates. A short Perl program has been written to extract the precise coordinates from the WDS which can be downloaded from

getWDS_PrecisionCoordinates.pl

The program is run from the directory containing a recent copy of the WDS catalog.

The resultant file, WDS.pre, is then sorted using the unix sort command:

```
sort -n WDS.pre > wdsPrecisionCoordinates
```

As the UCAC4, as of this writing, consists of 113,780,093 stars, it was not efficient to search the entire declination range of the catalog for each of the candidates. MkUCAC4_Regions.c reads the catalog and then splits it into files, each of which covers approximately a square degree of sky. Stars that border (within 30") a square degree are also included in the file. In this way, when a candidate star is searched for possible companions, only a single square degree need be searched. The program also creates a list of possible primary candidate stars, all brighter than mvC (Default setting for this is 11000 = 11.0mv) that findUnlistedDoubles.c will use for the search. Click on the link below to download the code.

mkUCAC4_Regions.c

Edit the program's holding directory location in lines 65 and 68 to match where you would like its square degree files to be written. The directory used to store the UCAC4 data must also be changed in line 104.

The program can be compiled using this command:

```
gcc -std=gnu99 -O2 -o mkr -W mkUCAC4_Regions.c -lm
```

and run using this: `mkr`

Find candidate binary pairs not in the WDS from UCAC4 data

Now that we have the precision coordinates from the WDS and the UCAC4 data for the brighter stars stored in square degree files, we can search for pairs not in the WDS with findUnlistedDoubles.c. Click on the link below.

findUnlistedDoubles.c

Many of the search parameters set by both programs can be changed, the programs recompiled, and different results obtained. If a very loose set of parameters is used, many thousands of possible pairs can be generated. More restrictive parameters will result in fewer pairs. Once the user is familiar with editing and compiling the programs, many interesting lists can be generated. Each list takes only about 5 minutes to compile and create on the author's machine. It complies with a command similar to the one given above.

The program's output file is in HTML format. Read it in your browser by opening it as a file. A sample output can be seen at the link listing 1.

The program ships with these default parameters. Their default values are the numbers in parentheses following the parameter's name:

- Only stars brighter than mvC (11000) are considered as primary candidates. Generally, the brighter the star, the more information about it is to be found in the literature, simplifying subsequent study. This can be changed by changing the value of mvC in mkUCAC4_Regions.c.
- Secondary stars must be brighter than mvS (12000) to be considered. This again can be changed by changing mvS in findUnlistedDoubles.c and mkUCAC4_Regions.c. Note that the UCAC4 does not list many stars fainter than 16.0mv (16000).
- The primary and secondary should be within dMv (1000) of each other. This is a fairly arbitrary restriction, and is used to simply cut down on the number of pairs found.

Searching for New Double Stars with a Computer

- XXX (30) is the size of the region of sky that will be searched, in arc seconds. A box of sky twice this distance on a side will be searched for possible companions to a given candidate star. This can be changed by changing XXX in both `mkUCAC4_Regions.c` and `findUnlistedDoubles.c`. Note: The programs have only been tested with XXX set to 30". Change this at your own risk!
- The minimum separation between the stars should be minSep (10) arc seconds or more. Pairs are manually verified by examining them on DSS plates. A pair of stars with less separation can be very difficult to differentiate from a single star.
- The larger the maximum separation, maxSep (30), the less likely a pair will be physical. Unless XXX is changed, 30 should be the largest separation used.
- The average proper motion of the two stars must be larger than minPM (50) milliarcseconds per year (mas/yr). This will help to eliminate slow moving pairs that are optical.
- The difference between the average proper motion of the candidate pair and their individual proper motions should be less than a given quantity pmR (5). This condition helps to eliminate possible optical pairs, and is defined as the differences between the primary and secondary proper motions. For example, if a pair had an average proper motion of 70 mas/yr but one component was moving north of the average proper motion at 30 mas/yr, the other south at 20 mas/yr, the pair would be rejected because of their individually disparate, though large, proper motions.
- There must not be a binary listed by the WDS within XXX arc seconds of the candidate pair. Visual magnitudes were ignored for this condition, as many WDS listings show magnitudes different from the UCAC4 magnitudes.
- The program converts all of its angles to radian measure for calculation, and then back to degrees or hours, minutes, and seconds for output.
- The output coordinates are in a format such that you can easily drag and drop them into DSS display tools such as Aladin, GoogleSky, or WikiSky.
- When a parameter is changed, the changed program must be recompiled before the changes will take effect.
- Directories that hold the UCAC4, WDS, and output data are as found on the author's computer. These will probably need to be changed to fit the user's computer.

A sample list

A sample list of possible binary stars not in the WDS is given in Table 2 at the end of this article. Column headers are as follows:

- RA and Dec are the J2000 coordinates of the primary.
- mv and mvb are the visual magnitudes of the primary and secondary, respectively. They are in units of millimagnitudes, that is 9000 = 9.0mv.
- mv src and mvb src are the source of the magnitude measurement, APASS (the AAVSO survey) or UCAC4 (the UCAC4 model magnitude).
- ρ is the separation of the pair, in arc seconds.
- Double Flag is the UCAC4 double flag for the primary.
- Primary and secondary proper motion in both right ascension and declination are given in milliarcseconds per century.
- A and B UCAC4 id give the UCAC4 declination zone and star number in that zone of the primary and secondary, respectively.
- Comments can be edited or added as further study of a pair is done.

Acknowledgments

The editorial assistance of Kathleen Bryant, Thomas Corbin, and R. Kent Clark are gratefully recognized.

References

1) The Washington Double Star Catalog, Brian D. Mason, Gary L. Wycoff, William I. Hartkopf, Geoffrey G. Douglass, and Charles E. Worley, 2001.

2) The Fourth US Naval Observatory CCD Astrograph Catalog (UCAC4), Zacharias, et al, 2012. http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/ucac

3) USNO web site: http://aa.usno.navy.mil

4) Aladin web site: http://aladin.u-strasbg.fr

5) William Hartkopf, Astrometry Department, U.S. Naval Observatory 3450 Massachusetts Ave, NW, Washington, DC 20392

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Table 2. Non-WDS Pairs

RA Dec	mv	mv src	mvb	mvb src	sep.	Dbl Flag	Pri PM in RA	Pri PM in Dec	Sec. PM in RA	Sec. PM in Dec	A UCAC4 id	B UCAC4 id
05:37:50.8 +43:01:42.54	9920	APASS	10306	APASS	17.32	3	-81	-13	-63	-19	666 960	666 961
05:39:32.51 -24:19:03.2	9564	APASS	10112	APASS	21.53	0	-142	-185	-149	-165	329 434	329 435
05:41:06.36 -24:34:06.80	9777	APASS	9958	APASS	20.79	0	-99	-92	-307	-168	328 446	328 447
05:42:39.68 -17:47:32.86	9880	APASS	10799	APASS	20.89	0	-52	-181	-126	-590	362 408	362 409
05:42:06.21 +12:24:25.20	9895	APASS	9976	APASS	26.60	0	23	-138	0	-134	513 464	513 465
05:07:34.24 -54:59:20.44	8717	APASS	9063	APASS	15.69	3	-483	535	-1031	-374	176 237	176 236
05:07:09.70 -18:18:07.83	9963	APASS	10690	APASS	27.23	0	-74	-46	-66	-57	359 326	359 325
06:15:49.19 +27:13:26.8	9889	APASS	9962	APASS	8.52	35	23	-67	-21	-100	587 720	587 719
06:18:28.41 -22:49:44.53	9974	APASS	10141	APASS	25.49	0	41	180	-76	164	336 559	336 558
06:34:30.0 +13:02:01.93	9713	APASS	10315	APASS	27.87	0	-16	-69	-9	-58	516 829	516 830
06:41:54.35 +23:56:02.41	9666	APASS	10431	APASS	27.95	0	16	-55	-24	-78	570 866	570 867
06:42:51.75 +26:25:09.4	9547	APASS	9564	APASS	25.01	0	-19	-76	-3	-71	583 879	583 881
06:43:16.39 -11:04:02.59	9920	APASS	10296	APASS	29.66	0	-64	129	-21	-30	395 656	395 655
06:43:28.69 +21:33:59.93	9278	APASS	9445	APASS	25.48	0	-12	-52	-81	-37	558 891	558 890
06:46:26.29 +20:52:52.31	9771	APASS	9777	APASS	11.40	36	-82	-109	-88	-135	555 927	555 926
06:48:42.82 +16:07:49.45	9988	APASS	10425	APASS	17.86	0	-421	-90	-419	-76	531 913	531 915
06:52:42.61 -05:25:59.44	9163	APASS	10136	APASS	18.74	36	-15	22	-80	22	423 772	423 771
06:53:40.34 -24:23:27.51	9207	APASS	10180	APASS	23.59	3	-90	-1520	-90	-1466	329 720	329 721
06:54:12.43 -12:52:56.67	10000	APASS	10856	APASS	22.34	0	-133	-45	-24	33	386 765	386 766
06:55:25.40 +13:48:55.72	9532	APASS	10269	APASS	22.77	0	32	-31	-42	-81	520 900	520 899
06:57:12.90 +11:00:36.72	9770	APASS	10408	APASS	22.10	0	-22	-70	-18	-62	506 857	506 856
06:57:42.60 -39:40:12.58	9679	APASS	10441	APASS	21.90	0	4	-44	-595	569	252 532	252 533
07:13:19.16 +12:25:29.44	9970	APASS	10556	APASS	22.02	0	-28	-320	-61	-37	513 980	513 981
07:15:00.56 -21:53:21.23	9181	APASS	9374	APASS	21.49	3	-136	191	-42	-19	341 870	341 869
07:15:57.1 -11:08:00.18	9909	APASS	10017	APASS	13.27	0	-72	8	-86	-10	395 859	395 858
07:16:17.25 -41:49:03.69	9748	APASS	10519	APASS	28.53	0	-51	-36	12	-77	241 613	241 612
07:18:41.98 -24:58:12.27	9495	APASS	9978	APASS	22.96	4	-41	80	-36	21	326 863	326 862
07:18:41.98 -24:58:12.27	9495	APASS	10479	APASS	18.24	4	-41	80	-43	53	326 863	326 868
07:19:50.28 +19:42:21.13	9407	APASS	10099	APASS	20.96	0	-46	-45	-45	-43	549 1055	549 1056
07:22:35.70 +06:19:40.23	9912	APASS	10912	APASS	26.02	0	-20	-91	-25	-111	482 1080	482 1082
07:33:07.89 -19:28:05.21	9739	APASS	10104	APASS	16.36	0	-173	153	-10	13	353 978	353 979
07:37:21.38 -28:05:21.72	9357	APASS	9521	APASS	26.41	0	-136	144	-54	85	310 992	310 991
07:38:53.92 -27:22:34.36	9956	APASS	10824	APASS	28.47	36	44	-239	-286	-158	314 961	314 962
07:42:07.78 -31:41:39.46	9450	APASS	9668	APASS	19.72	35	-194	142	-18	199	292 868	292 869
07:47:16.73 -57:16:01.96	9911	APASS	10170	APASS	26.91	0	-122	320	2	126	164 490	164 491
07:48:35.21 +42:50:53.81	9875	APASS	10608	APASS	24.27	0	-136	-57	-315	-381	665 1384	665 1383
07:50:10.53 -12:21:36.60	9452	APASS	10123	APASS	27.76	0	-96	-140	-11	26	389 1076	389 1077
07:54:19.82 -27:01:16.48	9914	APASS	10500	APASS	26.08	0	48	113	-50	151	315 1085	315 1084
07:58:01.13 -43:54:12.61	9682	APASS	10635	APASS	29.03	0	-78	61	-121	61	231 810	231 811
07:59:50.7 +19:46:58.2	9729	APASS	10547	APASS	18.55	0	-48	-24	-52	-662	549 1179	549 1180
07:07:14.49 -13:05:07.13	9395	APASS	10165	APASS	17.36	0	-72	-15	-64	-3	385 787	385 788
07:07:48.51 -02:49:56.75	9756	APASS	10543	APASS	28.41	0	-17	-74	-46	-54	436 1031	436 1032
07:08:09.72 +08:33:05.19	9591	APASS	10152	APASS	29.30	0	-88	8	-46	-58	493 1118	493 1120
08:10:49.46 -12:46:06.61	9979	APASS	10970	APASS	23.65	0	-134	-315	-19	-33	387 1249	387 1248

Table 2 continues on next page.

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Table 2 (continued). Non-WDS Pairs

RA Dec	mv	mv src	mvb	mvb src	sep.	Dbl Flag	Pri PM in RA	Pri PM in Dec	Sec. PM in RA	Sec. PM in Dec	A UCAC4 id	B UCAC4 id
08:12:07.94 -37:39:27.58	9562	APASS	9799	APASS	20.43	0	-39	34	-58	64	262 839	262 838
08:13:23.20 -32:29:59.67	9281	APASS	9364	APASS	8.15	0	-62	36	-1216	-802	288 1033	288 1032
08:21:02.30 +4:59:30.48	9988	APASS	10357	APASS	27.36	0	-564	-902	213	8	475 1289	475 1288
08:22:42.75 -12:05:00.27	9556	APASS	10498	APASS	14.05	36	-180	169	-54	-1	390 1282	390 1284
08:26:34.34 -23:05:01.24	9252	APASS	10142	APASS	24.31	0	-181	390	13	74	335 1406	335 1405
08:26:45.76 -31:20:45.97	9802	APASS	9933	APASS	29.55	0	-80	112	-117	137	294 1234	294 1233
08:30:46.92 -33:06:11.41	9893	APASS	10729	APASS	24.26	0	-37	-108	-45	18	285 1160	285 1161
08:34:00.5 -13:41:47.6	9751	APASS	10456	APASS	24.59	0	-120	-427	-9	36	382 1352	382 1353
08:40:21.21 -26:15:19.24	9837	APASS	9995	APASS	22.31	0	-139	40	-21	62	319 1483	319 1484
08:42:24.29 -37:21:43.79	9973	APASS	10757	APASS	29.18	0	-77	8	-60	-37	264 1134	264 1135
08:49:51.36 -52:04:29.41	9658	APASS	10367	APASS	23.19	0	-153	214	-89	110	190 723	190 724
08:50:07.33 -45:19:29.36	9289	APASS	10022	APASS	27.26	35	-26	56	-102	39	224 1037	224 1038
08:06:50.27 -30:47:28.40	9943	APASS	10384	APASS	20.02	0	-100	5	-70	-9	297 1109	297 1110
08:08:54.89 -24:49:15.73	9874	APASS	10812	APASS	21.10	0	1	14	-89	-80	326 1296	326 1295
09:00:48.10 -50:57:37.47	9912	APASS	10704	APASS	27.85	0	-353	333	8	90	196 799	196 800
09:10:59.84 -35:25:17.44	9749	APASS	10133	APASS	22.68	3	-84	35	67	71	273 1229	273 1227
09:14:25.3 -52:52:06.39	9940	APASS	10043	APASS	12.22	0	-128	-37	-105	-9	186 867	186 868
09:19:04.61 -44:10:31.68	9732	APASS	10391	APASS	17.54	35	-53	32	-17	43	230 1087	230 1088
09:20:15.2 +0:35:50.46	9755	APASS	10594	APASS	28.33	0	-194	5	-584	130	453 1479	453 1480
09:21:40.55 -44:55:41.10	9869	APASS	10159	APASS	20.20	0	-45	44	-129	9	226 1080	226 1079
09:30:05.52 -15:38:47.42	9918	APASS	10710	APASS	22.47	0	-102	20	-762	-475	372 1578	372 1577
09:31:19.76 -47:06:52.55	9859	APASS	10443	APASS	19.54	0	81	115	-153	-23	215 1119	215 1118
09:32:37.12 -52:42:00.7	9897	APASS	9996	APASS	15.18	35	-38	175	-93	11	187 920	187 919
09:36:42.24 -59:41:55.90	9753	APASS	10252	APASS	19.74	0	-93	66	-356	-1168	152 777	152 778
09:37:50.97 -36:14:53.91	9887	APASS	10617	APASS	23.44	0	46	-271	-46	-26	269 1380	269 1379
09:37:06.51 -51:35:38.26	9709	APASS	10148	APASS	10.57	0	-129	31	-344	1520	193 927	193 928
09:38:57.35 -33:45:03.43	9489	APASS	9555	APASS	21.97	0	-699	-826	-165	78	282 1486	282 1485
09:52:10.24 -53:53:47.1	9266	APASS	9313	APASS	10.78	0	-244	-75	-113	98	181 1105	181 1106
09:55:52.34 -56:07:10.83	9976	APASS	10000	APASS	20.19	0	0	193	-108	22	170 1028	170 1027
09:57:37.37 -54:40:33.74	9949	APASS	9964	APASS	19.58	3	-28	46	-80	47	177 1056	177 1057
09:06:36.90 -64:55:51.30	9802	APASS	10162	APASS	17.13	35	-81	97	-266	132	126 529	126 530
10:10:21.21 -67:15:48.21	8637	APASS	9010	APASS	21.83	3	-108	62	-1992	1789	114 651	114 652
10:13:28.6 -57:53:01.68	9923	APASS	10103	APASS	22.50	0	-307	338	-2	99	161 1037	161 1038
10:22:39.4 -37:44:59.69	9744	APASS	9849	APASS	28.41	0	-118	29	-496	115	262 1436	262 1435
10:24:28.70 -58:49:47.18	9061	APASS	9173	APASS	10.74	36	-147	222	-601	574	156 1168	156 1167
10:27:37.73 -57:38:23.71	9160	APASS	9195	APASS	8.98	36	-58	35	-121	-279	162 1168	162 1167
10:31:41.15 -57:18:37.66	8824	APASS	8850	APASS	9.15	0	0	0	-114	29	164 1208	164 1207
10:32:07.37 -32:10:33.15	9648	APASS	9666	APASS	22.02	0	34	-68	-120	-38	290 1683	290 1682
10:33:37.60 -59:35:21.28	9970	APASS	10009	APASS	16.75	0	-94	77	-164	127	153 1213	153 1212
10:42:33.6 -62:11:51.53	8933	APASS	9127	APASS	23.99	36	-124	-38	-101	29	140 995	140 994
10:44:05.54 -62:08:02.1	10000	APASS	10042	APASS	8.88	36	112	-250	-177	74	140 1007	140 1006
10:47:17.34 -62:06:38.44	9583	APASS	9632	APASS	14.56	2	-273	-8	-435	1950	140 1043	140 1044
10:49:33.17 -62:49:44.29	9880	APASS	10009	APASS	18.20	0	0	0	-102	78	136 956	136 957
10:50:40.32 -61:30:11.9	9756	APASS	9759	APASS	9.00	0	10	124	-100	4	143 1168	143 1169

Table 2 continues on next page.

Searching for New Double Stars with a Computer

Table 2 (continued). Non-WDS Pairs

RA Dec	mv	mv src	mvb	mvb src	sep.	Dbl Flag	Pri PM in RA	Pri PM in Dec	Sec. PM in RA	Sec. PM in Dec	A UCAC4 id	B UCAC4 id
10:56:07.4 -59:48:17.76	9958	APASS	10099	APASS	14.87	35	0	0	-112	75	151 1531	151 1530
10:09:05.78 +0:22:56.95	9855	APASS	10824	APASS	26.63	0	9	104	-207	229	452 1620	452 1619
11:01:28.65 -61:58:58.1	9983	APASS	10200	APASS	14.09	35	-55	-17	-1940	-1673	141 1175	141 1176
11:16:01.70 -55:13:33.60	9757	APASS	9825	APASS	18.83	36	-65	16	-219	-27	174 1551	174 1552
11:17:57.39 -27:02:07.46	9774	APASS	9935	APASS	8.29	0	0	0	-580	27	315 1863	315 1864
11:36:15.97 -62:28:56.77	9397	APASS	9950	APASS	21.66	0	-431	-258	-5	21	138 1205	138 1206
11:36:22.4 -61:35:38.90	8983	APASS	9549	APASS	25.80	36	-61	70	-59	-196	143 1581	143 1580
11:36:32.49 -58:55:01.12	9842	APASS	10559	APASS	19.57	0	-88	3	-133	20	156 1840	156 1838
11:36:37.77 -34:38:47.0	8773	APASS	9201	APASS	4.72	3	0	0	-2156	1217	277 1678	277 1677
11:36:50.33 -61:40:07.77	9182	APASS	9327	APASS	7.30	25	-309	-451	-38	54	142 1597	142 1598
11:05:37.90 -58:45:49.18	9629	APASS	9880	APASS	25.25	0	-94	44	-86	48	157 1551	157 1550
11:05:56.36 -58:49:08.59	9365	APASS	9506	APASS	23.48	36	-55	62	-104	65	156 1559	156 1558
11:52:58.61 -64:25:11.23	9994	APASS	10163	APASS	24.03	35	-34	-47	-57	-51	128 948	128 949
11:53:32.52 -62:48:04.65	9534	APASS	9884	APASS	11.74	0	339	-74	-376	-93	136 1270	136 1269
12:00:20.94 -62:03:19.92	9635	APASS	9758	APASS	17.03	0	0	0	-494	0	140 1530	140 1531
12:10:01.88 -65:42:26.96	9917	APASS	9969	APASS	26.63	36	-62	-31	-38	11	122 990	122 989
12:31:05.42 -53:46:15.47	9757	APASS	10524	APASS	28.34	0	-99	-16	-19	66	182 1866	182 1867
12:36:01.95 -34:11:59.87	9861	APASS	10149	APASS	19.22	0	103	-54	-422	-331	280 1843	280 1842
12:46:22.69 -59:34:38.94	9804	APASS	10532	APASS	6.28	26	0	0	-99	-117	153 2264	153 2265
13:39:09.69 -64:01:11.70	9583	APASS	10452	APASS	9.60	35	-426	-156	-402	158	130 1530	130 1529
13:52:59.50 -45:03:05.79	9803	APASS	10751	APASS	26.53	0	-95	-35	-71	-18	225 1978	225 1977
13:07:20.69 -71:01:11.21	9884	APASS	9891	APASS	13.28	0	-188	285	-97	-40	95 854	95 855
14:26:09.33 -53:19:26.22	9994	APASS	10862	APASS	20.57	0	-111	-73	14	-92	184 2185	184 2184
14:31:29.43 -49:41:52.28	9962	APASS	10490	APASS	21.66	0	-131	-35	-26	-79	202 2079	202 2080
14:46:47.89 -54:05:30.50	9175	APASS	9764	APASS	22.18	0	-95	-128	-110	-50	180 2422	180 2423
14:55:38.58 -54:38:02.33	9916	APASS	10300	APASS	12.18	35	-39	-71	-50	9	177 2402	177 2401
14:57:45.30 -33:07:17.48	9616	APASS	10517	APASS	21.22	36	-151	50	-27	-217	285 2157	285 2156
14:08:51.20 -43:04:35.78	9791	APASS	10214	APASS	24.32	0	-226	-60	-168	-126	235 2047	235 2046
15:03:13.44 -40:11:38.72	9809	APASS	10030	APASS	29.24	0	84	-88	-285	-609	250 2041	250 2040
15:30:55.1 -63:20:54.21	9856	APASS	10398	APASS	21.78	36	-5	-172	-186	29	134 2312	134 2311
15:32:44.63 +12:44:27.42	9862	APASS	10352	APASS	10.32	36	-437	-112	-272	-67	514 1652	514 1651
15:51:14.35 -42:43:23.20	9881	APASS	10016	APASS	6.45	0	0	0	-150	-110	237 2411	237 2412
15:07:35.3 -54:19:54.81	9608	APASS	10544	APASS	25.10	0	-43	-15	-96	-28	179 2475	179 2474
16:19:18.35 -57:53:36.43	9378	APASS	10350	APASS	19.92	0	5	-31	-221	-238	161 2867	161 2865
16:33:32.25 -53:20:21.49	9422	APASS	10189	APASS	29.64	0	25	-62	-58	-197	184 2845	184 2846
16:38:51.31 -31:53:29.65	9857	APASS	10775	APASS	19.91	0	-36	-48	-77	-28	291 2510	291 2509
16:43:01.42 -40:42:33.90	9793	APASS	9931	APASS	11.29	0	0	0	-124	-243	247 2452	247 2451
16:51:52.61 -39:46:36.62	9840	APASS	10812	APASS	16.36	2	-78	-48	-51	-41	252 2373	252 2372
16:09:21.36 -60:39:12.84	9827	APASS	10393	APASS	27.57	2	-90	-76	-90	-34	147 3159	147 3157
17:34:29.26 -37:15:46.31	9933	APASS	10029	APASS	27.52	0	-32	-166	-4	55	264 2699	264 2698
17:04:48.3 -39:18:54.70	9998	APASS	10026	APASS	10.01	25	-92	-12	-1	-28	254 2457	254 2459
17:52:21.76 -52:48:08.79	9204	APASS	9249	APASS	8.93	0	-43	-121	-828	-1106	186 3207	186 3206
17:54:51.15 +10:42:47.53	9666	APASS	10067	APASS	25.27	0	14	-414	31	-415	504 2100	504 2101
18:00:05.30 +30:24:26.48	8941	APASS	9856	APASS	27.18	0	15	30	-233	-191	603 1811	603 1812

Table 2 concludes on next page.

Searching for New Double Stars with a Computer

Table 2 (conclusion). Non-WDS Pairs

RA Dec	mv	mv src	mvb	mvb src	sep.	Dbl Flag	Pri PM in RA	Pri PM in Dec	Sec. PM in RA	Sec. PM in Dec	A UCAC4 id	B UCAC4 id
18:10:15.1 -27:20:02.61	9687	APASS	9778	APASS	7.79	0	-155	-913	11	115	314 2791	314 2792
18:13:51.30 -37:39:59.46	9650	APASS	10530	APASS	24.93	0	-51	-59	-17	-54	262 2954	262 2953
18:15:14.95 +19:21:30.64	9656	APASS	9885	APASS	27.66	0	0	-78	-45	-84	547 1912	547 1911
18:19:15.23 -28:45:40.20	9861	APASS	10355	APASS	15.12	0	-78	-309	-4	-20	307 3092	307 3091
18:19:24.93 -29:27:01.20	9819	APASS	10279	APASS	13.95	0	-384	1	-62	-24	303 3126	303 3125
18:21:16.74 +6:08:41.79	9877	APASS	10789	APASS	23.30	0	-52	-58	-33	-49	481 2346	481 2345
18:22:04.51 -22:17:52.10	7527	APASS	8497	APASS	20.58	6	50	-230	-80	-134	339 2709	339 2710
18:24:44.63 -21:57:21.64	9796	APASS	10005	APASS	6.76	0	-824	-728	-70	-174	341 2807	341 2808
18:38:19.0 -26:36:57.60	9575	APASS	9663	APASS	13.12	0	-190	-203	-13	-35	317 3134	317 3133
18:04:25.58 -40:01:20.90	9681	APASS	9960	APASS	25.68	2	-50	-40	11	-54	250 2697	250 2696
18:43:05.37 +22:47:01.66	9911	APASS	10774	APASS	24.38	35	-58	-95	-5	8	564 2101	564 2100
18:05:02.79 +74:47:25.17	9747	APASS	9955	APASS	10.30	25	-169	-94	98	-260	824 595	824 594
18:55:53.85 +12:13:13.69	9825	APASS	10039	APASS	8.49	0	0	0	-126	-67	512 2364	512 2363
18:07:24.98 -29:37:01.8	9531	APASS	9949	APASS	14.84	0	186	536	-313	-454	302 3073	302 3072
18:09:34.78 +16:41:42.60	9904	APASS	10609	APASS	25.51	0	-28	4	-17	-96	534 2048	534 2050
19:00:00.37 +13:42:29.58	9635	APASS	9726	APASS	17.64	35	47	28	-83	82	519 2287	519 2288
19:02:10.96 -24:34:40.26	9735	APASS	10609	APASS	26.18	0	-969	-724	79	-119	328 3055	328 3053
19:03:27.0 +18:22:49.93	9831	APASS	9965	APASS	29.38	0	-5	28	-65	-175	542 2286	542 2285
19:34:34.66 +31:07:26.22	9417	APASS	10066	APASS	28.98	0	-24	-103	-21	-107	606 2174	606 2173
19:55:57.77 +15:57:53.17	9343	APASS	9409	APASS	7.57	0	18	-89	-679	-501	530 2508	530 2507
19:56:52.49 +9:44:51.3	9357	APASS	10327	APASS	24.71	0	-95	-257	41	-12	499 2860	499 2862
19:09:11.17 +5:22:38.7	9674	APASS	10110	APASS	27.76	0	-114	-147	-8	-46	477 2641	477 2642
2:29:56.75 -3:19:07.36	9968	APASS	10725	APASS	24.25	0	-603	197	294	-388	434 197	434 196
20:15:07.67 +26:18:21.82	9965	APASS	10645	APASS	27.22	0	-53	-55	-32	-153	582 2445	582 2446
20:03:21.65 +15:44:39.84	9582	APASS	10053	APASS	11.47	35	22	-53	-696	-1078	529 2655	529 2654
20:05:10.32 +48:11:17.29	9562	APASS	9661	APASS	24.74	35	360	-228	360	-228	691 2132	691 2133
21:39:52.7 +11:06:33.56	9784	APASS	10666	APASS	17.30	0	-93	-266	59	28	506 3024	506 3025
21:46:16.77 +53:00:34.39	9774	APASS	10334	APASS	24.98	0	-26	-38	-118	-204	716 2181	716 2182
21:49:20.99 +56:33:32.89	9720	APASS	10308	APASS	29.20	0	-58	-61	-11	-33	733 1956	733 1955
22:38:54.26 -5:51:32.88	9943	APASS	10364	APASS	18.00	0	-3	13	-142	-188	421 3025	421 3024
23:38:05.81 +45:02:14.97	9280	APASS	10020	APASS	27.22	0	-113	-1111	90	-214	676 3198	676 3200

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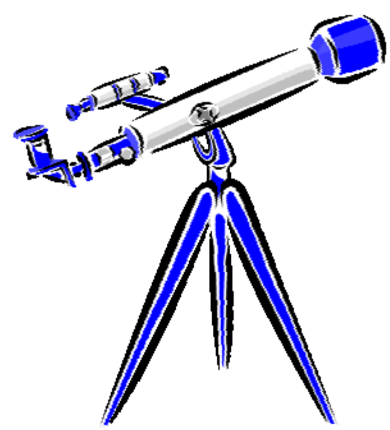

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