

**The Webb Deep-Sky Society**  
**Double Star Section Circular No 28**

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*This circular has been edited and arranged by R.W.Argyle, Director of the Webb Society Double Star Section.*  
E-mail: [rwa@ast.cam.ac.uk](mailto:rwa@ast.cam.ac.uk)

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E-mail: [james.whinfrey@gmail.com](mailto:james.whinfrey@gmail.com)

For further information about the Webb Society contact:

In the USA and Canada: J. E. Isles, 10575 Darrel Drive, Hanover, Michigan 49241, U.S.A.  
E-mail: [j\\_isles@yahoo.com](mailto:j_isles@yahoo.com)

In the UK: D. J. Miles, 10 Rosewood Gardens, Clanfield, Waterlooville, Hampshire, PO8 0LT, England.  
E-mail: [donjmiles@gmail.com](mailto:donjmiles@gmail.com)

## Editorial

The number of measures included in these Circulars is now 84927.

Observer	WDS code	Pairs	Measures	Method/source
A. Ahad	AHD	1	1	Internet astrometry
Astro. Assoc. Queensland	AAQ	16	107	CCD imaging
A. Alzner	ALZ	72	243	Lyot Micrometer
R. W. Argyle	ARY	56	139	RETEL micrometer
J.- F. Courtot	CTT	35	116	RETEL, homemade filar, Lyot micrometer
A. Debackère	DBR	1	1	Internet astrometry
J. Greaves	GRV	59	59	Internet astrometry
W. Knapp	KPP	40	40	CCD astrometry
G. Morris	GRM	22	22	CMOS astrometry
N. Webster	WST	48	48	Meade reticle eyepiece
TOTALS		<hr/> 350	<hr/> 776	

Bob Argyle, 2020 June

## Useful sites

The following websites also contain a considerable amount of interesting material for the serious double star observer and no claim is made for the completeness of the list. If anyone knows of any others please contact me:

The Washington Double Star catalogue - the complete reference for visual double stars - updated nightly. The site also contains the Sixth Catalogue of Visual Binary Star Orbits and much more at <http://ad.usno.navy.mil/wds>

*Journal for Double Star Observations* ([www.jdso.org](http://www.jdso.org))

*Observations et Travaux* (in French). A journal published by the Société Astronomique de France which often contains double star observations. The SAF Double Star Commission has a website at <https://boutique-saf-astronomie.com>

*El Observador de Estrellas Dobles* (in Spanish)

([www.elobservadordeestrellasdobles.wordpress.com](http://www.elobservadordeestrellasdobles.wordpress.com))

Observatori Astronòmic del Garraf ([www.oagarraf.net](http://www.oagarraf.net))

*Il Bollettino delle Stelle Doppie* (in Italian)

(<https://sites.google.com/site/ilbollettinodellestelledoppie/>)

The Double Star Section of the Astronomical Society of Southern Africa

(<http://assa.ac.za/sections/deep-sky/doublestars/news-and-articles>)

In addition the Stelle Doppie Double Star Database run by Gianluca Sordiglioni allows the WDS catalogue to be quizzed with various search parameters. You can get a user name and password at [stelledoppie.goaction.it](http://stelledoppie.goaction.it)

## Acknowledgements

Much of the work presented here has made use of the Washington Double Star Catalogue maintained at the U.S. Naval Observatory (see above).

# MICROMETER MEASURES OF DOUBLE STARS IN 2018

Bob Argyle, Lyndhurst, Ely Road, Waterbeach, Cambridge, CB25 9NW, UK

E-mail: `rwa@ast.cam.ac.uk`

## Introduction

In this publication, the author presents his micrometric measurements which were mostly made between 2018.0 and 2019.0. A small number of pairs have mean epochs outside this range either due to delay in getting a sufficient number of observations to form a mean, or which were inadvertently left out of earlier papers. The 8-inch f/14 Cooke refractor at the Observatories of the University of Cambridge has again been used for this work. It is equipped with a RETEL micrometer at a power of  $\times 450$ . Using a Barlow lens, the screw constant is  $12''.45$  per revolution which allows an equivalent reading accuracy of  $\pm 0''.025$ . The scale and orientation of the micrometer is derived at the beginning and end of each observing session using a number of fixed, wide pairs with astrometry from the Hipparcos satellite.

Measurements are arranged as usual (see Courtot & Argyle<sup>1</sup> for more details). Table 1 gives the name of the pairs using the WDS nomenclature<sup>2</sup> with the following codes and contains 248 measurements of 79 systems:

KUI	Kuiper, G. P.	SHJ	South & Herschel	STFA	Struve, W. Appendix
H	Herschel, W.	STF	Struve, F. G. W.	STT	Struve, O.
STTA	Struve, O. Appendix	BU	Burnham, S. W.	STFB	Struve, W. Appendix
S	South, J.				

The protocols followed here for measuring are very similar to earlier publications and consist basically of multiple double measures of separation (usually four or five) and repeated measures of position angle (usually four to six) taken on several different evenings taken together to get the final mean values of position angle and angular distance.

Table 3 gives the residuals from known orbits. The orbital elements come from the online version of the 6th USNO Catalogue of Orbits of Visual Binary Stars<sup>3</sup>.

## Acknowledgements

The author is grateful to Miss Mandy Cockrill, IoA Custodian, for her help and support in keeping the telescope and dome operational, and to Mr. I. Whittingham for maintaining the RA drive motor which he fitted to the telescope. Much of the work presented here has made use of the Washington Double Star Catalogue maintained at the U.S. Naval Observatory.

## References

- 1). Courtot, J.-F. & Argyle, R. W., *Webb Society Double Star Section Circular*, **12**, 1, 2004
- 2). Mason, B. D., Wycoff, G. L. & Hartkopf, W. I. : Washington Double Star Catalogue (References and discovery codes) <http://as.usno.navy.mil/ad/wds/wdsnewref.txt>
- 3). Hartkopf, W. I., Mason, B. D. & Worley C. E.: Sixth Catalog of Orbits of Visual Binary Stars. Astrometry Department, U.S. Naval Observatory. <http://ad.usno.navy.mil/ad/wds/hmw5.html>

**Table 1: Measures of double stars**

Pair	Comp	RA	Dec	$V_a$	$V_b$	PA ( $^\circ$ )	Sep ( $''$ )	Epoch (Julian)	N	Obs.
STF3062		00063	+5826	6.42	7.32	4.4	1.42	2018.586	2	ARY
H 5 17	AB	00369	+3343	4.36	7.08	174.5	36.22	2019.081	3	ARY
STF73	AB	00550	+2338	6.12	6.54	337.5	1.23	2019.087	4	ARY
STF138	AB	01360	+0739	7.50	7.63	246.3	1.65	2015.558	2	ARY
STF202		02020	+0246	4.10	5.17	263.5	1.93	2019.087	4	ARY
STF232		02147	+3024	7.82	7.90	69.4	6.74	2019.095	2	ARY
STF239		02174	+2845	7.09	7.83	212.2	13.95	2019.095	2	ARY
STF333	AB	02592	+2120	5.17	5.57	210.8	1.48	2019.103	2	ARY
STF425	AB	03401	+3407	7.52	7.60	60.9	2.11	2016.460	3	ARY
STF554		04301	+1538	5.70	8.12	14.6	1.36	2018.103	2	ARY
STF698	AB	05252	+3451	6.65	8.33	348.2	31.38	2019.201	2	ARY
STT747	AB	05350	-0600	4.70	5.51	223.9	36.07	2018.564	2	ARY
STF749	AB	05371	+2655	6.54	6.55	323.5	1.13	2019.223	2	ARY
STF753	AB-C	05386	+3030	5.46	8.41	269.1	12.43	2019.201	2	ARY
STF764		05413	+2929	6.38	7.08	14.6	25.84	2019.216	2	ARY
STF785	AB	05459	+2555	7.27	8.32	348.0		2019.223	2	ARY
BU1008		06149	+2230	3.52	6.15	254.6	1.68	2018.710	2	ARY
STF982	AB	06546	+1311	4.75	7.80	145.1	7.28	2018.973	4	ARY
STF1083		07256	+2030	7.32	8.13	225.5	6.86	2019.288	2	ARY
STF1110	AB	07346	+3153	1.93	2.97	53.1	5.51	2019.286	8	ARY
STTA89		07510	+3137	6.83	7.69	84.0	76.58	2017.288	2	ARY
STF1177		08056	+2732	6.69	7.41	351.0	3.45	2019.020	4	ARY
STF1196	AB	08122	+1739	5.30	6.25	9.3	1.17	2019.282	5	ARY
STF1196	AB,C	08122	+1739	4.92	5.85	68.0	6.01	2019.282	5	ARY
STT191		08248	+2009	7.41	8.62	191.7	36.85	2019.299	3	ARY
STF1224	A,BC	08267	+2432	6.92	7.53	52.7	5.65	2019.328	3	ARY
STF1223		08268	+2656	6.16	6.21	219.4	5.24	2019.328	3	ARY
STF1273	AB,C	08468	+0625	3.49	6.66	310.8	2.98	2019.258	2	ARY
STF1291	AB	08542	+3035	6.09	6.37	310.2	1.51	2019.374	2	ARY
STF1487		10556	+2445	4.48	6.30	114.3	6.53	2018.000	3	ARY
STF1523	AB	11182	+3132	4.33	4.80	154.6	1.99	2019.384	7	ARY
STF1536	AB	11239	+1032	4.06	6.71	96.6	2.00	2019.371	4	ARY
STT575	AB	11416	+3145	5.79	9.75	311.4	44.62	2017.764	3	ARY
STF1615	AB	12141	+3247	6.99	8.61	88.4	26.25	2016.938	2	ARY
STF1670	AB	12417	-0127	3.48	3.53	357.4	2.90	2019.369	6	ARY
STF1677		12453	-0353	7.30	8.12	348.8	16.19	2018.681	3	ARY
STF1678		12454	+1422	7.16	7.68	169.1	38.12	2015.408	2	ARY
STF1728	AB	13100	+1732	4.85	5.53	193	0.59	2019.413	1	ARY
STF1744	AB	13239	+5456	2.23	3.88	154.3	14.58	2019.514	4	ARY
STF1764	AB	13377	+0223	6.79	8.56	31.4	16.05	2018.413	2	ARY
STF1821	AB	14135	+5147	4.53	6.62	235.3	13.79	2019.514	2	ARY
STF1864	AB	14407	+1625	4.88	5.79	112.4	5.37	2019.500	3	ARY
STF1889	AB	14495	+5122	6.53	9.64	93.4	14.97	2015.591	3	ARY
STF1888	AB	14514	+1906	4.76	6.95	298.4	5.18	2019.434	8	ARY
STT288		14534	+1542	6.89	7.55	160.4	1.14	2019.547	2	ARY
STF1938	Ba,Bb	15245	+3723	7.09	7.63	5.2	2.32	2019.556	1	ARY

STF2032	AB	16147	+3352	5.62	6.49	240.2	7.23	2019.528	3	ARY
STF2084		16413	+3136	2.95	5.40	110.3	1.63	2019.557	3	ARY
STF3127	AB	17150	+2450	3.12	8.3	292.7	13.67	2019.575	1	ARY
STF2262	AB	18031	-0811	5.27	5.86	292.7	1.61	2019.537	1	ARY
STF2272	AB	18055	+0230	4.22	6.17	123.9	6.62	2019.540	4	ARY
STT588	AB	19250	+1157	5.24	8.65	281.2	107.61	2018.786	2	ARY
STT588	BC	19250	+1157	8.65	10.34	267.0	44.82	2018.786	2	ARY
STF2799	AB	21289	+1105	7.37	7.44	261.5	2.11	2018.881	3	ARY
SHJ355	AC	23300	+5833	4.87	7.23	269.4	75.33	2015.594	2	ARY
STF3050	AB	23595	+3343	6.46	6.72	342.9	2.46	2019.087	4	ARY

**Table 2: Residuals from known orbits**

Pair	ADS	Residual(O-C)		Orbit	Period	Date	Grade
		PA (°)	Sep (")		(yrs)		
STF73	755	+3.9	+0.06	Muterspaugh	167.51	2010	2
STF202	1615	+2.8	+0.09	Prieur	3267.4	2017	4
STF333	2257	+0.8	+0.16	Rica	1215.953	2012	4
STF425	2668	-0.2	+0.36	Kiyaeva	947	2018	4
STF554	3264	-0.1	-0.19	Baize	180.0	1980	4
STF749	4208	+4.5	-0.05	Scardia	986.6	2007	4
BU1008	4841	+2.8	+0.07	Baize	473.7	1980	5
STF982	5559	+2.7	-0.05	Mason	1898.12	2014	4
STF1110	6175	+1.1	+0.18	Docobo	459.8	2014	3
STF1196AB	6650	+1.8	+0.03	Josties & Mason	59.98	2018	1
STF1273	6993	+0.8	+0.16	Drummond	589	2014	4
STF1523	8119	-0.3	-0.14	Mason	59.878	1995	1
STF1536	8148	+4.2	-0.21	Söderhjelm	186	1999	2
STF1670	8630	-0.9	+0.04	Scardia	169.104	2007	2
STF1728	8804	+1.1	-0.18	Muterspaugh	25.852	2015	1
STF1888	9413	+1.1	-0.05	Söderhjelm	151.6	1999	2
STT288	9425	+4.4	+0.19	Heintz	313.0	1998	4
STF1938	9626	+2.5	+0.08	Kiyaeva	265	2014	2
STF2032	9979	+1.3	-0.02	Raghavan	726	2009	4
STF2084	10157	+1.5	+0.25	Söderhjelm	34.45	1999	1
STF2262	11005	+2.9	+0.13	Söderhjelm	257.0	1999	3
STF2272	11046	+1.7	-0.03	Eggenberger	88.37	2008	1
STF2799	15007	+3.8	+0.22	Hartkopf	978.0	2011	4
STF3050	17149	+1.0	0.00	Hartkopf	717.0	2011	4

# MICROMETRIC MEASURES OF DOUBLE STARS IN 2019

Jean–François Courtot, Chaumont, France

## Introduction

The measurements presented here have been made during 2019 using two different telescopes: a home-made 205-mm (8-inch) Newtonian and either a Retel filar micrometer at a power of x508 or a Lyot double-image micrometer at x464, and a 279-mm (11-inch) Schmidt-Cassegrain telescope at a power of x430 and a homemade filar micrometer. This setup is described in Ref. 1.

The measurement procedures have been outlined in previous circular DSSC 23<sup>2</sup>. Further indications on some observed peculiarities with double-image micrometers can also be found in DSSC 24-25<sup>3,4</sup>.

Measurements have been arranged as usual in Table 2. Epochs are in Julian years. In last column, ‘T205’ designs the 205 mm Newtonian telescope, ‘C11’ the 11-inch Schmidt-Cassegrain, ‘L’ is for the Lyot double-image micrometer whilst ‘F’ indicates that a filar micrometer has been used. Table 3 gives a short comment on each measured pair.

Besides a few known orbital pairs, some wider pairs have been measured. Attention has been paid in these cases to compare present observed relative positions with ancient positions. Once position angles of historic measurements have been corrected from precession, the long time-baselines considered here (over one century) offer valuable opportunities to check presently catalogued proper motions with observations whilst some of these pairs may appear as possible long period orbital pairs as well.

When available, GAIA-DR2 parallaxes, proper motions, luminosity and radial velocities data have been used also to investigate the true nature of the observed pairs. Similar parallaxes and proper motions suggest a gravitational link between components but those may have similar parallaxes and proper motions and simply travel in company along parabolic, hyperbolic or rectilinear parallel paths. Plotting historic and current measurements on a graph helps here but an analytical approach has been explored as well.

In 1955, the late Belgian astronomer Jean Dommanget (1924-2014) established a first criterion for the non-periodicity of the relative motion of double star components for which the apparent relative velocity is appreciable and for which the parallax is known<sup>5</sup>. It starts with the expression for the energy integral in the two-body problem<sup>5,6</sup> and makes use of the mass-luminosity relationship to eventually establish an upper limit for the apparent separation between components behind which the relative motion is certainly non-periodic.

Dommanget non-periodicity first criterion has been used under the following form:

$$\log \rho_1 (") = 1.90 - 2 \log V_a ( " \text{ yr}^{-1} ) + 3 \log \pi ( " ) + \log M_{AB} ( M_{\odot} )$$

where  $\rho_1$  is the maximum apparent separation in arc-second ( " ) behind which the relative motion is certainly non-periodic, and  $V_a$  is the apparent relative speed (in arc-second per sidereal year) of one component as compared to the other. It can be determined graphically by plotting precession-corrected historic positions and up-to-date measurements as suggested in Ref. 5 and then divide the observed displacement in arc-seconds by the time elapsed between historic and current measurements. Another straightforward method has been used here to determine the apparent displacement of the secondary star. It uses the classical al-Kashi theorem for any triangle:

$$a^2 = b^2 + c^2 - 2bc \times \cos A.$$

$\pi$  is the mean parallax in arc-second (i.e. here GAIA-DR2 parallax in mas/1000).

$M_{AB} ( M_{\odot} )$  is the mass of the pair in solar masses. Individual masses  $M_A ( M_{\odot} )$  and  $M_B ( M_{\odot} )$  have been determined from GAIA-DR2 luminosity data and the mass-luminosity relation<sup>7</sup> with the Sun as unity. For instance, for A:  $\log M_A ( M_{\odot} ) = \log L_A ( M_{\odot} ) - \log 4$  (log 4, since L nearly

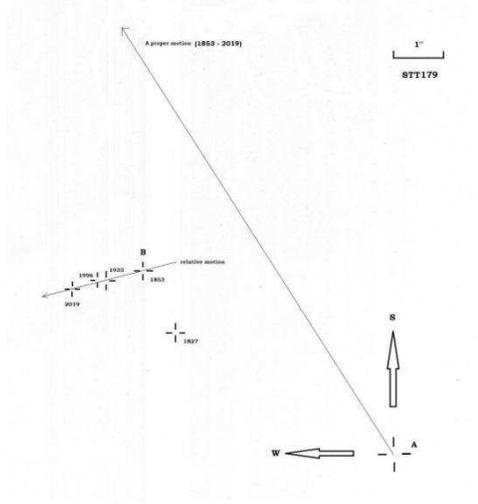


Figure 1: Figure 1: STT179, see Table 3 / ADS 6321

varies with  $M^4$  for stars within 1 and 30 solar masses<sup>7</sup>, the usual cases in this series).

Example: WDS13073+0035 – STF1719AB – ADS8786

Historic measurement:	1825	$\theta = 5^\circ.0$ ( $4^\circ.7$ after precession correction)	$\rho = 8''.1$ (WDS)
Current measurements:	2015.5 2019.4	$358^\circ.6$ $358^\circ.7$	$6''.98$ (GAIA-DR2) $6''.94$ (CTT)

Table 1: GAIA-DR2 data for STF1719AB

	RA(J2000)	Dec(J2000)	Plx(mas)pmRA $\epsilon_\pi$ $\epsilon_{\mu_\alpha}$	pmDE $\epsilon_{\mu_\delta}$	Gmag $\epsilon_G$	RPmag $\epsilon_{R_p}$	RV	$L_\odot$	Epoch
A	13 07 19.7069738382	+00 35 05.832900627	13.1279    -95.663 0.4558    0.590	-102.055 0.445	7.4187 0.0003	7.0549 0.002	-87.75 1.05	4.569	2015.5
B	13 07 19.6939329611	+00 35 12.812527233	15.2285    -96.674 0.0567    0.110	-105.080 0.053	7.9454 0.0003	7.5096 0.024	-89.84 0.19	2.114	2015.5

From the above equations and data in Table 1:  $V_a = 0''.0072/\text{yr}$ ,  $\pi_{\text{moy}} = 0''.0142$ ,  $M_A = 1.46M_\odot$ ,  $M_B = 1.21M_\odot$ ,  $M_{AB} = 2.67M_\odot$

$$\log \rho_1(") = 1.90 - 2 \log 0.0072 + 3 \log 0.0142 + \log 2.67 = 1.07$$

$$\rho_1 = 10^{1.07} = 12''$$

The Dommaget first criterion happens here to be  $\rho = 12''$ , the upper limit in this case for a periodic relative motion. The current observed separation being less ( $7''$ ), this does not mean that the pair is necessarily a true orbital pair but indicates that it is possible. The future will tell.

As an alternative, using the same mathematical method, Jean Dommaget established in 1960<sup>8</sup> a second criterion  $\rho_2$ . This time the relative radial velocity  $V_r$  (in km/s) is used instead of the apparent relative velocity  $V_a$  (in arc-second/year). The relevant equation is in this case:

$$\log \rho_2(") = 3.249 - 2 \log V_r \text{ (km/s)} + \log \pi(") + \log M_{AB} (M_{\odot})$$

GAIA-DR2 Catalogue mentions radial velocities for both components of STF1719AB. "RV" column in Table 1 indicates  $-87.75 \text{ km,sec}^{-1}$  for A and  $-89.84 \text{ km sec}^{-1}$  for B. The relative radial velocity is:

$$V_r = 89.84 - 87.75 = 2.09 \text{ km sec}^{-1}$$

$$\log \rho_2 = 3.249 - 2 \log 2.09 + \log 0.0142 + \log 2.67 = 1.19$$

$$\rho_2 = 15'' \text{ compatible with first criterion.}$$

Most of the observed apparent displacements in this series are very small however, often the same order than measurements errors and thus impairing the reliability of the first criterion. As a test for the observed pairs and their catalogued parameters, each time complete suitable GAIA-DR2 data were available for both components (25% of the cases here), similar investigations have nevertheless been attempted and reported in Table 3. GAIA-DR2 positions and proper motions data happened to be available for nearly 50% of the observed pairs. The GAIA astrometric satellite is still working however, observing and re-observing 70 million stars in a day and hopefully more data will be released in 2020<sup>9</sup>.

For known observed orbital pairs, residuals O-C with recently computed orbits are to be found in Table 4. Of possible interest for the observer and orbit calculator: SHJ345AB in acceleration quite near the periastron with a large O-C residual. For this interesting pair, GAIA-DR2 gives data for one component only (see also Ref 10).

**Table 2 - Measures**

Pair	Comp	RA	Dec	$V_a$	$V_b$	PA ( $^{\circ}$ )	Sep ( $''$ )	Epoch (Julian)	N	Obs.	Method
STF2		00093	+7943	6.7	6.9	14.6	0.94	2019.923	4	CTT	T205 / L
STF644	AB	05103	+3718	7.0	6.8	221.9	1.64	2019.127	3	CTT	T205 / F
VBS10	AC	05103	+3718	7.0	10.5	191.7	73.37	2019.130	3	CTT	T205 / F
STT545	AB	05597	+3713	2.6	7.2	304.3	4.21	2019.137	3	CTT	T205 / F
STT545	AC	05597	+3713	2.6	11.1	300.3	56.37	2019.141	3	CTT	T205 / F
STT545	AD	05597	+3713	2.6	10.1	349.3	139.2	2019.147	3	CTT	T205 / F
STF872	AB	06156	+3609	6.9	7.4	216.2	11.32	2019.152	3	CTT	T205 / F
STTA75		06206	+1803	7.7	8.9	128.8	46.92	2019.184	3	CTT	T205 / F
STT179		07444	+2424	3.7	10.0	242.7	7.18	2019.217	4	CTT	T205 / F
STF1177		08056	+2732	6.7	7.4	350.3	3.45	2019.226	3	CTT	T205 / F
STF1210	AB	08158	+0248	7.3	9.5	113.3	15.65	2019.237	3	CTT	T205 / F
STF1223		08268	+2656	6.2	6.2	218.2	5.05	2019.245	3	CTT	T205 / F
STF1283		08499	+1450	7.7	8.5	123.4	16.47	2019.271	3	CTT	T205 / F
STF1311	AB	09074	+2259	6.9	7.1	199.2	7.51	2019.293	3	CTT	T205 / F
STF1450		10350	+0839	5.8	7.9	157.1	2.04	2019.325	4	CTT	T205 / F

STF1559		11388	+6421	6.8	8.0	325.8	2.04	2019.377	4	CTT	C11 / F
STF1642		12257	+4444	8.8	9.4	179.6	2.46	2019.365	4	CTT	C11 / F
STT257		12567	+4537	8.5	9.6	353.3	12.94	2019.389	3	CTT	C11 / F
STF1719	AB	13073	+0035	7.6	8.2	358.7	6.94	2019.408	3	CTT	T205 / F
STF1723		13082	+3844	8.7	10.1	11.7	6.11	2019.421	4	CTT	C11 / F
STF1838		14241	+1115	7.5	7.7	335.0	9.34	2019.453	3	CTT	T205 / F
STF1910		15075	+0914	7.4	7.5	211.7	3.73	2019.477	4	CTT	T205 / F
STF1950		15300	+2530	8.1	9.2	90.8	3.42	2019.488	4	CTT	T205+C11/F
HO399		15554	+2932	7.7	10.5	116.4	3.61	2019.504	3	CTT	C11 / F
STF2007	AB	16060	+1319	6.9	8.0	322.4	37.74	2019.532	4	CTT	C11 / F
STF2140	AB	17146	+1423	3.5	5.4	102.9	4.95	2019.586	4	CTT	T205+C11 / F
STF2245	BA	17564	+1820	7.4	7.6	111.7	2.66	2019.601	3	CTT	T205+C11 / F
STF2273	AB	17592	+6409	7.3	7.6	282.1	21.44	2019.630	4	CTT	T205+C11 / F
STF2351		18362	+4117	7.6	7.6	161.3	5.02	2019.644	4	CTT	T205+C11 / F
STF2448		19037	+3545	8.8	8.8	190.5	2.46	2019.657	3	CTT	T205+C11 / F
STF2523	AB	19268	+2110	8.0	8.1	148.3	6.31	2019.692	4	CTT	T205+C11 / F
STF2705	AB	20377	+3322	7.5	8.5	263.5	3.11	2019.762	4	CTT	T205 / F
SHJ345	AB	22266	-1645	6.4	6.6	90.0	1.23	2019.880	6	CTT	T205 / F+L

### Table 3 - Notes

Pair	ADS	Notes
STF2	102	Long period orbital pair. Retrograde relative motion: $327^\circ$ in 189 years. No GAIA-DR2 radial velocity nor luminosity data. Relative positions from GAIA-DR2 equatorial positions for 2015.5: $23^\circ.9 / 0''.75$ , not consistent with other measurements (CHARA 2012.038: $16^\circ.9 / 0''.86$ or CTT 2015.841: $17^\circ.2 / 0''.86$ ).
STF644AB	3734	Nearly fixed since W. Struve (1828). ‘A’ visually brighter than B at the time of observation (WDS gives V 6.96 for A and 6.78 for B). Common WDS proper motions but different GAIA DR2 proper motions. Starting from W. Struve’s measurement in 1828.60 ( $219^\circ.2 / 1''.61$ ) the effect of GAIA proper motions gives for 2019.13: $232^\circ.5 / 1''.77$ (observed: $221^\circ.9 / 1''.64$ ).
VBS10AC	-	Slow retrograde relative motion ( $4^\circ$ in 116 yrs), getting slightly wider ( $+0''.8$ in 116 yrs). Two different proper motions are mentioned in WDS for A component: one for STF644A and the other for VBS10A which are the same star. Starting from 1903 measurement ( $195^\circ / 72''.6$ ), the effect of proper motion mentioned for STF644AB gives for 2019: $192^\circ.2 / 74''.4$ (observed: $19^\circ.1 / 73''.4$ ). The proper motion mentioned for VBS10AC gives: $191^\circ.8 / 73''.1$ better matching the observation. No GAIA-DR2 data for C.
STT545AB	4566	Likely an optical pair. Retrograde relative motion: $62^\circ$ in 148 years. Getting wider: $+2''.1$ . No GAIA-DR2 data for this pair. No proper motion indication for B in WDS. Assuming the WDS proper motion mentioned for A is correct (not exactly the same is mentioned for AB, AC and AD pairs in WDS), from historic measurements, B proper motion can be estimated as: $\alpha: +0''.019/\text{yr}$ and $\delta: -0''.076/\text{yr}$ .
STT545AC	4566	Optical pair. Direct relative motion ( $8^\circ$ in 167 yrs); getting wider: $+13''$ . Starting from O. Struve’s measurement in 1852 ( $290^\circ.9 / 43''.19$ ), the effect of proper motions in WDS gives for 2019: $274.1^\circ / 47''.5$ (observed: $300^\circ.3 / 56''.4$ ). Assuming WDS proper motion is correct for A ( $0''.044 / 0''.078/\text{yr}$ ), the proper motion for C can be estimated to: $\alpha: -0''.008/\text{yr}$ and $\delta: -0''.006/\text{yr}$ . No GAIA-DR2 data for A.
STT545AD	4566	Optical pair. Much different WDS proper motions for A and D. Retrograde relative motion: $3^\circ$ in 179 yrs. Getting quickly wider: $+16''$ . Starting from O. Struve’s 1840.16 measurement ( $350^\circ.7 / 123''.3$ , the effect of WDS proper motions gives for 2019/15: $349^\circ / 137''.8$ (observed: $349^\circ.3 / 139''.2$ ).
STF872AB	4849	Very slow retrograde relative motion ( $3^\circ$ in 191 yrs). Getting slightly wider ( $+0''.3$ ). Starting from 1828.94 W. Struve’s measurement ( $217^\circ.4 / 11''.03$ ), the effect of WDS proper

		motions gives for 2019: $229^{\circ}.3 / 12''.61$ . Observed: $216^{\circ}.2 / 11''.32$ (in 2015.5, GAIA measured: $216^{\circ}.1/11''.39$ ). Similar GAIA–DR2 parallaxes for both components (12.9 mas). Dommanget’s first criterion: $62''$ . No radial velocity data for B. Possibly a very long period orbital pair.
STTA75	–	BDS3305. Nearly fixed since Dewbowski’s measurement in 1876.33. Similar GAIA–DR2 parallaxes for both components (2.4 mas) but different proper motions for each star according to WDS and GAIA–DR2. Starting from Dembowski’s measurement ( $127^{\circ}.4 / 47''.51$ ), the effect of WDS proper motions gives for 2019: $126^{\circ}.6 / 47''.3$ . GAIA proper motions give: $125^{\circ}.7 / 45''.1$ (Observed: $128^{\circ}.8 / 46''.9$ ). First and second Dommanget criteria respectively: $0''.25$ and $0''.06$ . Clearly an optical pair.
STT179	6321	Direct relative motion: $9^{\circ}$ in 166 years. Getting wider: $+0''.9$ . No proper motion indication for B in WDS. GAIA–DR2 catalogue mentions similar proper motions and parallaxes (23.6 & 21.9 mas) for both stars. First Dommanget criterion: $46''$ . No radial velocities GAIA data to determine the second criterion. Possibly a long period orbital pair. The measurement mentioned in WDS for 1827 ( $240^{\circ} / 5''.0$ ) probably erroneous (see Fig. 1).
STF1177	6569	Slow retrograde relative motion: $5^{\circ}$ in 191 yrs. Separation without any noticeable change. No GAIA–DR2 luminosity or radial velocity data: Dommanget’s criteria undetermined. Similar parallaxes and proper motions for both stars according to WDS and GAIA DR2: possibly a long period orbital pair.
STF1210AB	6698	No noticeable change since W. Struve (1829). Different parallaxes according to GAIA DR2: 3.05 & 2.00 mas. No GAIA–DR2 luminosity data. Dommanget criterion undetermined. Starting from W. Struve’s measurement (1829.22: $113^{\circ}.5 / 15''.80$ ), the effect of WDS proper motions gives for 2019.2 : $116^{\circ}.0/16''.64$ (measured $113^{\circ}.3/15''.65$ ). GAIA DR2 proper motions give: $113^{\circ}.7/16''.01$ .
STF1223	6815	Very slow direct relative motion ( $5^{\circ}$ in 190 yrs). Getting slightly wider: $+0''.5$ . Starting from Struve’s 1829 measurement ( $212^{\circ}.0 / 4''.56$ ) the effect of WDS proper motions gives for 2019.2: $199^{\circ}.1 / 5''.86$ (measured: $218^{\circ}.2 / 5''.05$ ). GAIA DR2 proper motions give: $216^{\circ}.1 / 5''.02$ . Similar GAIA parallaxes for both stars. A: 9.12, B: 9.21 mas. Assuming from apparent magnitudes (6.2/6.2) that both components have the same absolute luminosity, the mass–luminosity relationship gives 4.7 solar masses for A + B. First Dommanget criterion: $20''$ . No GAIA radial velocity data. Possibly a physical pair.
STF1283	7031	Nearly fixed since W. Struve. Similar GAIA–DR2 parallaxes for both stars ( $\sim 5$ mas). Similar WDS and GAIA proper motions. First Dommanget criterion: $40''$ , uncertain however due to very small apparent displacement ( $0''.2$ in 190 years). No GAIA radial velocity data for B to determine the second criterion.
STF1311AB	7187	Very slow retrograde relative motion: $2^{\circ}$ in 188 yrs. Separation without any noticeable change ( $+0''.3$ ). Nearly the same important common WDS and GAIA–DR2 proper motions. Nearly the same GAIA–DR2 parallaxes (16 mas). Dommanget’s first and second criteria respectively: $196''$ and $2^{\circ}$ , both unreliable however due to small apparent displacement ( $0''.4$ in 188 years) and much similar radial velocities for both components (29.99 and 30.13 km/s).
STF1450	7837	Very slow retrograde relative motion: $4^{\circ}$ in 189 years. Possibly getting closer: $-0''.4$ . No WDS / GAIA–DR2 proper motion or parallax data for the secondary.
STF1559	8249	Very slow direct relative motion: $4^{\circ}$ in 183 years. Separation without any noticeable change. Different proper motions in WDS and GAIA–DR2 catalogues. Starting from W. Struve’s measurement in 1836.55 ( $321^{\circ}.7 / 2''.09$ ), the effect of GAIA–DR2 proper motions gives for 2019.38: $308^{\circ}.1 / 1''.90$ (observed: $325^{\circ}.8/2''.04$ ). Similar GAIA–DR2 parallaxes for both components (4.0 and 4.4 mas). No luminosity data for A. No radial velocity data.
STF1642	8546	Very slow retrograde relative motion: $3^{\circ}$ in 187 years. Possibly getting slightly closer: $-0''.4$ . Similar WDS and GAIA–DR2 proper motion and parallaxes for both components. First Dommanget criterion: $8''.7$ . Measured separation: $2''.5$ . Possibly an orbital pair. No GAIA–DR2 radial velocity data.
STT257	8714	Nearly fixed since O. Struve’s measurement (1846.73: $353^{\circ}.6 / 13''.08$ ). Similar GAIA–DR2 parallaxes and proper motions for both components according to WDS and GAIA–DR2. First Dommanget criterion: $88''$ but quite uncertain due to small observed apparent motion. No GAIA–DR2 radial velocity data for A.
STF1719AB	8786	Very slow retrograde relative motion: $6^{\circ}$ in 194 yrs. Getting closer: $-1''$ . Similar WDS and GAIA–DR2 proper motions. Similar GAIA parallaxes (14 mas). First and second Dommanget criteria respectively: $12''$ and $15''$ . Measured: $7''$ . Possibly an orbital pair (see Example, above).
STF1723	8795	Very slow direct relative motion: $4^{\circ}$ in 187 yrs. Getting closer: $-0''.6$ . Similar WDS

		and GAIA–DR2 proper motions. Similar GAIA parallaxes ( $\sim 14$ mas). First and second Dommanget criteria respectively: $25''$ and $70''$ . Measured: $6''$ . Likely an orbital pair.
STF1838	9251	Very slow direct relative motion: $1^\circ$ in 187 years. Getting slightly wider: $+0''.5$ . Common mproper otions. Similar parallaxes for both components. First Dommanget criterion: $400''$ . No GAIA–DR2 radial velocity data for B: second criterion undetermined. Possibly an orbital pair.
STF1910	9507	Very slow direct relative motion: $3^\circ$ in 187 years. Separation without any noticeable change. Common proper motions. Similar parallaxes for both components. First Dommanget criterion: $3000''$ not coherent with $110''$ calculated from radial velocities for the second criterion. The latter to be preferred due to very small apparent observed displacement ( $0''.2$ in 187 years) nearly the same order than measurement errors. Possibly an orbital pair.
STF1950	9675	Very slow direct retrograde motion: $2^\circ$ in 187 years. Separation without any noticeable change. Common proper motions. Similar parallaxes for both components. No luminosity data for the secondary. Dommanget criteria not determined.
HO399	9844	Nearly fixed since Hough (1891). Common proper motions. Similar parallaxes for both components. No GAIA–DR2 luminosity nor radial velocity data. Dommanget criteria not determined.
STF2007AB	9922	Retrograde apparent motion: $5^\circ$ in 189 years. Getting wider: $+5''.8$ . Different proper motions and parallaxes for A and B. Starting from W. Struve’s 1830.14 measurement ( $328^\circ.2 / 31''.97$ ), the effect of GAIA proper motions gives for 2019.5: $321^\circ.9 / 38''.46$ (observed: $322^\circ.4 / 37''.74$ ). First and second Dommanget criteria not coherent, respectively: $0''.04$ and $23''.4$ . Optical pair.
STF2140AB	10418	$\alpha$ Her. Very long period orbital pair. Retrograde relative motion: $15^\circ$ in 190 years. Possibly getting wider. No GAIA–DR2 data for A.
STF2245BA	10905	Nearly fixed since W. Struve (1829). Similar parallaxes and proper motions for both components. No GAIA–DR2 luminosity data for the component labeled A in WDS (the faintest of the two in this case). Dommanget’s criteria undetermined.
STF2273AB	10985	No noticeable rotation since W. Struve (1832). Getting wider: $+1''$ . Similar GAIA–DR2 parallaxes and proper motions for both components ( $\sim 15$ mas). First and second Dommanget criteria respectively: $32''$ and $65''$ (measured: $21''$ ). Possibly a very long period orbital pair.
STF2351	11500	Nearly fixed since W. Struve (1830). Similar parallaxes and proper motions for both stars. No GAIA–DR2 luminosity nor radial velocity data. Dommanget criteria undetermined.
STF2448	12002	Nearly fixed since W. Struve (1831). Similar parallaxes for both stars but somewhat different proper motions according to GAIA–DR2. No radial velocity nor luminosity data. Dommanget criteria undetermined.
STF2523AB	12451	Nearly fixed since W. Struve (1830). No GAIA–DR2 data for this pair.
STF2705AB	14078	Nearly fixed since W. Struve (1831). Similar proper motions and parallaxes. First Dommanget criterion: $5''.1$ . No GAIA–DR2 radial velocity data. Second Dommanget criterion undetermined. Possibly an orbital pair however.
SHJ345AB	15934	Long period orbital pair. Direct relative motion: $147^\circ$ in 196 yrs. Near periastron. Apparently in acceleration. GAIA–DR2 data for A component only.

**Table 4 - Residuals from known orbits**

Pair	ADS	Residual(O-C)		Orbit	Period (yrs)	Date	Grade
		PA( $^\circ$ )	Sep( $''$ )				
STF2	102	+0.1	0.00	Heintz	540	1997	3
STF2140AB	10418	+0.2	+0.31	Baize	3600	1978	4
SHJ345AB	15934	+8.7	-0.10	Hale	3500	1994	4

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The Gaia mission website is <https://www.cosmos.esa.int/gaia>.

The Gaia archive website is <https://archives.esac.esa.int/gaia>.

# MICROMETER MEASURES OF DOUBLE STARS 2008.29 TO 2019.42

Andreas Alzner, Zeckerner Hauptstrasse 3, 91334 Hemhofen, Germany

E-mail: aalzner@t-online.de

## Results and Method

The total number of measurements is 217 on 69 double stars not counting the negative results on 3 stars. Most of the pairs are in orbital motion and about 45% were closer than  $1''.0$  at the time of the measurement. All measurements were obtained by using the 32.5-cm f19 Cassegrain positioned in Hemhofen (latitude  $N49^{\circ} 42'$ ) close to Erlangen/Germany. The telescope was designed and constructed in 1996 by Peter Grosse, formerly Zeiss Jena.

The limit for clearly resolvable stars is  $0''.40$ .

The following micrometer was used: MECA PRECIS Double Image Micrometer. Magnifications: 390x (only in some few cases for faint pairs), 490x, 620x, 690x, 920x. Mostly, the 620x magnification was applied. On each night, the distance and the PA each are set 2 to 10 times (mostly 4 times). When the distance is less than about  $0''.4$ , the distance is always measured and estimated, and the final value is the mean value. Mostly, the difference between the 2 methods does not exceed  $0''.05$ . Residuals were calculated for 65 pairs with known orbits.



Figure 2: 325-mm/f19 Cassegrain running on Alt 7AD equatorial mount with MECA PRECIS Double Image Micrometer



Figure 3: The MECA PRECIS Double Image Micrometer ‘Bernard Lyot’, here with a 10 mm Zeiss ortho eyepiece. At right: screw for PA setting: rotates the box around the angular scale. At left: screw for distance setting: rotates the calcite plate located under the eyepiece. A setting of  $\pm 10$  corresponds to a distance of  $0''.83$ .

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The measurements:

1. column: Name of star
2. column: Component
3. column: RA 2000
4. column: DEC 2000
5. column: estimated magnitude difference
6. column: PA(°)
7. column: Separation(")
8. column: Epoch
9. column: number of nights
10. column: observer
11. column: note indicated

**Observer:** Andreas Alzner **Method:** 325mm Cassegrain, Double image micrometer

Pair	Comp	RA	Dec	$\Delta m$	PA(°)	Sep(")	Epoch	N	Obs.
STT159		0657.3	+5825	1.4	231.3	0.63	2009.21	1	ALZ
STT170		0717.6	+0918	-	353.1	0.29	2009.21	2	ALZ
STF1110	AB	0734.6	+3153	0.7	58.2	4.47	2009.21	1	ALZ
STF1196	AB	0812.2	+1739	0.4	41.3	1.02	2009.21	2	ALZ *
				0.3	38.6	1.09	2010.26	1	ALZ
	AC			0.8	65.5	6.49	2010.26	1	ALZ
VDK3		0850.7	+0752	1.2	164.4	1.44	2009.57	3	ALZ
STF1280		0855.4	+7048	0.2	349.2	2.24	2008.29	2	ALZ
				0.2	350.3	2.36	2009.21	2	ALZ
KUI37		0900.6	+4147	2.5	304.8	0.58	2008.30	1	ALZ
STF1306		0910.4	+6708	4.0	350.9	4.04	2010.26	1,2	ALZ
STF1338		0921.0	+3811	0.4	299.4	1.11	2009.21	2	ALZ
STT200		0924.9	+5134	1.7	333.8	1.22	2009.28	2	ALZ
STF1356		0928.5	+0903	0.4	99.7	0.75	2009.21	2	ALZ
STF1372		0937.1	+1614	0.4	253.3	0.37	2010.26	1	ALZ
STT215		1016.3	+1744	0.3	177.2	1.45	2009.22	3	ALZ
STF1424		1020.0	+1951	1.2	126.2	4.67	2010.26	2	ALZ
STF1429		1025.0	+2437	0.3	160.6	0.74	2009.28	2	ALZ
STT229		1048.0	+4107	0.4	264.7	0.69	2008.80	2	ALZ
				0.3	263.0	0.74	2011.36	1	ALZ
STF1523	AB	1118.2	+3132	0.5	224.1	1.61	2008.29	2	ALZ *
				0.4	214.5	1.58	2009.24	3	ALZ
				0.3	210.7	1.59	2010.26	3	ALZ
				0.4	201.2	1.56	2011.36	2	ALZ
				0.5	155.3	2.09	2019.40	3	ALZ
STF1527		1119.0	+1416	-	166.5	0.26	2008.29	2	ALZ
				0.5	176.2	0.30	2009.26	3	ALZ

			0.7	187.8	0.31:	2010.26	3	ALZ
			0.5	195.6	0.29:	2011.36	2	ALZ
STF1536	1123.9	+1032	2.4	93.1	2.16	2019.41	2	ALZ
STT235	1132.2	+6105	1.7	19.7	0.70	2008.38	1	ALZ
STF1555	1136.3	+2747	0.3	148.7	0.79	2010.25	1	ALZ
STF1606	1210.8	+3953	0.5	142.5	0.65	2019.41	2	ALZ
STF1639	1224.4	+2535	1.1	326.4	1.76	2010.26	2	ALZ
STT251	1229.1	+3123	1.2	57.1	0.66	2008.30	1	ALZ
STF1670	1241.7	-0127	0.0	38.6	1.01	2008.29	2	ALZ
			0.0	30.8	1.21	2009.28	4	ALZ
			0.0	22.7	1.45	2010.26	3	ALZ
			0.0	16.8	1.64	2011.36	2	ALZ
			0.0	6.7	2.15	2014.42	2	ALZ
			0.0	3.3	2.46	2016.42	2	ALZ
			0.0	358.3	2.82	2019.41	4	ALZ
STF1687	1253.3	+2114	2.3	198.2	1.26	2019.41	2	ALZ
BU1082	1300.7	+5622	companion not seen			2019.41	1	ALZ
STT260	1308.1	+2657	0.4?	46.8	0.33:	2019.42	2	ALZ *
STF1728	1310.0	+1732	0.0	9.6	0.63	2009.39	1	ALZ
STT261	1312.0	+3205	0.7	338.7	2.52	2011.36	2	ALZ
STF1781	1346.1	+0507	0.5	198.0	1.04	2019.41	2	ALZ
STF1785	1349.1	+2659	0.4	180.9	3.09	2009.39	2	ALZ
			0.8	189.9	2.77	2019.41	2	ALZ
A1614	1357.7	+5200	0.2	300.9	1.42	2009.07	2	ALZ
STF1820	1413.1	+5520	0.3	120.1	2.66	2008.91	2	ALZ
STF1816	1413.9	+2906	0.4	99.9	0.38	2019.41	2	ALZ
STF1817	1414.2	+2642	round			2019.42	1	ALZ
STF1865	1441.3	+1344	0.0	294.6	0.60	2008.40	2	ALZ *
			0.0	294.8	0.60	2009.37	4	ALZ
			0.2	293.6	0.60	2011.41	1	ALZ
			0.2	293.8	0.44	2014.42	2	ALZ
			0.1	290.8	0.37	2016.42	2	ALZ
			-	284.8	0.30:	2018.45	2	ALZ
			0.0	282.5	0.24:	2019.40	3	ALZ
STF1877	1445.0	+2704	1.8	344.2	2.89	2008.40	2	ALZ
STF1888	1451.4	+1906	2.3	309.4	6.08	2009.41	3	ALZ
			1.8	300.4	5.31	2018.45	1	ALZ
STT287	1451.5	+4456	0.5	357.2	0.74	2009.39	1	ALZ
STT287	1451.4	+4456	0.2	5.4	0.62	2019.41	2	ALZ
STT288	1453.4	+1543	0.6	164.0	1.10	2008.40	2	ALZ
			0.5	160.2	1.09	2010.84	2	ALZ
			0.6	156.0	1.00	2019.41	2	ALZ
STF1909	1503.8	+4739	0.8	58.8	1.78	2008.40	2	ALZ
			0.5	58.6	1.67	2009.39	2	ALZ
			0.3	61.2	1.47	2011.41	1	ALZ
			0.6	66.4	1.07	2014.42	2	ALZ
			0.6	72.2	0.81	2016.42	2	ALZ
			0.7	85.4	0.53	2018.45	2	ALZ
STF1909	1503.8	+4739	0.6	95.4	0.33	2019.40	3	ALZ
STF1926	1514.9	+3818	round			2019.41	1	ALZ
STF1932	1518.3	+2650	0.0	263.4	1.61	2008.45	2	ALZ

STF1937	1523.3	+3017	0.3	148.0	0.54	2008.40	2	ALZ
			0.4	159.6	0.59	2009.42	2	ALZ
			0.3	199.4	0.69	2014.42	2	ALZ
			0.4	215.9	0.61	2016.42	2	ALZ
			0.4	248.0	0.46	2018.45	2	ALZ
			0.4	264.2	0.38	2019.40	2	ALZ
STF1938	1524.5	+3723	0.4	6.9	2.25	2008.40	2	ALZ
			0.5	3.1	2.27	2018.45	2	ALZ
			0.3	3.3	2.26	2019.40	2	ALZ
STF1944	1527.7	+0605	0.5	296.1	0.72	2008.42	1	ALZ
			0.5	292.8	0.68	2019.42	2	ALZ
STT298	1536.0	+3948	0.3	185.6	1.24	2016.42	2	ALZ
STF1969	1541.3	+5959	0.5	27.8	1.03	2008.45	2	ALZ
STF1967	1542.8	+2618	1.6	106.6	0.65	2008.45	2	ALZ
STF2028	1612.8	+3921	-	139.8	0.35	2008.42	1	ALZ
STF2059	1630.9	+3804	0.3	188.8	0.36	2008.45	2	ALZ
STF2084	1641.3	+3136	-	194.6	0.95	2008.48	1	ALZ
			2.4	185.9	1.05	2009.59	2	ALZ
D15	1643.9	+4329	-	30.4	0.34	2008.48	1	ALZ
STF2118	1656.4	+6502	0.0	66.6	1.06	2008.48	1	ALZ
STF2130	1705.3	+5428	0.0	9.5	2.35	2008.48	1	ALZ
STF2205	1745.8	+1743	0.0	4.0	1.06	2009.59	2	ALZ
STF2315	1825.0	+2723	0.8	115.9	0.61	2009.59	2	ALZ
STF2382	1844.3	+3940	0.7	348.3	2.41	2009.59	2	ALZ
STF2383	1844.4	+3937	0.2	78.9	2.31	2009.59	2	ALZ
BU648	1857.0	+3254	2.3	258.8	0.99	2009.70	2	ALZ
STT371	1915.9	+2727	0.4	159.5	0.89	2009.70	2	ALZ
STF2525	1926.6	+2719	0.3	290.4	2.11	2009.59	2	ALZ
STT383	1942.9	+4043	1.0	16.4	0.92	2009.70	2	ALZ
STF2579	1945.0	+4508	3.8	218.7	2.72	2009.59	2	ALZ
STF2576	1945.6	+3337	0.1	158.9	2.84	2009.70	2	ALZ
STT387	1948.7	+3519	0.8	122.7	0.56	2009.59	2	ALZ *
STF2652	2008.9	+6205	-	214.3	0.27	2009.59	2	ALZ
BU151	2037.5	+1436	0.5	22.3	0.40	2009.66	3	ALZ
STF2737	2059.1	+0418	0.6	284.8	0.58	2009.70	2	ALZ
STF2909	2228.8	-0001	0.1	170.2	2.10	2009.70	1	ALZ

### Notes to individual stars (\*)

System	ADS	Notes
STF1196	6650	AB,AC. Residuals for Heintz' orbital solution (AB and AC, 1996) have been calculated using the ephemeris given by Heintz (1996).
STF1523	8119	AB: P=59.878 (Mason 1995, grade 1) AB: P=59.84 (Heintz 1996, grade 1) Aa-A: P=1.834 (Heintz 1996, grade 9) Residuals were calculated first: - combining AB (Mason 1995) and Aa-A (Heintz 1996) (according to the elements given in the Sixth Catalog of Orbits of Visual Binary Stars) and secondly: - combining AB (Heintz 1996) and Aa-A (Heintz 1996)
STT260	8791	The periastron passage has not been observed. The large residual to the orbit by

Zirm has been confirmed by R. Wasson (Journal of Double Star Observations, Vol. 15 No.2 April 2019) and by M. Scardia (AN 340, 771-779, 2019), both with speckle measurements.

STF1865	9343	This bright pair with equal components allowed use of high magnifications up to 920x. Not separated in 2018 and 2019, but still measurable with the Double Image Micrometer.
STT387	12972	Residuals for WSI2006 and for Josties/Mason 2018 are calculated. The orbit from 2006 represents the early visual measurements in the first and in the fourth quadrant better, e.g. the measurements by W. J. Hussey at Lick observatory 1898.

### Residuals for Micrometer measurements by Andreas Alzner 2008.29 to 2019.42

Pair	ADS	Residual(O-C)		Orbit	Period	Date	Grade
		PA(°)	Sep(")		(yrs)		
STT159	5586	+1.1	-0.02	Alzner	262	2000	3
STT170	5958	+11.1	+0.05	Scardia	300.9	2016	3
STF1110	6175	+0.1	-0.14	Docobo	459.8	2014	3
STF1196AB	6650	+0.6	-0.06	Heintz	58.90	1995	1
		+1.8	0.00				
STF1196AB	6650	-0.4	-0.04	Josties&Mason	59.98	2018	1
		+0.8	+0.02				
AC	6650	-0.3	-0.06	Heintz	1115	1995	4
VDK3	7044	-1.9	+0.11	Washington Speckle I	177.0	2006	4
STF1280	7067	-0.7	+0.06	Heintz	609	1997	4
		-0.7	+0.05				
KUI37	—	-5.4	+0.10	Muterspaugh	21.797	2010	1
STF1306	7203	+1.4	-0.14	Scardia	970	2015	4
STF1338	7307	-0.6	0.00	Scardia(II)	444.27	2002	3
STF1338	7307	-1.7	+0.03	Mason	424.2	2018	3
STF1356	7390	+2.0	+0.02	Muterspaugh	117.98	2010	2
STF1372	7456	+4.8	+0.07	Alzner	371	2005	3
STT215	7704	-0.6	-0.02	Scardia	702.4	2018	4
STF1424	7724	+0.4	+0.05	Mason	510.3	2006	4
STF1424	7724	+0.4	-0.02	Pulkova	554	2014	4
STF1429	7758	0.0	+0.02	Zulevic	1280.7	1981	4
STT229	7929	+2.3	+0.02	Alzner	320	1998	3
		+2.7	+0.08				
STF1523 AB	8119	-2.1	-0.02	Mason/Heintz	see notes		
		-3.1	-0.03				
		-0.8	0.00				
		-1.9	-0.03				
		-0.1	+0.02				
		-0.7	0.00	Heintz/Heintz	see notes		
		-1.8	-0.01				
		+0.6	+0.02				
		-0.7	-0.02				
		+0.5	+0.02				
STF1527	8128	+4.9	-0.06	Tokovinin	415	2012	3

		+2.5	-0.03				
		+2.3	-0.02				
		-2.7	-0.04				
STF1536	8148	+0.6	-0.05	Söderhjälm	186	1999	2
STT235	8197	+3.9	-0.07	Söderhjälm	72.7	1999	2
STF1555	8231	-0.4	+0.08	Docobo	1730	2017	4
STF1606	8446	+1.7	+0.04	Mason	1431	1999	4
STF1639	8539	+2.8	-0.02	Olevic	575.44	2000	4
STT251	8569	-2.8	0.00	Scardia	540.56	2003	5
STF1670	8630	+0.9	+0.01	Scardia	169.10	2007	2
		+2.3	-0.02				
		+0.5	+0.01				
		-0.1	-0.02				
		-0.6	-0.03				
		+0.2	-0.01				
		+0.1	-0.04				
STF1687	8695	-3.0	+0.08	Drummond	539.4	2014	4
STT260	8791	-33.4	-0.05	Zirm	233.79	2008	3
STF1728	8804	-2.7	-0.01	Muterspaugh	25.853	2015	1
STT261	8814	+0.1	-0.04	Kiselev	860.8	2012	4
STF1781	9019	-0.1	+0.01	Alzner	261.6	2007	3
STF1785	9031	+0.2	-0.02	Heintz	155.75	1988	2
		-0.4	0.00				
A1614	9071	-1.4	+0.04	Robo-AO	205	2015	3
STF1820	9167	-0.4	+0.04	Kiyaeva	1013	1998	4
STF1816	9174	-0.7	+0.03	Zirm	1340	2014	4
STF1865	9343	-1.6	-0.02	Scardia	125.24	2007	2
		-0.7	+0.01				
		-0.5	+0.06				
		+2.5	-0.01				
		+2.2	-0.02				
		0.0	-0.01				
		+0.3	-0.03				
STF1888	9413	+0.4	0.00	Söderhjälm	151.6	1999	2
		+1.8	-0.04				
STT287	9418	-0.3	-0.05	Heintz	340	1997	4
		+1.7	-0.04				
STT288	9425	+1.9	0.00	Heintz	313	1998	4
		-0.7	+0.02				
		0.0	+0.05				
STF1909	9494	-0.4	+0.03	Zirm	209.8	2011	2
		-1.4	0.00				
		-0.6	+0.01				
		+0.3	0.00				
		+0.7	+0.04				
		+1.4	+0.06				
		-2.1	-0.01				
STF1932	9578	+0.8	-0.01	Scardia	203.15	2015	2
STF1937	9617	-2.7	0.00	Muterspaugh	41.63	2010	1
		-2.0	+0.02				
		-2.6	+0.03				

		-3.1	+0.04				
		+1.6	+0.04				
		-2.3	+0.01				
STF1938BaBb	9626	+0.5	0.00	Kiyaeva	265	2014	2
		0.0	+0.02				
		+0.5	+0.02				
STF1944	9647	-2.7	+0.04	Zirm	1030	2015	4
		+0.3	+0.08				
STT298	9716	+0.2	+0.03	Söderhjelm	55.6	1999	1
STF1969	9756	-0.3	+0.07	Robo-AO	434	2015	3
STF1967	9757	-5.9	-0.03	De Rosa	91.2	2012	2
STF2028	9970	-4.5	-0.03	Hartkopf	105.34	2014	3
STF2059	10093	+3.4	-0.02	Zirm	955	2014	4
STF2084	10157	+3.2	-0.15	Söderhjelm	34.45	1999	1
STF2084	10157	+4.2	-0.07				
D15	10188	-3.8	+0.02	Alzner	120.05	2007	2
STF2118	10279	-0.7	-0.10	Scardia	422.22	2002	3
STF2130	10345	-0.1	-0.03	Prieur	812	2012	4
STF2205	10769	+2.0	-0.01	Cvetkovic	1971.1	2008	4
STF2315	11334	-3.4	-0.02	Washington Speckle I	2094	2004	4
STF2382AB	11635	+0.6	+0.02	WS2004	1725	2004	4
STF2383CD	11635	+0.5	-0.06	Docobo	724.31	1984	4
BU648	11871	+0.7	-0.07	Muterspaugh	61.412	2010	2
STF2525	12447	+0.4	-0.01	Prieur	882.89	2017	4
STF2579	12880	-1.2	+0.04	Scardia	918.1	2012	4
STF2576	12889	-0.4	-0.07	Söderhjelm	232	1999	2
STT387	12972	-1.3	+0.02	WSI	165	2006	2
		-1.2	+0.02	Josties & Mason	178.1	2018	2
STF2652	13449	+5.7	-0.04	Zirm	495	2014	4
BU151	14073	+1.3	+0.01	Muterspaugh	26.683	2010	1
STF2737	14499	+0.8	+0.03	Tokovinin	104	2017	2
STF2909	15971	+2.1	+0.07	Tokovinin	540	2016	3

# CMOS ASTROMETRY OF DOUBLE STARS ON THE ISLAND OF KAUAI, HAWAIIAN ISLANDS

Grant L. Morris, Greeley, Colorado, USA

E-mail: glmorri@aol.com

## Introduction

The north shore of the island of Kauai in the Hawaiian Island chain is usually cloudy. However, when the clouds do take a break, the seeing can be exceptional. This, coupled with the island's latitude at my location ( $22^{\circ} 11' 47''$ ) provided an opportunity to measure more southerly stars than those to which I usually have access. These southerly stars are less frequently measured compared to those readily observable in the northern hemisphere.

## Equipment

A fork-mounted 8-inch SCT was combined with a motorized Crayford focuser, and a flip-mirror for switching between a finding and centering eyepiece or the remainder of the optical train. This consisted of a 3X Barlow and a ZWO ASI 120 monochrome CMOS camera. This optical train and camera produced a pixel scale of approximately  $0''.0934$  per pixel. The ZWO ASI 120 camera has a peak spectral sensitivity of nearly 80% at 540 nm. A broadband interference filter (Astronomik Green Type 2c Filter: 95% transmission at  $\lambda_c = 535$  nm,  $\Delta\lambda_{HM} = 90$  nm) was used when helpful to minimize atmospheric dispersion in stars well off the zenith.

## Image Acquisition and Reduction

The star images were reduced using speckle interferometry techniques. However, the small aperture of the telescope used combined with the above average seeing (large  $R_o$ ) and the longer exposure times needed to capture faint doubles meant that the technique could be more accurately called 'blur interferometry'. Also, speckle interferometry exposure times ideally are about 40 ms or less so as to 'freeze' the speckles (multiple binary star images) caused by the different isoplanatic cells present across the aperture of a larger telescope. Exposure times this short could be achieved with the present setup only for stars of magnitude approximately 7 or brighter. Exposures in some instances approached 300 ms. This yielded usable star images because of the robustness of the interferometry/autocorrelation technique and the extraordinary 'seeing' at the observing site. A maximum of 500 star images were collected in an acquisition sequence depending upon the exposure time required to adequately image the target.

Acquisition was carried out with SharpCap software<sup>1</sup> controlling the ASI 120MM camera. Images were stored as FITS files. Calibration stars were selected for long term stability of position angle and separation. These calibration stars and the calibration PA and separation values used on a date are identified in the Table 1 below.

To calibrate the camera for a night's run, images from the calibration binary's acquisition sequences were cropped using REDUC<sup>2</sup>. Each acquisition sequence was then reduced using the AutoCorrelation procedure in REDUC. This yields a correlogram, which looks like a binary pair with an extra star symmetrically flanking the primary. Determination of the true location of the companion star is determined by examining the raw FITS images. This will identify which of the two 'stars' symmetrically flanking the center primary 'star' in the autocorrelogram should be measured. ("Note that the autocorrelogram displays radial symmetry. It is not an actual image of the double star, but rather a graphical portrayal of the two-dimensional autocorrelation of



Figure 1: The 8-inch (200-mm) SCT telescope with 3x Barlow lens attached and ZWO ASI CMOS camera

the averaged power spectrum. The symmetric nature of the display results from the fact that autocorrelation of any real function is inherently symmetrical”<sup>3)</sup>

After the autocorrelograms had been created from each calibration pair acquisition sequence, preliminary position angles and separations were determined, and these values would be averaged for all of the autocorrelograms. The known PA and separation of the calibration pair would then be entered to determine the true  $\Delta$  (camera angle) and  $E$  (pixel size in arcseconds) for that night’s run.

The  $\Delta$  and  $E$  would be transferred into the SPECKLETOOLBOX<sup>3)</sup> program that was used for interferometric reduction of the remaining stars. SPECKLETOOLBOX has efficient batch procedures for reducing a large number of acquisition sequences, and has filtering capabilities that are useful for extracting measurable autocorrelograms from close and/or large  $\Delta m$  binaries. There was very close agreement between the autocorrelogram measurements in REDUC and SPECKLETOOLBOX.

SpeckleToolBox was also used for a drift calibration technique to determine the camera angle. This independent calibration yielded values for  $\Delta$  that often matched to the second decimal place with those generated in REDUC using calibration stars.

**Table 1. Calibration double stars. N is the number of acquisition sequences. PA (position angle) is in degrees( $^{\circ}$ ), and Sep (separation) is in arc seconds( $''$ ). Epoch identifies the night when that star was used to calibrate the measurements in Table 2. Any differences between PA and Sep values used for calibration and values preferred by the reader may be properly treated as constant error and applied to values in Table 2.**

Pair	Comp	RA	Dec	Va	Vb	PA	Sep	Epoch	N
STF 1129	AC	07413	+1807	8.91	9.68	64.47	21.65	2020.295	4
STF 1308		09050	-0359	8.09	9.19	84.77	10.92	2020.254	5
STF 1649		12316	-1104	7.97	8.43	193.99	15.71	2020.377	6

**Table 2. Measures of double stars. N is the number of acquisition sequences. PA (position angle) is in degrees ( $^{\circ}$ ), and Sep (separation) is in arc seconds( $''$ ).**

Pair	Comp	RA	Dec	Va	Vb	PA	Sep	Epoch	N
STF 1077	AB	07210	-0040	9.89	9.78	318.8	5.45	2020.3	1
STF 1103		07306	+0515	7.12	8.64	245.31	4.19	2020.3	2
B 161		08386	-2502	9.23	10.78	316.75	8.29	2020.25	4
STF 1255	AB	08397	+0546	7.33	8.56	30.36	26.06	2020.3	7
STF 1260		08407	-1210	7.86	8.07	301.19	5.3	2020.25	3
STF 1270		08453	-0236	6.89	7.54	265.01	4.67	2020.25	3
STF 1273	AB,C	08468	+0625	3.49	6.66	310.74	2.93	2020.25	3
STF 1292	AB	08538	-0035	9.32	9.53	187.84	6.06	2020.25	4
STF 1295		08555	-0758	6.73	6.93	3.28	4.04	2020.3	9
HJ 4166	A,BC	09033	-3336	7.1	7.93	153.83	13.76	2020.25	5
DUN 78		09308	-3153	6.15	6.83	212.04	8.25	2020.3	7
STF 1424	AB	10200	+1950	2.37	3.64	126.62	4.74	2020.3	4
BU 412		12084	-1835	8.43	8.96	152.4	1.98	2020.38	5
S 634		12114	-1647	7.17	8.79	302.27	4.60	2020.38	1
STF 1619		12151	-0715	8.06	8.3	265.51	6.96	2020.38	4
BU 920		12158	-2321	6.86	8.22	307.12	1.91	2020.38	9
STF 1627		12182	-0357	6.55	6.9	195.65	20.12	2020.38	6
SHJ 145	AB	12299	-1631	2.95	8.47	215.66	24.21	2020.38	6
STF 1669		12413	-1301	5.88	5.89	314.21	5.31	2020.38	8
STF 1670		12417	-0127	3.48	3.53	356.8	3.01	2020.38	4
STF 1677		12453	-0353	7.3	8.12	348.69	16.08	2020.38	5
S 643		12540	-1802	7.07	8.17	295.17	23.46	2020.38	6

**Table 3. Residuals from known orbits.**

Pair	ADS	Residual(O-C)		Orbit	Period (yrs)	Date	Grade
		PA(°)	Sep(")				
STF 1273	6993	-0.04	+0.10	Izmailov	589	2019	4
STF 1424	7724	+0.02	+0.01	Pulkovo (I)	554	2014	4
STF 1424	7724	-0.81	-0.01	Pulkovo (II)	554	2014	4
STF 1619	8477	+0.19	+0.15	Rica et al	4802	2017	5
BU 920	8481	-0.14	-0.02	Izmailov	873	2019	5
STF 1670	8630	-0.21	+0.03	Scardia et al	169	2007	2

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# NEARBY STARS WITH EVIDENCE OF ORBITAL MOTION

John Greaves

E-mail: [cpmjg@tutanota.com](mailto:cpmjg@tutanota.com)

## Abstract

High proper motion pairs within 20 parsecs of the Sun are examined for differential proper motion and pairs exhibiting potential orbital motion but having no known published orbit are presented as candidate observational targets.

## Introduction

Stars with very high proper motion are usually near to very near the Solar System and the recent release of GAIA Data Release 2 (DR2)<sup>1</sup> has provided high precision proper motion values for many of these stars as well as parallax estimations. From this sample of objects common motion pairs can be found that lie relatively to very adjacent to each other upon the sky and when these high motion objects are of similar high parallax values this translates into true physical proximity for the pair.

In sufficiently nearby pairs where orbital motion is also noted said orbital motion also causes differential proper motion. This is well exemplified by Porrima ( $\gamma$  Virginis =  $\Sigma$ 1670 AB) which has a well-known orbit and according to GAIA DR2 lies around 12 parsecs away with has high proper motions differing in Right Ascension and Declination by 67 and 148 mas yr<sup>-1</sup> respectively. Using this principle GAIA DR2 can be used to search for candidate objects of a similar differential motion nature that have heretofore gone unnoticed.

These pairs, being likely close together in absolute terms, are most likely to have orbital periods on the order of decades to a few centuries and thus able to fall within the remit discernible motion via visual measurement, whether using the eye or a digital receiver. Most well known stellar masses are determined via binary star orbits. However the majority are from eclipsing binaries where the eclipse profile, multi-passband derived surface temperature and multiple radial velocity measurements are combined to determine the absolute orbit, so to speak, and enable the relative physical dimensions of the system and subsequently the individual masses for the objects to be determined from their mass ratio against the orbit derived total mass.

The problem here is that many eclipsing binaries have not evolved naturally to their current state due to mass transfer at some point or other, which leads to the current primary potentially having been the secondary before the then primary evolved far enough to exceed its Roche Lobe and donate material to the then secondary, thus reversing which star is the brighter and more massive. In other words, eclipsing binary stars do not necessarily properly reflect the standard stellar evolutionary path of a non-interactive star. Stellar masses from visual orbits are more able to reflect the masses of stars that have undergone stellar evolution without interference due to their larger physical separation relative to the stellar radii.

This work is presented here as a point of information for people who measure double star particulars, whether via traditional visual means or more modern digital imaging, and to some extent as a call for observations. A small number of these objects likely will return sufficient measures to enable a reasonable orbit to be estimated within a couple of decades, or possibly sooner for objects already possessing a history of observations. Even if that is not the case, the orbits of some stars, for example the aforementioned Porrima, would not be known as well as they are now without the measurements of observers long past. Double stars can be one of the few endeavours of observational astronomical science where simple measurement by both amateur and professional can be instrumental in directly observing true changes over time within the stellar heavens, albeit not always within one observer's lifetime.

On the other hand, there is a caveat. Many of this study’s candidate objects are either faint, close to very close together, of large differential magnitude or combinations of all three. This is to be expected, otherwise a lot of the following objects would already have sufficient data for an orbit to have already been published. Nevertheless many of this study’s objects are known pairs (albeit not previously suspected of orbital motion) that were first detected visually, or at least photographically, and even most of the digitally discovered objects were discovered in optical passbands.

## Methodology

Using the IRSA IPAC GATOR catalogue server<sup>2</sup> Gaia DR2 was examined and a preliminary shortlist of objects selected having combined proper motion of over 100 milliarcseconds per year ( $\text{mas yr}^{-1}$ ) and parallaxes higher than 25 milliarcseconds (mas) which latter equates to 40 parsecs distance when distance is simplistically determined via parallax reciprocalisation. After giving each star a unique running number to act as a reference index an exact copy of the resultant list was generated and the two lists tested against themselves in order to find pairs of stars within 5 arcsec of each other.

This of course also leads to each star being matched with itself as well as any true neighbours. Through the use of the unique index reference number these “self-pairs” are removed simply by deleting those where both stars from each pair have the same identifying number. Double entries (and in some rare cases higher multiples) also occur due to the basic fact that if A is associated with B then B is associated with A and these are simply removed by hand for interesting objects as the analysis progresses.

The final pairs are reverse sorted on parallax (that is, looking at stars from the nearest outwards), then candidate pairs are examined for substantial differential proper motion in at least either right ascension or declination. The limiting ‘distance’ to which this is done is determined by the data, such that around 20 parsecs equivalent distance this difference begins to be less than around  $10 \text{ mas yr}^{-1}$ . Although this is much higher than the theoretical limit of precision for GAIA DR2 it is sufficiently large enough to be well above any expected practical error range whilst also reflecting a level of motion likely to be noticeable over time by either a visual telescopic observer or a telescopic observer utilising either direct or drift digital imaging. Only objects with distance ratios of largest to smallest less than 1:1.01 are examined. This is a relatively low value given much anecdotal evidence of GAIA DR2 parallax issues for known physically associated binary stars is somewhat prudent. Porrima for example has a parallax ratio of 1:1.1 despite a well determined orbital semimajor axis of 3.68 arcsecs or around 45 Astronomical Units (AU) and being a well-known physical pair with an orbit observed for longer than one full revolution. Consequently that the GAIA DR2 parallaxes suggest large radial separation is nonsensical. This could be excused as due to the brightness of the naked eye magnitude stars giving measurement problems. However, third magnitude  $\chi$  Eridani below has a close comes six magnitudes fainter than the primary but a parallax ratio for the pair of only 1:1.0002! Whatever the situation, using a ratio of 1:1.1 added only a few extra objects of small differential proper motion so a ratio of 1:1.01 is retained as upper threshold.

Candidate objects are checked against an October 2019 version of the Washington Double Star Catalog (WDS)<sup>3</sup> and those noted therein as having a known orbit are removed from the list. It is not clear whether the orbit notes within the WDS are updated real time with every updated online version or are currently frozen at the point the Sixth Orbit Catalog<sup>4</sup>. Accordingly the IAU Double Star circulars (IAUDS circulars<sup>5</sup>), from 140 onwards (in order to comfortably predate the Sixth Orbit Catalog) are also checked to ensure none of the candidate objects has a published orbit in the circulars.

Similarly, the WDS notes and the Second Rectilinear Catalog<sup>6</sup> and the IAUDS circulars are also checked for objects with published linear solutions. These are not removed from the candidate list for as it states in the catalogue particular orbits (especially slow eccentric ones) can have long

stretches of orbit that are indistinguishable from linear motion. In the case of these matching objects the following assumption is made : for two stars to be within 20 parsecs distance, have a projected physical separation of between 20 and 40 AU, and have nearly common proper motion in the hundreds of millarcseconds per year range in highly similar directions, to be random field stars coincidentally passing each other at this time is a far more ‘pleading special circumstance’ interpretation than for the two stars to be associated. They are also assumed to be of sufficient true proximity to be subject to gravitational interaction.

Finally, position angle and separation for the pair are obtained, and the astrometric parameters and magnitudes are noted using GAIA DR2. SIMBAD<sup>1</sup> is examined for any extra information to be added, as are the WDS notes. The handful of objects with the greatest difference between the first and last separation dates listed in the WDS have their data requested from the observation and measures database held by the WDS to further examine any potential for orbital motion.

## Results

The astrometric solution and magnitudes pertinent to the WDS for all 26 candidates, as determined from GAIA DR2 positions and magnitudes, are presented in Table 1. Consequently the epoch of observation is 2015.5 throughout and the data are given to the precision of one decimal place for position angle and two decimal places for separation in order to reflect that dataset’s precision. Separation in Astronomical Units is simply the current projected separation via reciprocalising the pair’s average parallax. All of the objects are already included within the WDS except for one, with that object being included in the Washington Double Star Supplement (WDSS<sup>7</sup>), thus no new identifiers were required and each object is listed as per its discovery name in the WDS or by its WDSS identifier.

Astrophysical parameters are listed in Table 2. The distance is determined by simply reciprocalising the pair’s average parallax. When the individual distances for each of the objects in a pair are determined in this way to 0.1 parsec precision 14 have the same distance, eleven differ by only 0.1 parsecs (mostly for the more distant objects) and only one differs by 0.2 parsecs, however even this is something of a rounding artefact as the two decimal difference is 0.13. The differential proper motion in both Right Ascension and Declination are also quoted in order to give a potential observer an indication of the level of relative motion to be expected from each candidate pair.

Particular objects are now presented individually where clarification and/or matters of note are appropriate. This includes at least two very good candidates with record of past observations.

### HJ 3473

The primary of this pair is the third magnitude naked eye star  $\chi$  Eridani, a G8 giant and the pair lie nearly 18 parsec distant. The motion of the secondary relative to the primary from archived observations provided from the WDS team (Mason<sup>4</sup>) are presented in Figure 2, where North is up.

These are plentiful enough but have a large gap between the first and the main body of observations and similarly the last, around six decades in both cases. If these extrema observations are removed (and the first appears to be approximate) the rest of the data would be safely represented by a linear solution as can be seen from Figure 2. However, for two stars to have proper motion around  $740 \text{ mas y}^{-1}$  in very similar directions and yet have a projected separation of only 45 AU would be very coincidental. Even omitting the original observation of John Herschel still leads to the suggestion of an approaching periastron from a likely long eccentric orbit. The differential Declination is not greatly pronounced and as would be expected from Figure 2 that for Right Ascension barely exists.

Observationally the main problem is the large differential magnitude for the pair and in tandem with the Southerly Declination are probably the reasons for no observations in recent times.

### BEU 5

This 12th magnitude or fainter red dwarf pair has a linear solution in IAUDS circular 190 but this nearly  $700 \text{ mas yr}^{-1}$  similar motion and direction pair of 22 AU projected separation

are unlikely to be coincidentally aligned. The pair are very faint and very close to each other on the sky with some small increase in separation over their known history, so present a strong challenge.

**NSN 207** These are all pairs found from fairly recent modern astrometric survey data and consequently  
**NSN 488** representing *stella incognita* to coin a pun, with little to no historical observations.  
**KPP 2693** These red dwarf pairs are all quite faint and will present a challenge to even the well-equipped  
& **KPP 3056** visual observer.

All the remaining pairs either contain a red dwarf or are red dwarf pairs with some discovered recently and others having initial observations over five decades old. Their astrometric particulars can be seen in Table 2 and their red-biased GAIA DR2 magnitudes in Table 1.

**RST 203AB** The WDS gives a separation of 1.2 arcsec in 1929 relative to a GAIA one of 2.3 for 2015.5. It also notes that a linear solution exists, however given the near coincident sizeable proper motion of this 2015.5 35 AU projected separation pair orbital motion is more likely. The 9th magnitude primary is a late K dwarf and the pair form an optical triple with ENO 11AC.

**JSP 208BC** This binary is in fact a trinary along with LDS 198AB. Given the matching parallaxes and similar high motion for all three from GAIA DR2 gives the BC pair a projected separation of around 40 AU with the 60.6 arcsec separation LDS 198A lying a projected separation of around 310 AU from the pair. The differential proper motion of the pair for Right Ascension is large but not markedly so and that for Declination negligible. Both motions also differ slightly from LDS 198A, which should be relatively fixed with respect to the common centre of gravity of that pair, suggesting that it could be used as a reference point for the JSP 208BC pair and after any orbit was determined help determine the projected centre of mass of that pair.

Archival observations from the WDS team (Mason<sup>4</sup>) give few data points and mostly suggest an increasing then decreasing separation. In contradiction the position angle has increased in a slow near monotonic way over 85 years. If two very closely spaced mid 1980s observations are removed then a very slow increase in separation appears with a slow increase in position angle.

**LDS 3836** Also known as the variable flare star EI Cnc this pair of late red dwarfs is a target for both Northern and Southern Hemispheres. The pair are around a mere 5 parsecs distant leading to a projected separation of only 11 AU and have by far the largest differential proper motions of all the candidates, comparable to that of known orbiters (qv. Porrima above).

The WDS states an initial observation of 4.5 arcsec in 1960. When the albeit sparse archival observations provided from the WDS team (Mason<sup>4</sup>) are plotted as secondary positions relative to a fixed primary it seems the secondary underwent periastron passage around the turn of the Millennium or soon after as shown in Figure 1, where North is up. One apparently discrepant observation for 2005 was removed as it would have led to a retrograde motion!

Fitting the observations with a not entirely appropriate parabola and extrapolating the unrealistic parabolic arc forwards in time suggests that the 2015 epoch 2.1 arcsec separation will have extended to around 3 arcsec by the late 2020s and have reached the same 4.5 arcsec 1960 measure by 2040. On the other hand the observations suggest that the relative separation shrank from 4.5 arcsec to near 1.5 arcsec in 40 years.

A symmetric parabola could present a small near periastron section of a much larger orbit. Then again orbital motion for an apparent orbit is faster near periastron and slows toward apastron and if the orbit is instead relatively small the relative motion may move away from an apparent parabola. Finally, the differential proper motion in Right Ascension is nearly three times the size that of that for Declination so the separation could henceforth be widening more than relative to the parabolic case and in tandem with a decreasing post-periastron rate of

motion the increasing separation may end up being at a slower rate than either the putative small orbit case or the parabolic arc case.

Nevertheless this is a very good candidate for both measurement and observationally aesthetic prospects that is even a naked eye observer should note the pair widening in timescales not too large relative to a person's lifespan. The main downside being that the pair are around 13th magnitude visually.

#### **GKI 4**

This pair of high but sizeably differing proper motion appear to have narrowed by 0.7 arcsec between a 1998 measure and 2015.5. The main point of interest though is that although the WDS notes it as being a red dwarf and late red dwarf pair, (Bardalez Gagliuffi *et al.*<sup>4</sup> list the secondary as L0 spectral type, a brown dwarf. Distance is around 11 parsecs and projected separation about 25 AU. The main observational problem lies with the pair's magnitudes, the GAIA DR2 magnitudes are somewhat red magnitudes so the 10th and 15th magnitudes in that data source will be even less visually. Nevertheless stacked unfiltered exposures from a red sensitive CCD may show it to some amateur scopes as followers of outbursting cataclysmic variables achieve magnitudes as faint as this often adequately enough and with short enough exposures to discern decimagnitude scale variations over very short timescales. Whether the large differential magnitude will allow the fainter star not be within the potentially overexposed image of the brighter star at this separation is another matter.

#### **SKF 104**

With an initial separation that appears to have increased by 0.6 arcsec between 2000 and 2015 and large differential motion this presents a good candidate orbital motion pair but with a short observational arc presenting little to work with and thus in need of future observations. It is likely a red dwarf pair with a primary nearly 10th magnitude and a secondary nearly 12th magnitude visually so represents a challenge, but not a dramatic one.

#### **TSN 119CD = CPO 84AB**

During the examination of this pair it became apparent that no third and fourth stars appeared in the field for this object, and that further the magnitudes listed for both pairs in WDS were of a similar nature. In fact the two are the same and given priority likely will return to just being CPO 84AB. There is a 1905.5 'AC' measure of 4.2 arcsec separation, but given there is no C star it is not entirely clear what this represents in terms of reality. It is certainly different from the 2.3 arcsec GAIA DR2 separation of 110 years later. This is a faint red dwarf pair of around 11th magnitude or less so presents a challenge in that context.

#### **COO 228**

The WDS gives a separation of 5.0 arcsec in 1892 whilst GAIA gives 2.7 arcsec for 2015.5. The WDS also notes that a linear solution exists for the pair, however with 12 parsec distances for both the objects, similar scale and direction proper motions in excess of 400 mas y<sup>-1</sup>, and a projected separation of 32 AU, a coincidental association seems unlikely. This late-K dwarf pair having similar 9th magnitudes appears to be one of the more tractable candidates for follow up.

#### **SKF 245AC**

This multiple apparently consists of this pair as well as HDS 3080 Aa,Ab and MLB 1093AB. However the former is likely an artefact Hipparcos pair and the latter can be seen to be optical due to a very different proper motion and is noted in WDS as having a linear solution. Joining the ranks of not unknown WDS objects were a subsequently connected pair is found for one of an optical pair this differential magnitude pair presents something of a challenge observationally.

## **Conclusions**

The use of GAIA DR2 astrometric information and the WDS with extra information backup from SIMBAD can lead to finding near in space close pairs with very high proper motion where the proper motion difference is not sufficient to disassociate the pair but sufficient enough to give a

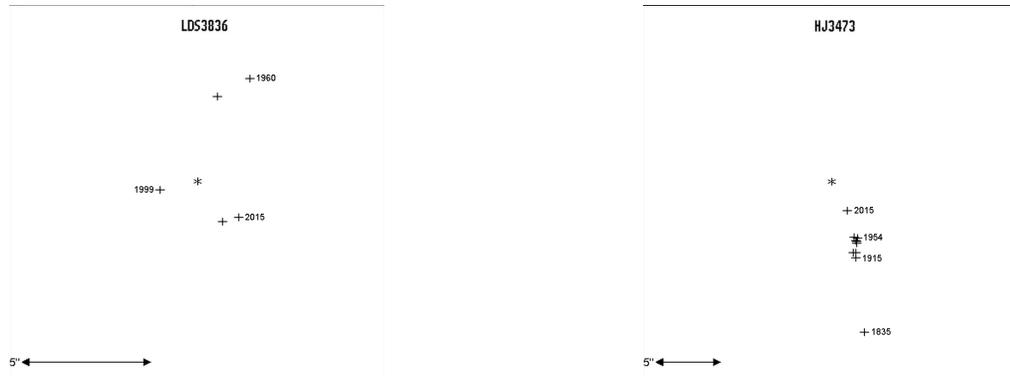


Figure 2: Observations over time for LDS 3836 (left) and HJ 3476 (right). North is up

signal of modification due to other kinds of motion. The most likely signal being that of orbital motion.

In such a way candidate targets can be selected for observation which in relatively reasonable timescales would lead to enough datapoints to enable at least a preliminary orbital solution to be presented.

However for objects that have meaningful motions which have not already been noted means that fresh candidates unknown to the community are likely to be very visually challenging even on professional level equipment, with even imaging technologies being taxed. Nevertheless the fact that all the candidates had already been detected sufficient to have been included in either the WDS or its Supplement shows that it is possible to so detect these objects and measure them astrometrically.

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**Table 1: Double star astrometric solutions as taken or derived from GAIA DR2. RA and DEC are Right Ascension and Declination to Epoch 2015.5,  $G_1$ ,  $G_2$  are GAIA DR2 magnitudes, dist pc is the distance in parsecs derived by simply taking the average of both objects' parallax and inverting it, Position Angle in degrees and Separation in both arcseconds and Astronomical Units are all derived values.**

NAME	RA J2000 ( $^{\circ}$ )	Dec J2000 ( $^{\circ}$ )	RA2 ( $^{\circ}$ )	Dec2 ( $^{\circ}$ )	$G_1$	$G_2$	dist (pc)	PA ( $^{\circ}$ )	$\rho$ (")	Sep (AU)
HJ 3473	28.99413	-51.60761	28.99360	-51.60823	3.4	9.7	17.4	27.6	2.56	45
BRT 357	33.11909	-8.07150	33.11809	-8.07165	11.2	13.7	16.7	261.4	3.61	60
LDS3404	39.19713	+32.07192	39.19771	+32.07223	12.3	12.6	19.5	57.8	2.09	41
BEU 5	61.83621	-24.48988	61.83657	-24.48991	11.6	12.1	18.5	93.5	1.18	22
NSN 207	62.23165	-31.48271	62.23126	-31.48272	13.0	16.0	18.0	268.3	1.23	22
CHR 15	63.28937	+50.52725	63.28993	+50.52754	12.7	13.3	19.9	50.8	1.65	33
JNN 28	71.71513	-11.28015	71.71472	-11.28004	11.4	12.2	18.9	285.3	1.50	28
HEN 4	97.6929	+76.71707	97.69447	-76.71697	13.2	13.4	8.9	74.2	1.32	12
RST 203AB	99.29783	-50.03823	99.29774	-50.03887	9.0	11.2	15.1	185.2	2.31	35
LDS6200	100.95809	+51.13510	100.95734	+51.13508	11.5	12.5	18.9	267.6	1.70	32
HEN 2	104.49087	+62.31979	104.49016	+62.31964	12.2	13.6	11.5	245.5	1.30	15
WDSS 0749509 -031719	117.46148	-3.28894	117.46094	-3.28898	11.6	11.9	17.0	266.8	1.94	33
JSP 208BC	119.48320	-60.29903	119.48193	-60.29876	9.2	11.6	16.2	293.2	2.47	40
LDS3836	134.55930	+19.76297	134.55882	+19.76258	12.0	12.5	5.1	228.6	2.12	11
KUI 55	167.82745	+43.41542	167.82880	+43.41555	10.5	10.6	16.7	262.4	3.56	60
GKI 4	220.58672	+66.05562	220.58830	+66.05557	9.9	15.3	10.9	94.5	2.32	25
HDS2118	225.23291	+45.42768	225.23310	+45.42715	8.5	11.6	11.7	165.9	1.97	23
SKF 104	263.80722	-48.67884	263.80594	-48.67787	9.3	11.6	9.7	318.9	4.63	45
KPP3056	272.81490	-78.98837	272.81636	-78.98864	11.2	12.7	11.7	134.1	1.40	16
JOD 15	275.86768	+28.16696	275.86771	+28.16662	11.4	13.4	14.8	174.1	1.23	18
TSN 119CD	282.17342	-46.78515	282.17385	-46.78458	11.2	11.3	17.6	27.9	2.32	41
COO 228	284.37739	-55.99380	284.37732	-55.99306	8.6	9.0	12.3	357.0	2.67	33
NSN 488	297.90130	-35.17665	297.90177	+35.17703	12.2	12.4	11.3	134.7	1.95	22
SKF 245AC	324.50394	+27.72346	324.50424	+27.72435	9.1	12.5	13.1	16.6	3.34	44
KPP2693	329.08118	-10.33914	329.08128	-10.33950	13.3	14.6	19.7	164.7	1.34	26
BRG33	340.08096	-49.51717	340.08206	-49.51638	13.2	13.4	11.9	42.1	3.83	46

**Table 2: Astrometric parameters from GAIA DR2. Parallax (Plx) is in milliarcseconds per year, PMRA and PMDEC are the Proper Motion in Right Ascension and Declination respectively whilst delPMRA and delPMDEC are their differences all in milliarcseconds and distance in parsecs is derived from average parallax.**

NAME	$\pi_1$ (mas)	$\pi_2$ (mas)	$\mu_{\alpha_1}$ mas/yr	$\mu_{\alpha_2}$ mas/yr	$\mu_{\delta_1}$ ma/yr	$\mu_{\delta_2}$ mas/yr	$\Delta\mu_{\alpha}$ mas/yr	$\Delta\mu_{\delta}$ mas/yr	dist pc
HJ 3473	57	57	+682	+686	+295	+332	3	36	17.4
BRT 357	60	60	-605	-609	-489	-448	4	41	16.7
LDS3404	51	51	-331	-325	-60	-92	6	32	19.5
BEU 5	54	54	+186	+219	-643	-669	33	26	18.5
NSN 207	55	56	-2	-19	-251	-217	18	34	18.0
CHR 15	50	50	-396	-394	-195	-176	1	19	19.9
JNN 28	53	53	-142	-141	-58	-43	1	15	18.9
HEN 4	112	113	-37	-13	+524	+448	24	76	8.9
RST 203AB	66	66	+158	+190	+5	+3	32	2	15.1
LDS6200	53	53	+86	+105	-870	-911	19	41	18.9
HEN 2	87	87	+300	+320	-536	-476	20	60	11.5
WDSS 0749509	59	59	-174	-140	-65	-38	34	28	17.0
031719									
JSP 208BC	62	62	+502	+536	+122	+125	34	3	16.2
LDS3836	195	195	-766	-939	-99	-36	173	63	5.1
KUI 55	60	60	-624	-638	-443	-453	15	10	16.7
GKI 4	91	92	-299	-338	-39	25	38	64	10.9
HDS2118	85	85	+225	+258	+329	+315	33	14	11.7
SKF 104	103	104	+74	-9	+470	+503	84	32	9.7
KPP3056	86	85	+60	+98	+304	+275	37	29	11.7
JOD 15	68	68	-77	-95	-184	-195	18	11	14.8
TSN 119CD	57	57	+216	+180	+136	+124	36	12	17.6
COO 228	81	81	-8	+35	-442	-451	44	9	12.3
NSN 488	88	88	+382	+351	+98	+45	31	52	11.3
SKF 245AC	76	77	+481	+453	-63	-80	28	17	13.1
KPP2693	51	51	-307	-284	-272	-259	23	13	19.7
BRG 33	84	84	+468	+459	+172	+145	9	27	11.9

# DOUBLE STAR MEASUREMENTS PERFORMED WITH A MEADE 12 MM ASTROMETRIC EYEPIECE DURING 2019

Neil Webster, St Marys Platt, Kent TN15 8NF

E-mail: [nweb124@gmail.com](mailto:nweb124@gmail.com)

## Introduction

The following measurements (Table 1) were made throughout 2019 using a Meade 12 mm astrometric illuminated reticle eyepiece plus 2.5x powermate attached to an Altair Astro 115 mm triplet refractor (f.l. 805 mm, f7). The total magnification was 167.5x with a field of view of  $0^{\circ}.3$ .

All final separation values were calculated from a calibration determined by the timing/transit method (Simple Techniques of Measurement: E.T.H. Teague, Chapter 12 in *Observing and Measuring Visual Double Stars* ed. Argyle, pub. Springer). This was performed at the start of the year and gave a final value of  $12''.53 \pm 0''.01$  per division on the reticle measurement scale.

Position Angle measurements were made using the now tried and tested method previously outlined in DSSC 25 which involves using the directional west arrow on the synscan handset to electronically steer the primary to the outer edge of the protractor scale. This enables repeated measurements to be made with ease without having to disable the tracking of the mount.

As before, 10 separation and 10 position angle measurements ( $N = 20$ ) were performed on the same evening for each pair and the final results and associated uncertainties later calculated.

Extensive use was again made of the Astroplanner software. Separations throughout this year were all limited to a range from 15 to 70 arc-seconds. As in previous years magnitudes ranged from 0.5 to 8.5.

As most of these systems are comparatively wide the orbits are generally very long (678 years+) and, as a result, very few have attempted orbit calculations. Residuals (from the online version of 6th USNO Catalogue of Orbits of Visual Binary Stars) have, however, been given for the few systems calculated but none have a better than grade 4 certainty (Table 2).

Values from the Fourth Catalogue of Interferometric Measurements have provided a more extensive set of residuals but most of these are from 1991 which is 28 years before the author's measurements. Although many of the systems have not changed in this time-interval some have and, in certain cases, this may possibly explain the larger residuals calculated (Table 3).

For the systems with larger residuals, alternative values have been calculated using the latest WDSC measurements (mostly 2018) for comparison. As can be seen many of the residuals calculated from these WDSC figures are smaller. This would seem to imply measurable PA and separation changes to these systems over relatively short timescales (27 years maximum) which is surprising when the possible orbital periods are potentially thousands of years (Table 4).

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<http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/orb6/sixth-catalog-of-orbits-of-visual-binary-stars>

Fourth Catalogue of Interferometric Measurements of Binary Stars:

<http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/int4>

Astroplanner: <http://www.astroplanner.net/>

**Table 1: Measurements**

Pair	Comp	RA	Dec	Va	Vb	PA ( $^{\circ}$ )	$\pm$	Sep ( $''$ )	$\pm$	Epoch (2019+)	N	Obs
S 457	AB	04531	-0117	7.93	8.07	354.0	0.1	40.8	0.2	.112	20	WST
STF 612	AB	04543	+0722	8.33	8.41	199.4	0.1	15.3	0.2	.112	20	WST
SHJ 49	AB	04590	+1433	6.06	7.43	306.0	0.1	39.0	0.1	.112	20	WST
STF 627	AB	05006	+0337	6.59	6.95	260.0	0.1	21.9	0.1	.112	20	WST
BVD 50	AB	05092	+1130	8.35	8.49	104.0	0.1	31.1	0.3	.112	20	WST
STF 696	AB	05228	+0333	4.95	6.76	28.5	0.1	32.0	0.2	.112	20	WST
STF 697	AB	05235	+1602	7.27	8.10	287.0	0.1	25.4	0.2	.123	20	WST
STF 734	AC	05331	-0143	6.67	8.35	243.0	0.1	29.2	0.2	.123	20	WST
STF 747	AB	05350	-0600	4.70	5.51	224.3	0.1	36.3	0.1	.123	20	WST
STF 855	AB	06090	+0230	5.68	6.68	114.6	0.1	29.1	0.2	.295	20	WST
STF 1026	AB	07229	+5517	5.76	6.71	316.9	0.1	13.8	0.1	.295	20	WST
STF 1315	AB	09128	+6141	7.33	7.65	27.8	0.1	25.1	0.1	.295	20	WST
STF 1321	AB	09144	+5241	7.79	7.88	98.2	0.1	16.7	0.2	.295	20	WST
STF 1369	AB	09354	+3958	6.98	7.98	149.8	0.1	25.1	0.1	.295	20	WST
STF 1415	AB	10178	+7104	6.65	7.27	168.0	0.1	16.5	0.2	.295	20	WST
STF 1603	AB	12081	+5528	7.82	8.26	84.0	0.1	22.6	0.1	.295	20	WST
STF 2245	AB	17419	+7209	4.60	5.59	14.0	0.1	29.6	0.2	.295	20	WST
STTA 163	AB	17563	+6237	7.77	7.59	52.6	0.1	54.1	0.2	.298	20	WST
STF 2270	AB	17592	+6409	7.31	7.63	282.3	0.1	22.6	0.1	.298	20	WST
STF 2300	AB	18002	+8000	5.70	6.00	232.0	0.1	18.7	0.1	.358	20	WST
STF 2278	AB	18029	+5626	7.78	8.14	28.9	0.2	36.3	0.1	.358	20	WST
STF 2420	AB	18512	+5923	4.77	8.26	316.0	0.2	37.6	0.1	.358	20	WST
SHJ 286	AB	19050	-0402	5.52	6.98	211.3	0.1	39.6	0.2	.701	20	WST
STF 2497	AB	19200	+0535	7.73	8.49	356.0	0.1	29.3	0.2	.701	20	WST
STFA 43	AB	19307	+2758	3.19	4.68	54.3	0.1	35.2	0.3	.703	20	WST
STF 2540	AD	19312	+6319	8.34	8.03	268.5	0.1	55.8	0.2	.358	20	WST
ARN 82	AB	19364	+3541	8.10	8.43	33.0	0.1	43.9	0.1	.717	20	WST
STFA 46	AB	19418	+5032	6.00	6.23	131.7	0.2	39.5	0.2	.717	20	WST
H 5 137	AB	19459	+3501	6.22	8.18	25.0	0.1	38.8	0.1	.717	20	WST
STFA 48	AB	19534	+2020	7.14	7.34	147.0	0.1	41.7	0.2	.703	20	WST
STF 2594	AB	19546	-0814	5.65	6.35	171.0	0.1	36.3	0.1	.701	20	WST
SHJ 314	AF	20060	+3547	6.78	7.30	28.0	0.1	36.3	0.1	.717	20	WST
WEB 12	AB	20078	+1950	8.36	8.37	77.0	0.1	40.1	0.1	.703	20	WST
S 738	AB	20106	+3338	7.76	8.43	106.0	0.1	42.6	0.1	.717	20	WST
S 735	AB	20113	-0008	7.16	7.98	211.0	0.1	56.4	0.1	.701	20	WST
S 740	AB	20142	+0635	7.77	8.06	192.2	0.1	43.9	0.1	.701	20	WST
STF 2664	AB	20196	+1300	8.07	8.34	321.0	0.1	27.1	0.2	.703	20	WST
STF 2687	AB	20264	+5638	6.37	8.31	117.5	0.1	25.1	0.1	.722	20	WST
S 749	AB	20275	-0206	6.76	7.51	188.9	0.1	60.1	0.3	.703	20	WST
STF 2691	AB	20297	+3808	8.14	8.45	32.0	0.1	16.3	0.1	.722	20	WST
STF 2690	AB-C	20312	+1116	7.12	7.39	256.0	0.1	18.5	0.1	.703	20	WST
STF 2703	AB	20368	+1444	8.35	8.42	290.0	0.1	25.1	0.1	.703	20	WST
STF 2758	AB	21069	+3845	5.20	6.05	153.8	0.1	31.7	0.2	.722	20	WST
STF 2769	AB	21105	+2227	6.65	7.42	299.0	0.1	18.8	0.1	.703	20	WST
STT 447	AE	21395	+4144	7.67	8.48	42.8	0.2	29.1	0.2	.722	20	WST
S 800	AB	21538	+6237	7.07	7.91	145.0	0.1	62.7	0.1	.358	20	WST

ARY 45	AB	22083	+6959	7.86	8.11	206.7	0.1	66.7	0.2	.358	20	WST
STF 2872	AB-C	22086	+5917	7.14	7.98	315.0	0.1	22.8	0.2	.358	20	WST

**Table 2: Residuals from Known Orbits (6th Catalogue)**

Pair	ADS (HIP)	Res. PA ( $^{\circ}$ )	Res. Sep ( $''$ )	Orbit	Period (years)	Date	Grade
STF 1321 AB	7251	-1.0	-0.1	Chang	975	1972	4
STF 2241 AB	10759	-2.8	0.0	Kiselev	10000	2009	5
STF 2308 AB	11061	+0.8	-0.1	Kiselev	18000	1996	5
STFA 46 AB	12815	-1.3	-0.3	Marcy	135127	1999	4
STF 2758	14638	+1.3	-0.1	Pulkovo	678	2006	4

(All Residuals: Observed - latest Catalogue measurement)

**Table 3: Residuals from Fourth Catalogue of Interferometric Measurements**

Pair	Comp	ADS(BDS)	HIP (TYC)	Epoch (Catalogue)	Residuals PA ( $^{\circ}$ ) Sep( $''$ )	
S 457	AB	(2400)	2271	1991.57	-0.7	-0.2
STF 612	AB	3514	(9165 00808)	1991.43	-0.4	-0.9
SHJ 49	AB	3579	23161	1991.46	+0.6	-0.3
STF 627	AB	3597	2328	2004.11	-0.1	+0.9
BVD 50	AB		23977	1991.665	+0.2	0.0
STF 696	AB	3962	25142	2002.901	-0.4	+0.4
STF 697	AB	3969	25207	1991.54	+1.3	-0.6
STF 734	AC	4150	26020	2002.901	-0.3	-0.1
STF 747	AB	4182	26199	1991.64	+0.6	+0.1
STF 855	AB	4749	29151	2002.977	+0.9	+0.4
STF 1062	AB	6012	35785	2002.996	+1.2	-0.9
STF 1315	AB	7226	45206	1991.59	+0.9	+0.3
STF 1321	AB	7251	45343	1991.81	+7.7	-0.8
STF 1369	AB	7438	47053	2003.311	-0.1	+0.2
STF 1415	AB	7705	50433	2003.251	+0.7	0.0
STF 1603	AB	8434	59176	1991.63	+1.6	+0.3
STF 2241	AB	10759	86614	1991.70	-1.5	-0.6
STTA 163	AB	(8295)	87815	1991.64	+2.6	-0.6
STF 2273	AB	10985	88071	1991.77	-0.9	+1.3
STF 2308	AB	11061	88136	2012.772	+2.0	-0.8
STF 2278	AB	11035	88381	1991.60	+0.9	+0.1
STF 2420	AB	11779	92512	2003.628	-3.4	+1.1
SHJ 286	AB	12007	93717	2003.418	+1.7	+0.4
STF 2497	AB	(9208)	95017	1991.79	-0.6	-0.7
STFA 43	AB	12540	95947	2003.418	+0.8	+0.8
STF 2549	AD	12586	96002	1991.76	-2.4	+1.2
ARN 82	AB	(BD+35 3705)	(2667 00321)	1991.61	-1.4	+0.6
STFA 46	AB	2815	96895	2003.628	-2.0	+0.4

H 5 137	AB	12900	97442	2003.628	0.0	+0.6
STFA 48	AB	(9705)	97876	1991.69	+0.2	-0.4
STF 259	AB	13087	97966	2003.418	+0.4	+0.6
SHJ 314	AF	13374	99002	2003.695	+0.3	+1.6
WEB 12	AB	(1625 00995)		1991.703	+0.2	-0.9
S 738	AB	13463	99409	1991.61	-0.6	+0.7
S 735	AB	(9961)	99476	1991.49	+1.7	+1.0
S 740	AB	(1001)	9972	1991.54	+0.4	+0.6
STF 2664	AB	(BD+12 4291)	100226	1991.49	-0.5	-0.5
STF 2687	AB	13870	100868	2003.629	+0.2	-0.7
S 749	AB	13868	100896	1991.46	+0.4	+0.2
STF 2691	AB	13919	101109	1991.68	+0.6	-0.9
STF 2690	A-BC	13946	101233	1991.52	+1.2	+1.3
STF 2703	AB	(10161)	101700	1991.64	-0.1	-0.2
STF 275	AB	14636	104214	1991.69	+5.8	+1.6
STF 276	AB	14710	104539	2003.784	-0.2	+0.9
STT 447	AE	15186	(3191 00346)	1991.67	-1.8	+0.2
S 800	AB	15434	108073	1991.61	-0.1	+0.2
ARY 45	AB	(1225)	109275	1991.67	+0.1	+0.1
STF 2872	A-BC	15670	(3981 1587)	1991.68	-0.9	+1.6

**Table 4: Alternative Residuals: WDSC**

Pair	Comp	Epoch WDSC	Epoch(4th Cat)	Residual PA ( $^{\circ}$ )		Residual Sep ( $''$ )	
				(WDSC)	(4th Cat.)	(WDSC)	(4th Cat.)
STF 1321	AB	2018	(1991.81)	0.0	(-0.8)	-0.3	(+7.7)
STF 1603	AB	2018	(1991.63)	-0.5	(+0.3)	+0.1	(+1.6)
STTA 163	AB	2017	(1991.64)	-0.4	(-0.6)	-0.2	(+2.6)
STF 2308	AB	2018	(2012.7725)	-0.2	(-0.8)	0.0	(+2.0)
STF 2420	AB	2017	(2003.628)	-1.0	(+1.1)	+0.1	(-3.4)
STF 2549	AD	2018	(1991.76)	-2.0	(+1.2)	0.0	(-2.4)
STFA 46	AB	2018	(2003.628)	-1.9	(+0.4)	-0.4	(-2.0)
S 735	AB	2018	(1991.61)	0.0	(+1.0)	+0.4	(+1.7)
STF 2690	A-BC	2018	(1991.52)	+0.4	(+1.3)	+0.8	(+1.2)
STF 2758	AB	2018	(1991.69)	+0.7	(+1.6)	-0.3	(+5.8)
STT 447	AE	2017	(1991.67)	-1.5	(+0.2)	+0.2	(-1.8)
STF 2872	A-BC	2018	(1991.68)	-1.1	(+1.6)	+1.1	(-0.9)

# ON THE LOWELL PROPER MOTION SURVEY DOUBLE STARS LISTED IN SIMBAD BUT UNNOTED IN WDS

John Greaves

E-mail: [cpmjg@tutanota.com](mailto:cpmjg@tutanota.com)

## Abstract

High proper motion stars from the Lowell Proper Motion Survey noted double in SIMBAD but not in the WDS were checked against GAIA DR2 and their 2015.5 epoch separations and position angles for thirty six objects derived

## Methodology

During an earlier unrelated task it was noted that some stars from the Lowell Proper Motion Survey (Giclas<sup>1</sup>) denoted as double stars (\*\* in SIMBAD *e.g.* Wenger *et al.*<sup>2</sup>) were not actually included in the Washington Double Star Catalogue (henceforth WDS, *e.g.* Mason *et al.*<sup>3</sup>), despite 194 other objects from the Lowell survey being included.

Accordingly all objects denoted as double stars were derived from SIMBAD using their TAP interface which resulted in a total of over 630,000 such stars. As SIMBAD also includes the Washington Double Star Catalogue those stars had to be removed. Such an exercise was conducted by using the CDS X-Match service to cross link the results against the WDS and removing the resultant list from the main list via a relational database. Other objects were then manually removed, especially where SIMBAD had included the double star notation due to them being extrinsic variables, which meant eclipsing binaries of one form or another. This resulted in a master list of approximately 4,500 double stars remaining.

A casual glance revealed that a small but significant proportion of these still carried discoverer codes evidently of the kind used in the WDS. This is because these objects had originally appeared in data included within professional publications and/or legacy/classic lists which as a matter of course have been imported into SIMBAD over the years irrespective of their inclusion in the WDS. These were retained in the master list for potential future investigation, however examination of a random sample suggested that most are likely still in the WDS in some form or other, either having been missed by the CDS X-Match service due to poor original positional astronomy or included in the Washington Double Star Supplement (henceforth WDSS, Mason & Hartkopf, 2017 onwards<sup>4</sup>).

From this master list the final just over 50 objects from the Lowell Proper Motion Survey were selected and double checked for not being in either both the current WDS or WDSS (both being mid-September 2019 online versions). The former because such high proper motion objects as many of these stars are can still be missed by even relatively wide area crossmatch searches, the latter as it contains objects from large surveys of the kind not likely to be imported into SIMBAD due to their sheer scale. Several stars were removed due to their inclusion in the WDSS despite the fact that technically the Lowell survey has priority over the later survey discoveries by at least half a century in most cases. This is because SIMBAD carries the reference to the Lowell survey as the source of the data for the stars but does not clarify where it obtained the fact that these objects were members of a pair. Examination of the source paper for that survey revealed that it did not include these facts in the notes to the tables. The author could not determine why the class of double star had been added to these objects via SIMBAD. Equally, there is no worthwhile positional information from SIMBAD to allow for an accurate determination of Position Angle and Separation of each pair, in fact given the wide field nature of such surveys the eventual results (below) suggest that these pairs may not have even been separated on the original plates.

These objects were manually cross matched against a local subset copy of GAIA Data Release 2 (DR2) (*e.g.* Brown *et al.*<sup>5</sup>) from which their duplicity was examined. Both objects in the pair had to have data listed for proper motions and parallax to allow intercomparison given that the large proper motions of these objects is likely to take them close to faint field stars, as many of the secondary stars are quite to very faint. If the secondary had no such data despite an adjacent to very adjacent object being available from the GAIA data it was not included. In some cases this was the situation for the primary instead, although in one case the appropriate proper motions were known for the somewhat brighter primary despite not being included in GAIA and matched the GAIA details of the very adjacent secondary sufficient for it to be included in the final list.

The GAIA broadband magnitudes and their relative positions for epoch 2015.5 were derived from GAIA DR2, the identifiers and Epoch and Equinox J2000 coordinates were retained from the SIMBAD data and finally both SIMBAD and *LAMOST* data release 5 (DR5) was also examined to see if any stars had spectral classification.

## Results

A total of 36 objects were derived. The objects from the original list that were not included were shared evenly amongst those that had subsequently been noted in more modern large surveys and thus included in the WDSS and those with insufficient data for both pairs with which to be able to properly compare them.

The results revealed that the majority of the objects, whether in the final 36 or the full Lowell survey shortlist, had separations rarely greater than 2 arcseconds with none separated by more than 3 arcseconds and the majority separated by less than 2 arcseconds, with in some cases separations of less than 1 arcsecond. Pairs had common high proper motions according to GAIA, and a handful were as close as 40 to 50 parsecs based on a naïve interpretation of their parallaxes. Further, even given the small angular separations and relative proximity to the Solar System and further assuming that their current angular separations were reasonably representative of any orbit’s semimajor axis it is unlikely for any to have had an orbital period of less than a thousand years, but this does not preclude the chance of observers noting any relative motion over the years.

Most of the pairs had red dwarf primaries, with some exceptions, most notable of which is G 158-39 which is a white dwarf and has a similar brightness companion. However no independent colour information for the secondary is available, whether from GAIA or elsewhere, to suggest its type. Possibly a simple visual inspection by an observer may clarify that point, however the pair are quite faint and a mere 1.25 arcseconds apart at this time. As can often be the case with these very large equal motion transversely very proximate pairs the pair have somewhat disparate parallaxes in GAIA, but taking a pessimistic distance to the pair of 100 parsecs would give their current transverse angular separation as around 125 Astronomical Units, or just over 4 times the Sun – Neptune distance.

The results are presented below in Table 1. Note that for close brightness pairs the more red-biased GAIA magnitude may not give the same component as the brightest of the pair as Johnson *V* band or a visual inspection would.

**Table 1: The identifier from the original catalogue and J2000 coordinates as taken from SIMBAD, the position angle ( $\theta$ ) and separation ( $\rho$ ) derived and the magnitudes taken from GAIA DR2 and spectra mostly taken from *LAMOST* DR5.**

Identifier	RA J2000 ( $^{\circ}$ )	Dec J2000 ( $^{\circ}$ )	$\theta$ ( $^{\circ}$ )	$\rho$ ( $''$ )	Gmag A	Gmag B	Spec A
G 3–44	1.84771	+10.84897	351.6	0.73	13.50	14.77	–
G 13–51	2.69413	+36.77842	188.2	1.42	14.01	14.03	–
G 15–39	3.13408	–05.55891	108.5	1.25	16.73	16.98	DA4.8
G 17–27	13.27738	+48.49387	20.3	1.24	12.22	14.01	–
G 26–76	15.32325	–26.59242	17.4	0.75	14.10	15.37	–
G 7–31	15.88101	+05.07854	6.9	1.49	11.72	13.62	–
G 7–13	30.07446	+04.21708	217.9	1.87	13.78	15.53	–
G 15–41	32.18604	–00.33383	111.6	1.66	13.20	14.48	–
G 24–51	32.52013	+65.30658	288.5	0.79	13.58	14.59	–
G 3–39	73.30238	+38.50900	112.0	1.73	14.00	16.65	–
G 9–32	79.18679	+08.86483	298.7	1.50	15.62	18.20	–
G 10–16	100.58379	+40.30797	10.1	1.57	14.10	15.93	M0
G 25–18	101.70204	+64.14081	69.1	0.91	12.24	12.29	–
G 19–49	102.59633	+53.98978	77.8	1.71	12.74	15.30	F9
G 11–29	105.32192	+13.80239	90.0	1.33	13.44	14.13	M2
G 11–24	134.74300	–03.14580	87.2	2.23	12.14	14.17	–
G 4–40	141.08188	+24.64837	233.4	1.63	14.45	14.53	M3
G 23–50	149.38079	+64.40078	358.1	2.34	15.55	17.01	–
G 11–63	157.30078	+37.30306	307.0	2.69	12.02	14.76	M0
G 14–40	169.66038	+38.97233	223.5	1.79	15.16	17.75	–
G 16–76	170.05152	–00.78179	128.7	1.61	13.46	17.12	G7
G 23–79	174.93704	+71.00497	238.4	1.65	12.95	15.60	–
G 12–30	186.23283	+42.22547	186.9	1.78	13.59	15.17	–
G 14-13	193.89650	–02.91325	344.6	2.17	12.43	13.67	K7
G 6–24	211.01238	+07.59536	178.1	1.08	12.03	13.70	K7
G 18–16	239.46847	+43.89565	158.7	0.93	12.51	12.55	M2
G 18–15	254.18863	+38.63686	320.1	1.36	13.34	15.96	M2
G 17–40	261.97742	+22.14206	250.9	2.86	14.45	14.68	–
G 25–24	268.42838	+65.47047	302.9	1.19	14.70	14.90	–
G 25–34	275.26750	+71.61308	317.8	1.94	13.71	15.37	–
G 20–49	284.61229	+41.79267	56.9	1.19	12.11	12.63	–
G 12–68	302.76913	+36.31025	293.1	1.01	12.88	15.21	–
G 14–19	317.27511	+21.76655	168.2	1.14	12.93	13.21	–
G 23–46	330.16058	+53.61575	35.8	1.24	14.73	15.71	–
G 15–6	345.69538	–10.43661	209.4	1.49	13.99	15.31	–
G 12–79	353.63703	+24.52013	113.5	1.89	13.98	14.76	–

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# A MISCELLANY OF SIMBAD DOUBLE STARS NOT LISTED IN THE WDS

John Greaves

E-mail: [cpmjg@tutanota.com](mailto:cpmjg@tutanota.com)

## Abstract

Stars noted as being double in SIMBAD but not in the WDS were checked against GAIA DR2 and the 2015.5 epoch position angles and separations for twenty three objects derived.

## Methodology

As stated earlier in this circular it was noted that some stars from the Lowell Proper Motion Survey<sup>1</sup> denoted as double stars (\*\*) in SIMBAD<sup>2</sup> were not actually included in the Washington Double Star Catalogue (henceforth WDS<sup>3</sup>). Accordingly all objects denoted as double stars were derived from SIMBAD using their TAP interface which resulted in a total of over 630,000 such stars. As SIMBAD also includes the Washington Double Star Catalogue those stars had to be removed. Such an exercise was conducted by using the CDS X-Match service to cross link the results against the WDS and removing the resultant list from the main list via a relational database. Other objects were then manually removed, especially where SIMBAD had included the double star notation due to them being categorised as double stars as happenstance to their nature, for example eclipsing binaries and other classes of extrinsic variables. This resulted in a master list of approximately 4,500 double stars remaining.

These objects had originally appeared in data included within professional publications which as a matter of course have been imported into SIMBAD over the years irrespective of their inclusion in the WDS as double stars. Sampling representative objects from the final shortlist for each SIMBAD name category showed that many were indeed likely double stars but of the cataclysmic variable, young stellar object (usually from infrared surveys), astrometric, spectroscopic, interferometric and many other kinds. The catalogues that remained after this filtering primarily turned out to be proper motion surveys of one form or another or catalogues of objects likely containing some high proper motion objects as a consequence of the survey, for instance white or red dwarf candidates. Some surveys, relatively small in size and of some vintage, presented only one to at most a few objects, whilst others were from larger lists with these larger lists often already having representative objects in the WDS.

The smaller small numbers of candidate cases were examined individually and were manually cross-matched against a local subset copy of GAIA Data Release 2 (DR2)<sup>4</sup> from which their duplicity was examined. Both objects in the pair had to have data listed for proper motions and parallax to allow intercomparison given that the large proper motions of these objects is likely to take them close to faint field stars. If the secondary had no such data despite an adjacent to very adjacent object being available from the GAIA data the pair was not included. The GAIA broadband magnitudes and their relative positions for epoch 2015.5 were derived from GAIA DR2, the identifiers and Epoch and Equinox J2000 coordinates were retained from the SIMBAD data and finally both SIMBAD and LAMOST data release 5 examined to see if any stars had a spectral classification. These objects were also individually double checked against the WDS in case they were still present there in some form or another, either having been missed by the CDS X-Match service due to poor original positional astronomy or were alternatively included in the Washington Double Star Supplement (henceforth WDSS<sup>5</sup>) instead.

The final larger candidate list was somewhat sizeable, consisting of 730 pairs from only a handful of surveys that already have, often many, representative objects in the WDS. They are left to be dealt with in a potential future paper.

## Results

Twenty three of the objects are below in Table 1. Note that for similar brightness pairs the more red-biased GAIA magnitude may not give the same component as the brightest of the pair as Johnson  $V$  band or a visual inspection would.

It is unclear how these earlier surveys were aware of the double nature of these objects as often the high resolution of the GAIA DR2 data is the only thing splitting the pair, with many being very small separation pairs as well as with very faint companion stars, this being especially the case as it contains a sizeable fraction of known white dwarfs which are not only faint but sometimes the brighter primary! Only a handful are probably true visual doubles in a practical observational terms as some are likely impossible with even the best observing equipment and a good site, however for some their close distance and small separation give the potential for relative motion over comparatively short timescales if there is any orbital motion. Nevertheless none of the GAIA DR2 proper motion data for each star in a pair were sufficiently different enough to meaningfully exceed errors and thus reveal a hint of any such relative motion, albeit GAIA DR2 having a relatively short temporal baseline.

Notes on particular individual objects of interest follow, the data are in Table 1 below.

MCT 0134+4042	Thought to be a PG 1159 star (a star forming a proto-Planetary Nebula, that is, an old star that is evolving into a white dwarf central star and planetary nebula, not a protoplanetary nebula, which is a protoplanet-forming nebula surrounding a young star).
LSR J0254+3419	A very high motion pair moving south east at nearly an arcsecond per year.
Ross 698	This close pair turned out to be indirectly noted in WDS as they constitute the secondary star of LDS 414. That is, Ross 698 is LDS 414 Ba,Bb, with LDS 414 being a common proper motion triple rather than just an AB pair as listed in WDS. At the roughly 100 parsec distance this gives the secondary pair a projected separation of 90 to 100 Astronomical Units whilst the projected separation of LDS 414 A from the pair approaches 8000 Astronomical Units. RAVE DR5 <sup>6</sup> also gives comparable heliocentric radial velocities for the A star and the combined Ba,Bb pair of around 7 km s <sup>-1</sup> and 6 km s <sup>-1</sup> respectively.
NLTT 33054	Simply taking the average parallax of the pair from GAIA DR2 data and reciprocalising it gives a distance of 47 parsecs and at 1".27 separation a current projected separation of roughly 60 Astronomical Units, or twice the mean Sun – Neptune distance.
Wolf 925 ABC	Examination of the field revealed a third, much fainter, comes with good agreement in both proper motion and parallax according to GAIA DR2 data. Simply reciprocalising the mean GAIA DR2 parallax for these three stars gives a distance of approximately 56 parsecs to this common proper motion trinary. This gives projected separations of around 50 Astronomical Units and 710 Astronomical Units for the AB and AC pairs respectively, rounding to the nearest 10 Astronomical Units. SIMBAD notes the primary pair are of spectral class M4 with the $J - K$ colours in rough agreement with that such that the magnitude difference with the tertiary comes would suggest it was a brown dwarf. However if the primary of the AB pair was instead a mid-to-late K star then the six magnitude difference would also be appropriate for the tertiary being a late M dwarf or subdwarf.
Wolf 966	With a distance of approximately 53 parsecs from reciprocalised mean parallax the projected separation of this pair would be around 53 Astronomical Units, given the angular separation.
Wolf 1154	The nearest system in the list with a distance of 31 parsecs from the reciprocalised mean of the GAIA DR2 parallaxes for the stars. This gives a current projected separation of approximately 40 Astronomical Units, roughly the same as the semimajor

axis of Pluto’s orbit. The spectral type denotes emission lines from this red dwarf pair, usually suggestive of chromospheric and coronal activity due to a relatively strong magnetic fields. For red dwarfs this purportedly suggests a younger rather than an older red dwarf as convective stars are supposed to reduce their rotation rate with age due to frictional and/or magnetic drag sufficient for their rotation to eventually become too slow to enable a dynamo generated magnetic field and thus any significant chromospheric activity.

**Table 1: The ID, position and spectrum are from SIMBAD (with some of the latter supplemented by LAMOST DR5), the position angle, separation and magnitudes are derived or taken from GAIA DR2 data**

SIMBAD	RA J2000 (°)	Dec J2000 (°)	$\theta$ (°)	$\rho$ (")	Gmag A	Gmag B	Spec A	Note
Flo 384	14.85642	-74.61142	203.3	1.96	11.07	14.01	F5	
SA 4-368	22.74754	+30.98078	2.5	1.41	14.37	16.32	M0	
MCT 0134-4042	24.20051	-40.45933	357.4	0.61	16.37	16.77	DA1.5	
LSR J0254+3419	43.68441	+34.31707	349.1	1.01	19.40	20.11	-	
HG 7-19	57.35310	+10.71121	123.6	1.10	11.41	12.21	-	
HG 7-170	65.08296	+17.51525	184.7	0.83	12.30	12.93	G7	
LB 216	66.67378	+14.20433	168.3	1.03	17.87	18.94	DA2.6	
US 1158	149.76062	+45.18624	290.9	0.71	18.94	19.72	DA+DB	
GD 137	170.90301	+23.88796	207.9	0.77	16.54	16.78	DA+M	
Ruiz 440-128	177.17088	-29.26073	44.0	0.95	12.81	15.18	-	
Ross 698	189.31929	-17.06311	34.3	0.92	12.45	12.47	-	LDS 414B
CE 262	190.17475	-34.91233	109.2	1.31	15.36	15.68	M3.5	
PB 4428	195.08590	+3.46759	44.9	0.71	17.42	18.61	DA+dM	
NLTT 33054	197.31138	+1.41936	6.5	1.27	13.04	13.95	-	
Ross 1025	209.23067	+25.47519	46.9	1.42	12.30	15.10	G4	
WRAY 15-1160	210.10657	-56.75335	286.6	1.13	12.16	13.95	-	
LTT 5505	212.25167	-77.55239	242.0	1.77	14.29	14.64	-	
PG 1502+351	226.01244	+34.91132	243.3	0.56	16.03	17.47	DA2.7	
[LHJ2007]	242.61015	-22.78473	181.5	1.26	15.69	17.97	M2.5	J161026.46-224705.1
Wolf 925 AB	323.66021	+48.21497	81.0	0.92	13.12	13.49	M4	
Wolf 925 AC	323.66021	+48.21497	36.2	12.63	13.12	19.42	-	
Wolf 966	330.28590	+49.01967	198.2	0.99	11.53	11.54	-	
Wolf 1154	330.30823	+32.38691	235.9	1.28	11.44	12.89	M1.5Ve	

## Acknowledgements

This research has made use of the SIMBAD database and the CDS X-Match Service, both operated at CDS, Strasbourg. The SIMBAD helpdesk is especially thanked for helping correct the ADQL syntax gaffs of the author’s original TAP request. LAMOST is a National Major Scientific Project with funding for the project being provided by the National Development and Reform Commission. LAMOST was built and is operated and managed by the National Astronomical Observatories, Chinese Academy of Sciences.

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# A NEW COMMON PROPER MOTION PAIR IN LEO

Abdul Ahad, Luton, Bedfordshire

E-mail: ahad8307@gmail.com

## Abstract

In this paper, I report a new visual double star in Leo that is not listed in the Washington Double Star Catalogue. Upon analysis of the astrophysical parameters, proper motions and distances of the component stars, it seems that this is probably not a physical pair but originally members of a moving group.

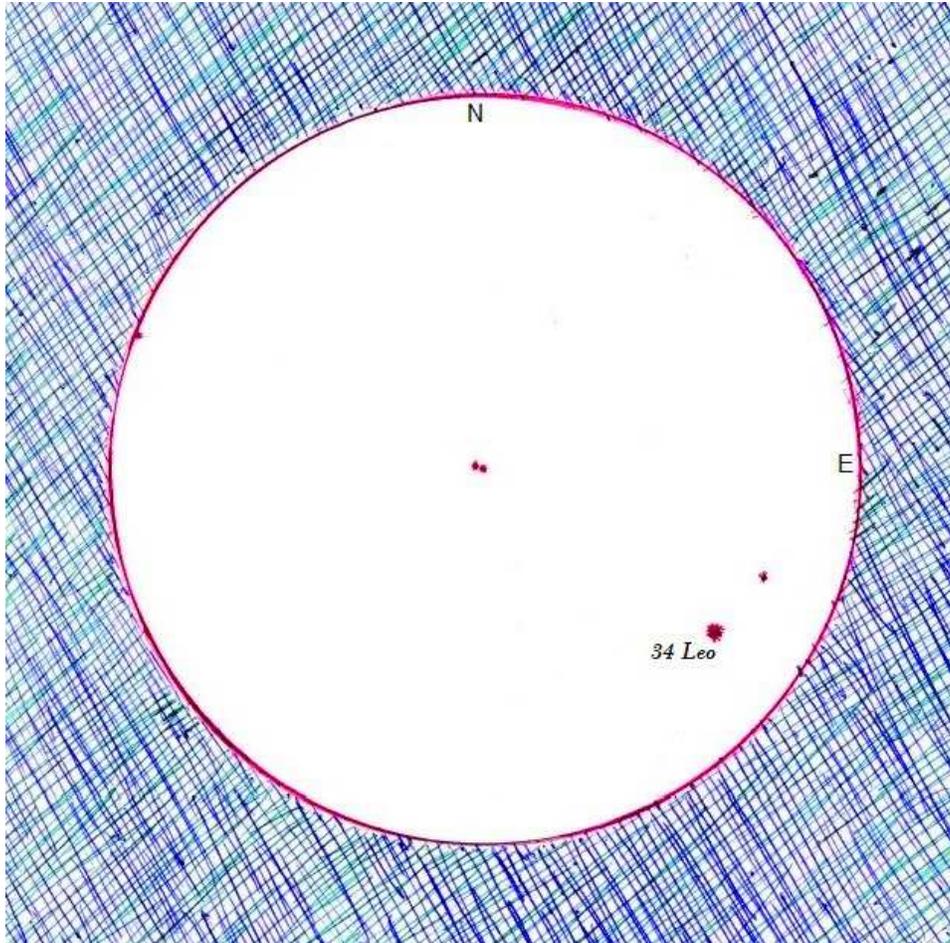


Figure 1: Field drawing made by the author using his 4.75" f/8.33 refractor at a magnification of x100.

## Introduction

Using the search method and selection criteria I had first outlined going back to years prior to the launch of the Gaia astrometry mission, this double star first came to my attention in the autumn of 2015. My method entailed scrutinizing the apparent brightnesses, colours and proper motions of each component star in the pair in order to make deductions as to the likelihood of it being a true binary system as opposed to merely being a line of sight optical double. I later observed and sketched this pair at approximately 05:00 UT on the morning of 2015 October 23. The two stars appeared finely separated in the eyepiece, of virtually identical brightness and situated

approximately 11.7 arc-minutes to the north west of 34 Leonis at J2000 ICRS: 10h 11m 00s.3 +13° 28' 09".2 (Figure 1).

The SIMBAD database<sup>1</sup> provided data for only one component in this pair bearing the Tycho designation TYC 836-1526-1 and of  $V$  magnitude 10.12.

## Measurements and Analysis

At the time of my observations in 2015, a number of catalogues were consulted which showed a broad similarity in proper motions between the two component stars for the pair to qualify as a bona-fide ‘common proper motion’ binary. However, the  $(B - V)$  and  $(J - K)$  colour indices taken together did not provide a satisfactory fit to establish precisely where the two stars were likely to be situated on the H-R diagram, resulting in considerable uncertainties as to their luminosity class and likely distance. I had communicated these difficulties to William Hartkopf at the USNO.

Furthermore there was no clear consistency across independently compiled catalogues, such as UCAC2, NOMAD, PPMXL, UCAC4, the Guide Star Catalogue, etc to determine which component in the pair was in fact the brighter one (i.e. the primary) and which of them was the fainter secondary when measured in the  $V$ -band. The situation was further complicated by the presence of an X-ray source located a mere 12 arc-seconds to the east of the binary in the sky, which meant the SIMBAD database would show data for only one component in the pair plus the X-ray source, 1RXS J101100.6+132820.

Gaia DR2<sup>2</sup> indeed confirms the two stars to be sharing similar proper motions in both RA and Dec, as shown in Table 1:

**Table 1: G-magnitudes and Proper Motion of Components**

	$G$	$\mu_\alpha$ mas yr <sup>-1</sup>	Error mas yr <sup>-1</sup>	$\mu_\delta$ mas yr <sup>-1</sup>	Error mas yr <sup>-1</sup>
Primary	9.91	-7.06	± 0.43	+30.77	± 0.48
Companion	10.01	-12.49	± 0.08	+30.46	± 0.09

(Note: To establish a basis for measurements, I have taken the rightmost star to be the brighter primary (A-component) in the pair and the leftmost to be the fainter companion.)

By differencing ICRS coordinates I obtain P.A. 118°.2 and Sep 14".65 (2020.0)

Gaia DR2 provides parallax data for both components as  $16.4255 \pm 0.2562$  and  $14.2737 \pm 0.0484$  mas yr<sup>-1</sup>, indicating distances of  $198.6 \pm 3.0$  and  $228.5 \pm 0.8$  light-years, respectively. Radial velocities are also found to be broadly similar and stated as  $-5.66 \pm 2.29$  and  $-3.53 \pm 0.26$  km sec<sup>-1</sup>. The parallax error for the primary is larger than expected and could be due to duplicity. In any event, the parallax discrepancy would appear to suggest the two components would be separated by ~30 light-years (~9.2 parsecs) along the observer’s line of sight.

Using the distance modulus formulae I had first stated in DSSC 18<sup>3</sup>, taking apparent  $V$ -mags of 10.21 and 10.25 in the PM2000 Bordeaux Proper Motion Catalogue<sup>4</sup>, we project absolute magnitudes of +6.3 and +6.0 for the A and B components. These in turn would suggest surface temperatures much cooler than that of the Sun and I have determined spectral types of roughly K3V and K1V<sup>5</sup>, which are certainly consistent with the deep yellow hues of the two stars we see in DSS colour images.

## Conclusions

In spite of a close angular separation of components in the plane of the sky and their common proper motions, the difference in Gaia parallax-measured distances argues against this being an orbital binary. The likelihood is that the two stars were probably once part of a moving group and are now isolated, but still sharing similar velocities in 3D space relative to our own particular vantage point.

## Acknowledgements

This research has made use of the Washington Double Star Catalogue maintained at the US Naval Observatory, and the Vizier and SIMBAD databases at the Centre de données Astronomiques de Strasbourg, France. I would also like to thank Bob Argyle for his assistance.

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# CATALOG ACCESS AND NEW LISTS OF NEGLECTED DOUBLES

Brian Mason, United States Naval Observatory, 3450 Massachusetts Avenue, NW, Washington, DC, 20392-5420, USA

E-mail: [brian.d.mason@navy.mil](mailto:brian.d.mason@navy.mil)

The availability of large astrometric catalogs and the admirable acumen of users has led to the republishing of the same measures and identification of the same "new" systems by multiple data-miners. This has significantly increased the amount of work needed to properly incorporate these data into the USNO double star catalogs. Therefore, in the future, data mining results will be added to the WDS and WDSS at the discretion of the catalogers. Furthermore, preference will be given to data prepared by those specifically associated with the original catalog project.

## Catalog Access

The US Naval Observatory Websites are undergoing modernization and will be offline starting Thursday, 24 October 2019. The expected completion of work and return of service is estimated as 30 April 2020\*. Until that time, the only access to double star catalogs will be via our website mirrors:

- The Washington Double Star Catalog : <http://www.astro.gsu.edu/wds/>
- Sixth Catalog of Orbits of Visual Binary Stars :  
<http://www.astro.gsu.edu/wds/orb6.html>
- item Second Catalog of Rectilinear Elements :  
<http://www.astro.gsu.edu/wds/lin2.html>
- Fourth Catalog of Interferometric Measurements of Binary Stars :  
<http://www.astro.gsu.edu/wds/int4.html>
- The Third Photometric Magnitude Difference Catalog :  
<http://www.astro.gsu.edu/wds/dm3.html>
- IAU Commission G1 (Binary and Multiple Stars) webpage :  
<http://www.astro.gsu.edu/wds/bs1/>
- Double Star Astronomy at the U.S. Naval Observatory :  
[http://www.astro.gsu.edu/wds/ds\\_history.html](http://www.astro.gsu.edu/wds/ds_history.html)

## Growth of the WDS and Data Mining

The availability of large astrometric catalogs and the admirable acumen of users has led to the republishing of the same measures and identification of the same "new" systems by multiple data-miners. This has significantly increased the amount of work needed to properly incorporate these data into the USNO double star catalogs. Therefore, in the future, data mining results will be added to the Washington Double Star (WDS) and Washington Double Star Supplement (WDSS) Catalogs at the discretion of the catalogers. Furthermore, preference will be given to data prepared by those specifically associated with the original catalog project.

As can be seen in the figure below, the WDS and the other catalogs we maintain are being added to at a prodigious rate. A great deal of this work is coming from data mining, most recently from Gaia (DR2). While this can be useful, it is always there to be mined and based on some private discussions it is possible that the best and final Gaia astrometric solution will not be produced until DR4 or later, so to avoid current data mining efforts being eventually superseded and replaced, data mining of Gaia results is not recommended at this time.

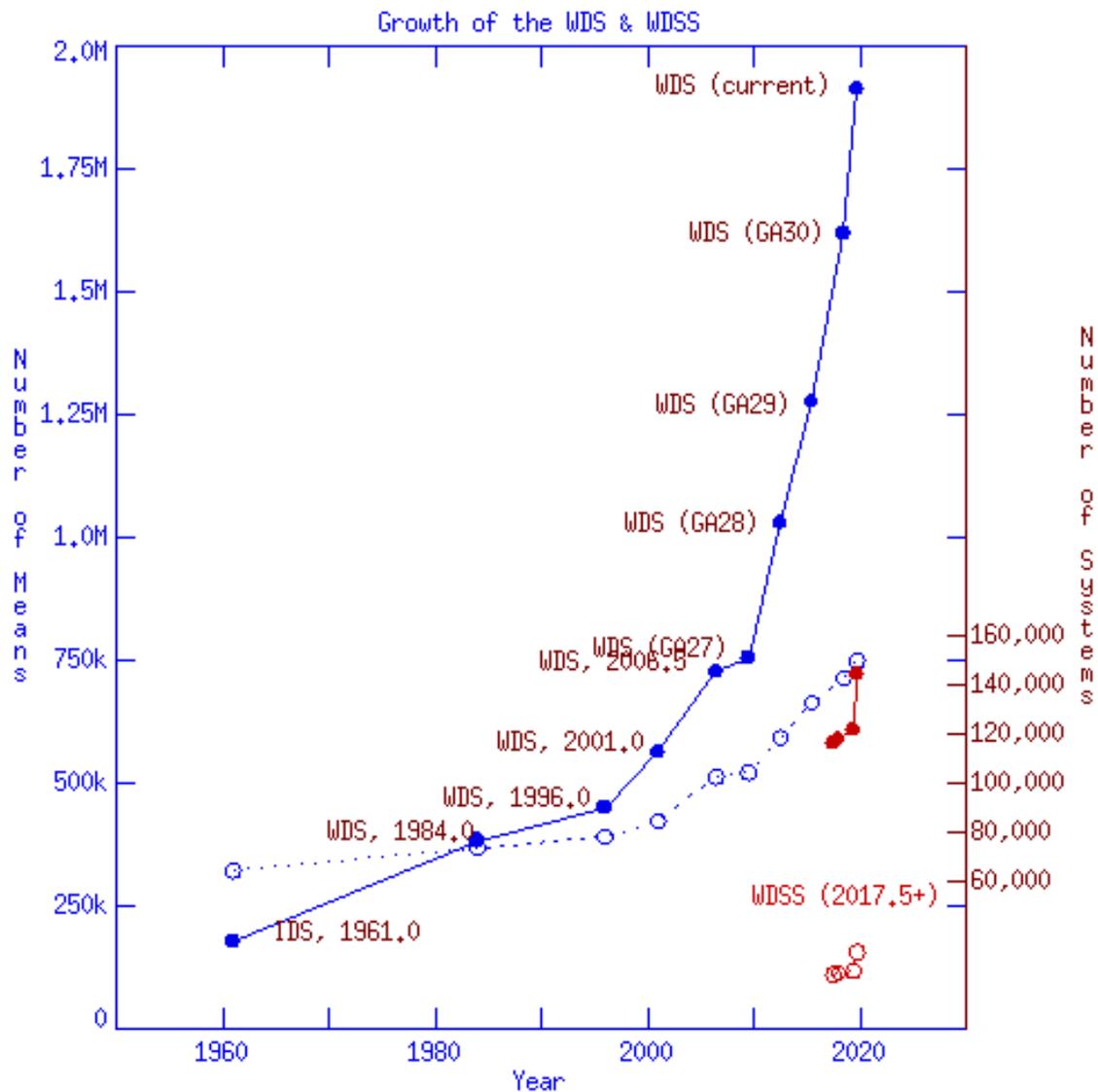


Figure 2: Growth of the WDS. The solid blue line and dots indicates the number of mean positions in the WDS, indicated on the left margin, at certain key dates. Indicated are publication of the IDS (1961), the major WDS data releases (1984, 1996, 2001, 2006.5), more recent dates corresponding to IAU General Assemblies (2009.5, 2012.5, 2015.5, 2018.5) and now (2019.75). The dashed blue line and open circles indicates the number of systems on those same dates and is indicated on the right margin. The solid/dashed red lines and filled/open red dots indicates growth of the new WDS Supplement at inception and later (2017.5, 2018.0, 2019.41, 2019.75), on the same scales as the WDS plots.

## What Needs to be Done?

Observe. Actual observations cannot be replicated. The observations you make tonight cannot be made tomorrow night or next week. Due to the slow motion of many of the pairs in the WDS and WDSS, to first order, the claim is absurd: the motion of most known visual pairs are insignificant and well below the measurement error on consecutive nights. However, it does get to the crux of the issue: your observations are a unique dataset which cannot be replicated.

As a result, lists have been generated of pairs which need to be observed. These lists include pairs which either are unconfirmed or pairs which have not been measured in many years (“many” set arbitrarily at 20 years). In the initial formulation two lists have been generated:

-[https://ad.usno.navy.mil/wds/Webtextfiles/neglected\\_list1.txt](https://ad.usno.navy.mil/wds/Webtextfiles/neglected_list1.txt): List 1 : Unconfirmed or (date - last) > 20 yrs., Va < 12, No X or K code systems.

-[https://ad.usno.navy.mil/wds/Webtextfiles/neglected\\_list2.txt](https://ad.usno.navy.mil/wds/Webtextfiles/neglected_list2.txt): List 2 : as above, but no magnitude restrictions.

The above lists are in WDS summary line format and are also available at the WDS mirror website at the weblinks below. These files will be automatically updated from the WDS as new observations and systems are added. The update of the lists will occur at least monthly, but may occur more often.

- [http://www.astro.gsu.edu/wds/Webtextfiles/neglected\\_list1.txt](http://www.astro.gsu.edu/wds/Webtextfiles/neglected_list1.txt)

- [http://www.astro.gsu.edu/wds/Webtextfiles/neglected\\_list2.txt](http://www.astro.gsu.edu/wds/Webtextfiles/neglected_list2.txt)

For these neglected pairs, even a non-detection can be useful if your observing capability is much greater than the parameters of the pair in question. For the neglected pairs where (*date - last*) is a very large number, the pair may be lost or miscatalogued, and it may involve detective work or the perusal of old articles. This type of investigative work may be found especially appealing.

Good observing!

\* Note added in proof. This work is still ongoing and is expected to be completed later in 2020.

# ASTRONOMICAL ASSOCIATION OF QUEENSLAND 2018 PROGRAMME: BLUE STAR OBSERVATORY MEASUREMENT OF 16 NEGLECTED SOUTHERN MULTIPLE STARS

Peter N. Culshaw, Diane Hughes, John Hughes, Des Janke, Graeme Jenkinson,  
Astronomical Association of Queensland, Australia.

E-mail: [bluestars@iprimus.com.au](mailto:bluestars@iprimus.com.au)

## Summary

This paper presents further results of a 2018 programme of photographic measurements of sixteen southern multiple stars. All results were obtained using an Atik 460EX mono CCD camera used in conjunction with an equatorially mounted 400-mm F4.5 Newtonian reflector. Fellow AAQ members Culshaw, Hughes and Hughes provided invaluable assistance with image processing using Losse's REDUC software.

System		Last listed measure			New measure			Comment
		PA °	Sep."	Epoch	PA °	Sep."	Epoch*	
BRT2021AB	Hor	23.0	14.6	2015	23.36	14.84	2018.886	Possible minor increases
RST4223	Eri	231.0	15.9	1969	231.0	15.18	2018.877	Possible decrease in sep.
RST4229AB	Eri	235.0	2.8	1949	231.9	2.96	2018.875	Movement in PA only
DAM832AC	Eri	24.0	20.9	2015	23.7	20.82	2018.883	No probable movement
HDS496AB	Eri	88.0	3.9	1991	343.3	18.55	2018.883	Large changes in both axes
AG76	Tau	14.0	6.3	1910	19.0	20.38	2018.883	Clear increase in both axes
RSS99	Pic	219.0	8.0	2015	218.6	7.90	2018.998	Little probable movement
BRT1594	CMa	355.0	2.8	2015	355.0	2.74	2019.009	No probable movement
B1519	CMa	75.0	3.0	1932	72.2	3.25	2018.056	Definite change in PA
I 1572	Cen	129.0	2.6	1938	187.8	10.27	2018.368	Considerable change
BRT3058	Sgr	N/A	N/	N/A	36.7	5.85	2018.541	New "C" component?
B374	Sgr	173.0	3.3	1927	158.7	3.68	2018.538	Definite change in PA
BRT1769	Sgr	331.0	2.4	1914	318.4	1.78	2018.532	Clear decrease in both axes
HU80	Cap	0.03	2.3	1960	6.4	2.50	2018.625	Consistent increase in PA
SEE454	Cap	212.0	5.2	1973	207.7	5.13	2018.702	Definite change in PA
B1398	PsA	151	3.9	2015	153.8	3.75	2018.677	Possible increase in PA

\* Epochs of new measures given in Besselian years as the average of the observations making up the measure.

The mean 95% confidence intervals for the new measures were  $\pm 1^{\circ}.143$  in PA and  $\pm 0''.142$  in separation. The results were as follows:

## Introduction

These latest results are part of an ongoing programme commenced in 2008 by the Double Star Section of the Astronomical Association of Queensland. The target stars were selected from the Washington Double Star Catalogue (WDSC) and were observed in Queensland, Australia from a latitude of approximately  $27^{\circ}$  S.

## Method

Sets of images were obtained with the equipment described above, the images were stacked using Atik DAWN software and then analysed using the astrometric double star program REDUC (Losse, 2008). Approximately ten stacked images of each target were taken per night for seven nights and the results averaged to obtain measures of separation and position angle with sufficient confidence.

Full details of the method are given in Napier-Munn and Jenkinson (2009). Some recent work on the errors inherent in the method is described in Napier-Munn and Jenkinson (2014). As proficiency has grown in the use of this equipment with the 400-mm reflector, close doubles with considerable magnitude difference between the components have been successfully measured.

## Results

For all of the systems shown below the WDSC information is first reproduced, showing the epoch 2000 position, magnitudes, separation, PA, and the last recorded measurement. The new measurements are then given in tabular form, including the mean and standard deviation and 95% confidence limits. Any uncertainties between the images and the last recorded measurements are discussed. Finally a conclusion is given as to whether any movement of the component stars has occurred in PA or separation, based on the P-value for the t-test comparing the new mean values with the catalogued value ( $P < 0.05$  is considered as evidence of change).

A possible new ‘C’ component for BRT3058 Sagittarius that has been imaged and measured awaits verification. Of the remaining pairs all except the four last measured in 2015 show clear movement in at least one axis.

HDS496AB shows a very large change in both axes since the last 1991 measure. With no other likely B component visible in the FOV, further investigation may be required.

The mean 95% confidence intervals for the new measures were  $1^{\circ}.143$  in PA and  $0''.142$  in separation. The results were as follows:



Figure 1: BRT 2021 in Horologium

Date	No. images	PA(°)	Sep''
02 November 2018	10	23.45	14.854
10 November 2018	10	23.06	14.834
19 November 2018	10	23.48	14.869
01 December 2018	10	23.47	14.833
09 December 2018	10	23.44	14.853
10 December 2018	10	23.44	14.828
11 December 2018	10	23.20	14.816
Mean		23.363	14.841
Standard deviation		0.165	0.018
95% CI ±		0.152	0.017
P(t) movement		0.001	0.000

Table 2: Individual measures of BRT 2021

**BRT2021AB** Horologium RA: 03 02.1 DEC: -54 18 Last Measure: 2015 MAG.11.8 & 12.6 PA.  $23^{\circ}$  SEP.  $14''.6$

COMMENTS: Possible minor increases in both axes consistent with previous measures.



Figure 2: RST 4223 in Eridanus

Date	No. images	PA(° )	Sep''
8 November 2018	10	231.23	15.183
10 November 2018	10	230.81	15.196
30 November 2018	10	230.62	15.119
1 December 2018	10	231.56	15.122
9 December 2018	10	231.13	15.204
10 December 2018	10	230.79	15.198
11 December 2018	10	231.03	15.276
Mean		231.024	15.185
Standard deviation		0.317	0.054
95% CI ±		0.294	0.050
P(t) movement		0.846	0.000

Table 3: Individual measures of RST 4223

**RST4223** Eridanus RA: 03 06.6 DEC: -6 05 Last Measure: 1969 MAG. 5.60 & 12.80 PA. 231°.0 SEP. 15''.9

COMMENTS: Possible minor decrease in separation since 1969.



Figure 3: RST 4229AB in Eridanus

Date	No. images	PA(° )	Sep''
10 November 2018	10	230.23	3.086
19 November 2018	10	232.17	2.858
1 December 2018	10	231.14	3.053
11 December 2018	10	234.19	2.849
Mean		231.933	2.962
Standard deviation		1.701	0.125
95% CI ±		2.707	0.200
P(t) movement		0.037	0.082

Table 4: Individual measures of RST 4229AB

**RST4229AB** Eridanus RA: 03 33.2 DEC: -4 37 Last Measure: 1949 MAG. 9.93 & 12.10 PA. 235°.0 SEP. 2''.8

COMMENTS: Reduction computed over four nights data as above, poor quality images the other three nights. Movement evident in PA only.

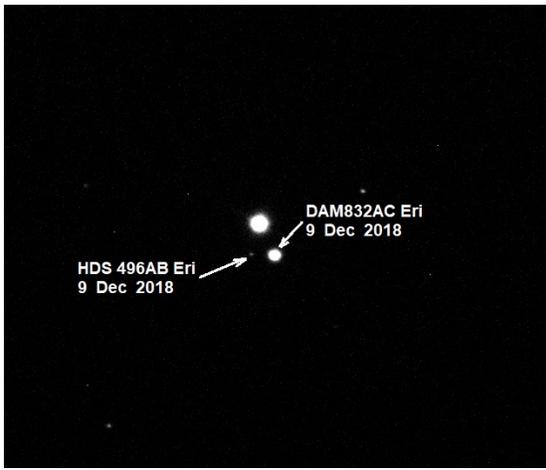


Figure 4: DAM 832 AC in Eridanus

Date	No. images	PA(°)	Sep''
10 November 2018	10	23.98	20.800
19 November 2018	10	24.15	20.635
30 November 2018	10	23.64	20.859
01 December 2018	10	23.87	20.878
09 December 2018	10	23.70	20.870
11 December 2018	10	23.70	20.811
18 December 2018	10	23.46	20.896
Mean		23.786	20.821
Standard deviation		0.231	0.089
95% CI ±		0.213	0.083
P(t) movement		0.000	0.000

Table 5: Individual measures of DAM 832 AC

**DAM832AC** Eridanus RA: 03 56.0 DEC: -29 49 Last Measure: 2015 MAG.9.14 & 10.5 PA 24° SEP. 20''.9

COMMENTS: No defined movement evident.

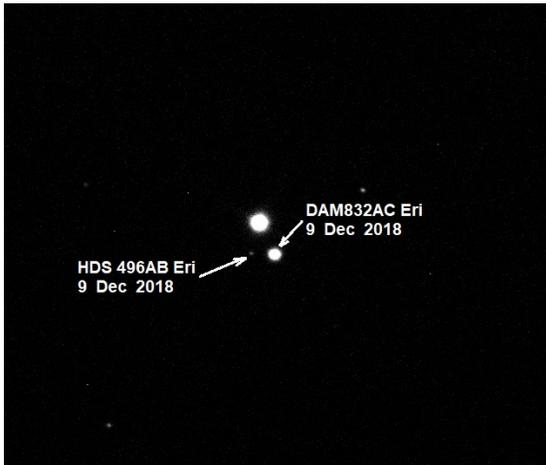


Figure 5: HDS 496AB in Eridanus

Date	No. images	PA(°)	Sep''
10 November 2018	10	343.45	18.547
19 November 2018	10	343.15	18.45
30 November 2018	10	343.76	18.428
1 December 2018	10	343.45	18.504
9 December 2018	10	343.31	18.652
11 December 2018	10	343.08	18.546
18 December 2018	10	343.21	18.75
Mean		343.344	18.554
Standard deviation		0.232	0.114
95% CI ±		0.214	0.105
P(t) movement		0.000	0.000

Table 6: Individual measures of HDS 496AB

**HDS496AB** Eridanus RA: 03 56.0 DEC: -29 49 Last Measure: 1991 MAG. 9.14 & 13.03 PA 88° SEP. 3''.9

COMMENTS: Such large changes in both axes seem unlikely, possible incorrect identification of 'B' component. Requires further investigation.

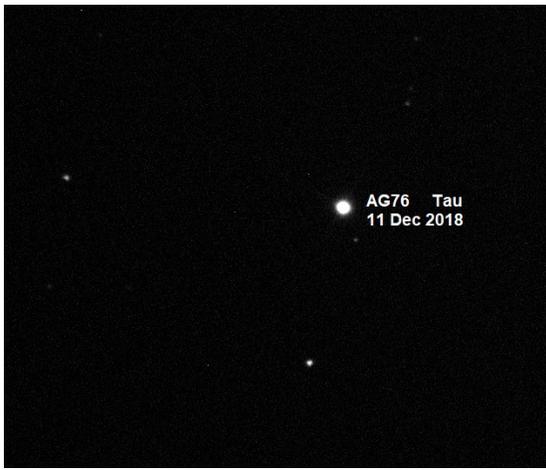


Figure 6: AG 76 in Taurus

Date	No. images	PA(°)	Sep''
10 November 2018	10	19.28	20.368
30 November 2018	10	19.05	20.422
1 December 2018	10	19.00	20.329
9 December 2018	10	19.02	20.331
10 December 2018	10	19.00	20.381
11 December 2018	10	19.00	20.366
19 December 2018	10	18.96	20.438
Mean		19.044	20.376
Standard deviation		0.107	0.042
95% CI ±		0.099	0.038
P(t) movement		0.000	0.000

Table 7: Individual measures of AG 76

**AG76** Taurus RA: 03 59.6 DEC: +2 41 Last Measure: 1910 MAG. 8.9 & 9.1 PA: 14°.0 SEP: 6''.3

COMMENTS: Definite increases in both axes over 109 years.



Figure 7: RSS 99 in Pictor

Date	No. images	PA(°)	Sep''
28 December 2018	10	218.91	8.044
29 December 2018	10	218.58	8.119
30 December 2018	10	218.98	7.938
31 December 2018	10	218.19	7.919
01 January 2019	10	219.16	7.732
02 January 2019	10	217.84	7.708
04-January 2019	10	218.94	7.834
Mean		218.657	7.899
Standard deviation		0.482	0.153
95% CI ±		0.446	0.141
P(t) movement		0.109	0.131

Table 8: Individual measures of RSS 99

**RSS99** RA: 06 08.3 DEC: -52 32 Last Measure: 2015 Pictor MAG. 8.90 & 15.00 PA: 219.0° SEP: 8''.0

COMMENTS: Little probable movement since 2015 measure.

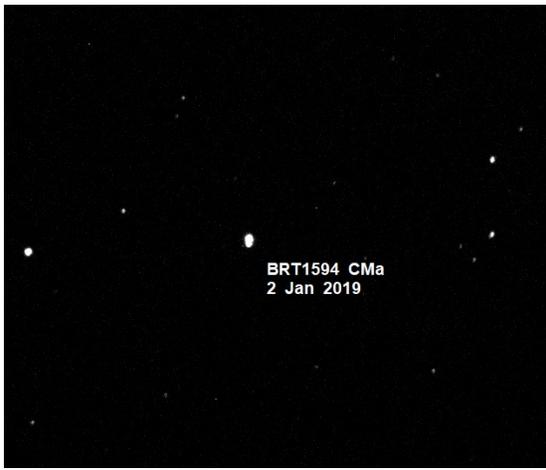


Figure 8: BRT 1594 in Canis Major

Date	No. images	PA(°)	Sep''
28-December-2018	10	355.2	2.63
29-December-2018	10	354.74	2.888
30-December-2018	10	356.04	2.649
31-December-2018	10	356.79	2.748
02-January-2019	10	356.07	2.936
04-January-2019	10	353.03	2.628
11-January-2019	10	353.7	2.716
Mean		355.081	2.742
Standard deviation		1.358	0.125
95% CI ±		1.256	0.116
P(t) movement		0.879	0.267

Table 9: Individual measures of BRT 1594

**BRT1594** RA. 06 24.5 DEC. -32 24 Last Measure: 2015 Canis Major MAG. 11.00 & 12.50 PA: 355° SEP: 2''.8

COMMENTS: No apparent movement.



Figure 9: B 1519 in Canis Major

Date	No. images	PA(°)	Sep''
16 January 2018	10	70.43	3.272
17 January 2018	10	73.37	3.387
19 January 2018	10	74.09	3.021
22 January 2018	10	71.42	3.094
26 January 2018	10	71.99	3.485
Mean		72.260	3.252
Standard deviation		1.475	0.194
95% CI ±		1.832	0.241
P(t) movement		0.000	0.000

Table 10: Individual measures of B 1519

**B1519** Canis Major RA. 06 47.2 DEC. -30 57 Last Measure: 1932 MAG. 7.93 & 13.5 PA: 75° SEP: 3''.0

COMMENTS: Definite movement in PA. Image acquisition limited to five nights only.

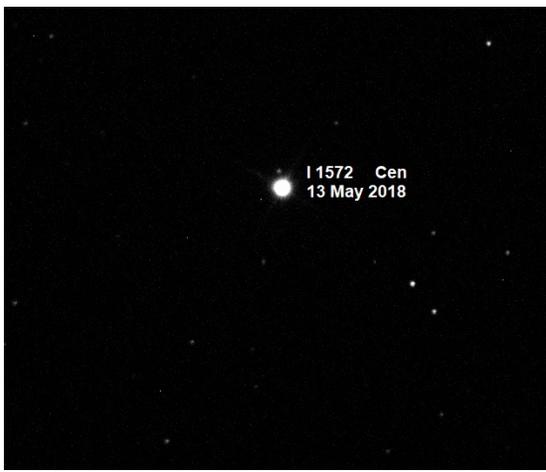


Figure 10: I 1572 in Centaurus

Date	No. images	PA(°)	Sep''
09 May 2018	10	187.82	10.355
11 May 2018	10	187.77	10.289
13 May 2018	10	187.72	10.238
15 May 2018	10	187.8	10.358
16 May 2018	10	187.99	10.242
20 May 2018	10	188.26	10.214
21 May 2018	10	187.53	10.194
Mean		187.841	10.270
Standard deviation		0.230	0.066
95% CI ±		0.212	0.061
P(t) movement		0.000	0.000

Table 11: Individual measures of I 1572

**I 1572** Centaurus RA: 13 56.2 DEC: -33 53 Last Measure: 1938 MAG. 8.6 & 13.4 PA: 129° SEP: 2''.6

COMMENTS Considerable changes over the last 80 years.

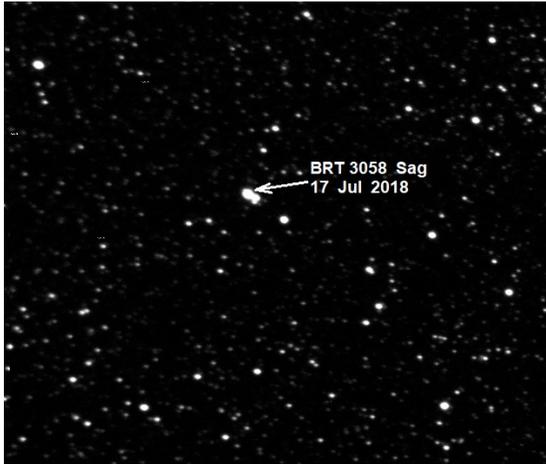


Figure 11: BRT 3058 in Sagittarius

Date	No. images	PA(°)	Sep''
10 July 2018	10	36.51	5.797
14 July 2018	10	35.87	6.004
15 July 2018	10	36.22	5.847
16 July 2018	10	37.94	5.805
17 July 2018	10	36.69	5.783
18 July 2018	10	37.91	5.761
22 July 2018	10	36.38	5.949
Mean		36.789	5.849
Standard deviation		0.817	0.092
95% CI ±		0.756	0.085
P(t) movement		0.000	0.000

Table 12: Individual measures of BRT 3058

**BRT3058** Sagittarius RA: 18 04.2 DEC: -28 46 Last Measure: n/a MAG. n/a & n/a PA: n/a SEP: n/a

COMMENTS: Possible new 'C' component not previously recorded.

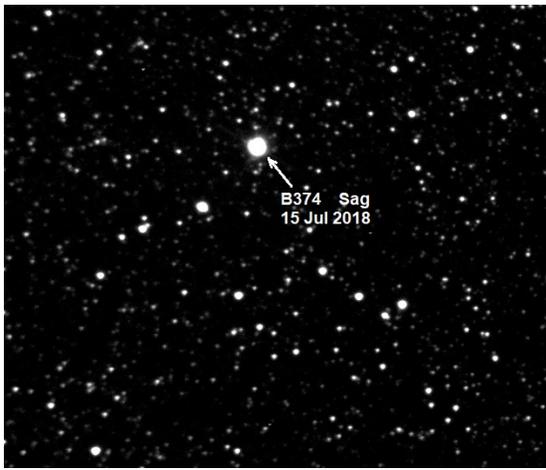


Figure 12: B 374 in Sagittarius

Date	No. images	PA(°)	Sep''
10 July 2018	10	158.68	3.622
14 July 2018	10	157.10	3.627
15 July 2018	10	159.18	3.417
16 July 2018	10	157.95	4.069
17 July 2018	10	158.32	3.478
18 July 2018	10	161.37	3.431
22 July 2018	10	160.95	3.848
Mean		158.697	3.677
Standard deviation		1.308	0.243
95% CI ±		1.373	0.255
P(t) movement		0.000	0.000

Table 13: Individual measures of B 374

**B374** Sagittarius RA: 18 05.3 DEC: -28 41 Last Measure:: 1927 MAG. 8.47 & 15.3 PA: 173° SEP: 3''.3

COMMENTS: Clear movement in PA only.



Figure 13: BRT 1765 in Sagittarius

Date	No. images	PA(°)	Sep''
04 July 2018	10	325.43	1.476
14 July 2018	10	318.14	1.51
15 July 2018	10	314.78	1.97
16 July 2018	10	318.68	1.972
17 July 2018	10	314.91	1.606
18 July 2018	10	316.83	2.00
22 July 2018	10	320.6	1.929
Mean		318.481	1.780
Standard deviation		3.699	0.238
95% CI ±		3.421	0.220
P(t) movement		0.000	0.000

Table 14: Individual measures of BRT 1765

**BRT1765** Sagittarius RA: 18 16.4 DEC: -32 57 Last Measure:: 1914 MAG.13.0 & 13.0 PA: 331° SEP: 2''.4

COMMENTS: Clear decreases in both axes over the last 104 years.

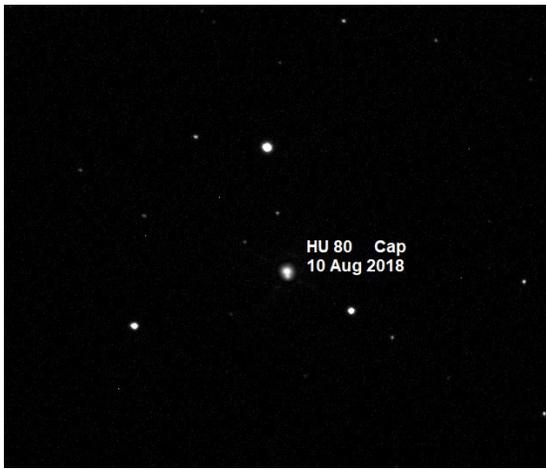


Figure 14: HU 80 in Capricornus

Date	No. images	PA(°)	Sep''
01 August 2018	10	6.37	2.183
08 August 2018	10	7.91	2.478
10 August 2018	10	5.07	2.459
13 August 2018	10	5.4	2.541
14 August 2018	10	5.43	2.495
15 August 2018	10	6.18	2.595
02 September 2018	10	8.55	2.768
Mean		6.416	2.503
Standard deviation		1.333	0.176
95% CI ±		1.233	0.162
P(t) movement		0.000	0.000

Table 15: Individual measures of HU 80

**HU80** Capricorn RA: 20 09.3 DEC: -19 25 Last Measure: 1960 MAG. 8.89 & 10.6 PA: 3° SEP: 2''.3

COMMENTS: Increase in PA is consistent with previous measures taken since 1897. Little change in separation over the same period.



Figure 15: SEE 454 in Capricorn

Date	No. images	PA(°)	Sep''
01 September 2018	10	206.58	5.006
02 September 2018	10	207.4	5.352
08 September 2018	10	205.57	5.052
16 September 2018	10	209.94	5.189
18 September 2018	10	208.45	5.314
22 September 2018	10	207.62	5.06
28 September 2018	10	208.48	4.968
Mean		207.720	5.134
Standard deviation		1.419	0.152
95% CI ±		1.312	0.141
P(t) movement		0.000	0.298

Table 16: Individual measures of SEE 454

**SEE454** Capricorn RA: 21 42.0 DEC: -23 16 Last Measure: 1973 MAG. 5.35 & 11.2 PA: 212° SEP: 5''.2

COMMENTS: Definite decrease in PA since 1973.

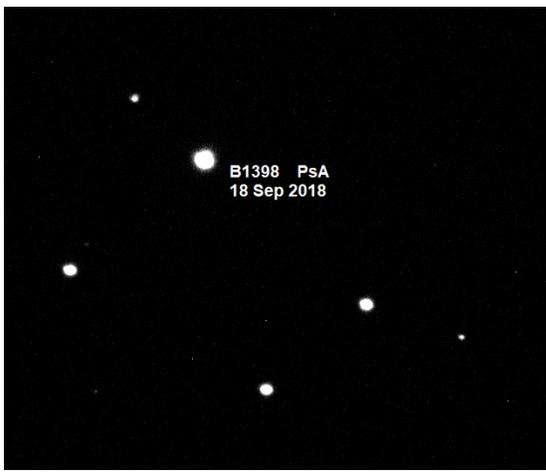


Figure 16: B 1398 in Piscis Austrinus

Date	No. images	PA(°)	Sep''
10 August 2018	10	154.13	3.335
08 September 2018	10	156.77	4.375
18 September 2018	10	153.97	3.689
22 September 2018	10	155.45	4.011
23 September 2018	10	151.63	3.540
28 September 2018	10	153.20	3.576
01 October 2018	10	151.50	3.744
Mean		153.81	3.753
Standard deviation		1.917	0.344
95% CI ±		1.773	0.318
P(t) movement		0.008	0.301

Table 17: Individual measures of B 1398

**B1398** Piscis Austrinus RA: 22 19.3 DEC: -31 42 Last Measure: 2015 MAG. 9.2 & 14.1 PA: 151° SEP. 3''.9

COMMENTS: Possible movement in PA only.

Please note that all attached images are aligned with North to the bottom and East to the right.

## Acknowledgements

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

The Edward Corbould Research Fund administered by the Astronomical Association of Queensland for granting of funds to upgrade imaging camera and observatory computer to suit.

Fellow AAQ members Peter Culshaw, Diane Hughes and John Hughes for all their help in taking over the huge task of turning unprocessed images into completed data sets ready for publication. Fellow AAQ member Des Janke for his work in processing the original FITS image files into JPEG photographs for this Circular.

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2. Napier-Munn, T.J. and Jenkinson, G., 2009. Measurement of some neglected southern multiple stars in Pavo. *Webb Society Double Star Section Circulars* **17**, 6-12.
3. Napier-Munn, T.J. and Jenkinson, G., 2014. Analysis of errors in the measurement of double stars using imaging and the Reduc software. *Journal of Double Star Observations* **10**, 193.
4. Argyle, R.W., 2012. *Observing and Measuring Visual Double Stars*, 2nd edition. Springer.

# OBSERVATION OF NEGLECTED DOUBLE STARS

André Debackère, Double Star Commission of the Société Astronomique de France

E-mail: [andre.debackere@free.fr](mailto:andre.debackere@free.fr)

## Abstract

After reading Brian Mason's note that Bob Argyle gave me on October 30, 2019, I began to observe neglected couples in the two new lists provided by the WDS.

## TDS 1237

WDS information: RA=00h 00m 17.81s, Dec. =+60° 23' 58".3

One observation in 1991,  $\theta = 217^\circ.20$ ,  $\rho = 1''.770$ ,  $V_A = 11.98$ ,  $V_B = 12.17$

## Observation

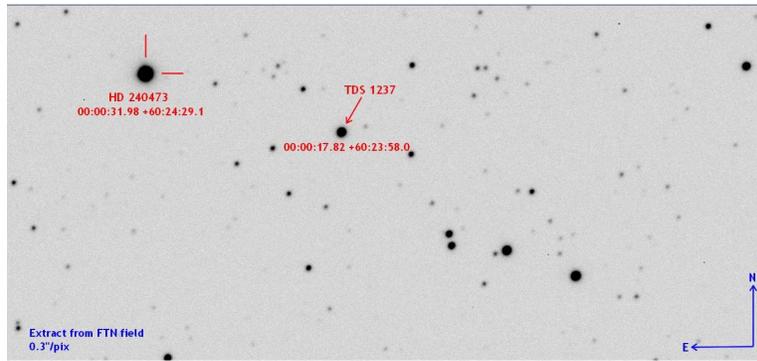


Figure 1: Extract of field of view of Faulkes Telescope North (FTN)

Sampling of FTN images is  $0''.3/\text{pixel}$ . TDS 1237 has a separation of  $1''.770$  in 1991 which takes about 6 pixels.

One night at FTN on November 23th, 2019 in  $V$  band TDS 1237 is seen as a single star with the FTN.

There is no image elongation of the target as you can see in the green window, we have a single star profile (see the yellow window).

## Position

The GAIA-DR2 catalog indicates only one star with coordinates :

RA(J2000) : 00h 00m 17s.8153907950 Dec(J2000) : +60° 23' 57".972419337

so either the coordinates given by the WDS are wrong (there is no double star at this separation in the entire  $10' \times 10'$  field) or the current separation is less than  $1''$ .

This observation requires a more suitable equipment.

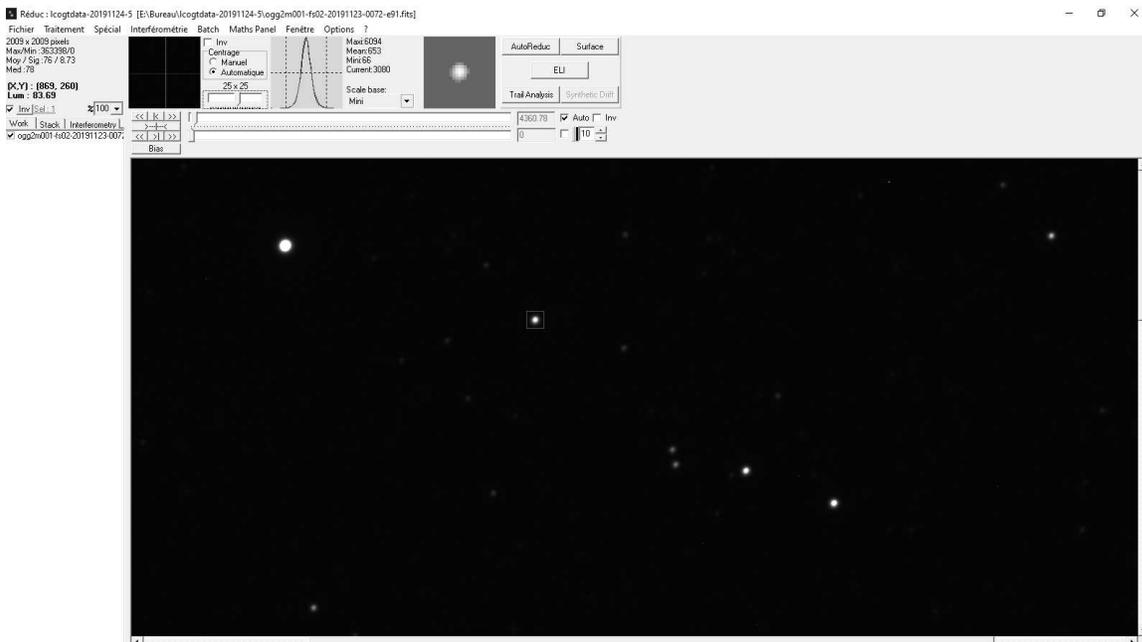


Figure 2: Image open in REDUC software

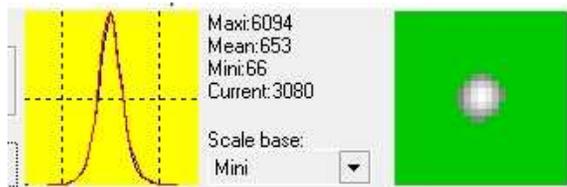


Figure 3: Profile of the target in REDUC software

### Photometry with *Subaru* MAKALI'I Image Processor

Four best images out of five images in *V*-band on Nov 23th, 2019,  $V = 12.310 \pm 0.006$

### LDS 5265

WDS information: RA = 00h 13m 34s.16, Dec =  $-32^\circ 24' 3''.2$

One observation in 1960:  $\theta = 111^\circ.00$ ,  $\rho = 3''.000$ ,  $V_A = 15.20$ ,  $V_B = 15.30$

### Observation

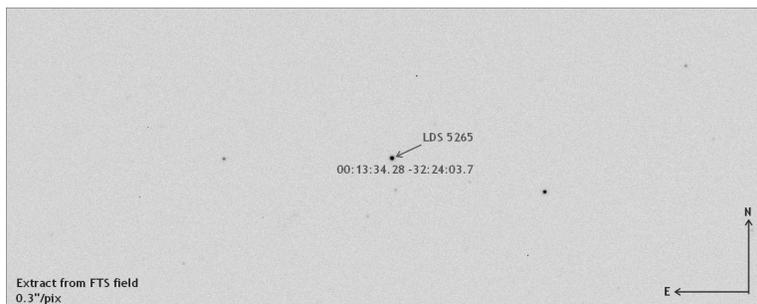


Figure 4: Extract of Faulkes Telescope South field of view

Sampling of FTS (Faulkes Telescope South) images is  $0''.3/\text{pixel}$ . LDS 5265 has a separation of  $3''.000$  in 1960 which takes 10 pixels.

Two nights at FTS (five images in  $V$  band on November 28th, 2019 and four images in  $V$  band on December 17, 2019).

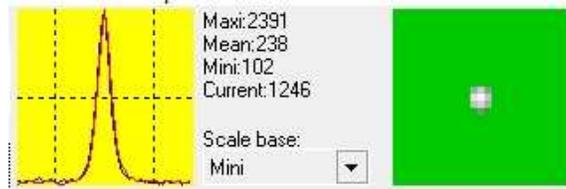


Figure 5: Profile of the target in REDUC software

There is no image elongation of the target as you can see in the green window, we have a single star profile (see the yellow window).

### Position

The GAIA-DR2 catalog indicates only one star with coordinates : RA(J2000) : 00h 13m 34s.2752499096  
Dec(J2000) :  $-32^{\circ} 24' 03''.679522009$

so either the coordinates given by the WDS are wrong (there is no double star at this separation in the entire  $10'' \times 10''$  field) or the current separation is less than  $1''$ .

This observation requires more suitable equipment.

### Photometry with *Subaru* MAKALI'I Image Processor

Three best images out of five images  $V = 15.707 \pm 0.031$  on Nov 28th, 2019

One best image out of four images  $V = 15.691 \pm 0.030$  on Dec 17th, 2019

Average  $V = 15.699 \pm 0.043$

### ARA 1257

WDS information: RA=01h 50m 32s.88, Dec =  $-20^{\circ} 42' 23''.9$

### Observation

One observation in 1920,  $\theta = 249^{\circ}.90$ ,  $\rho = 6''.853$   $V_A = 12.64$   $V_B = 12.74$

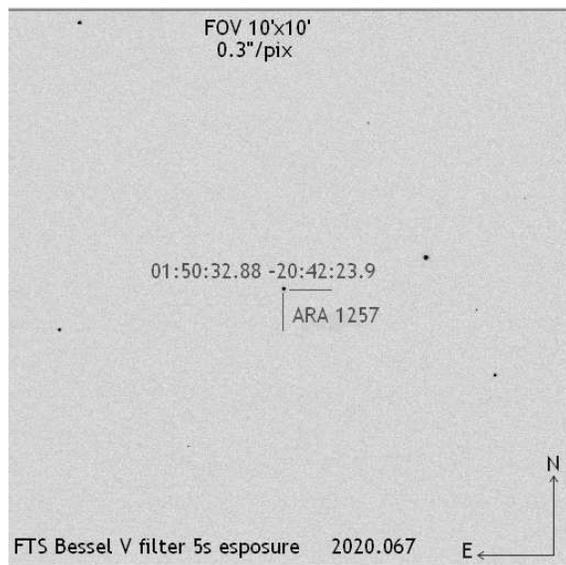


Figure 6: FTS field of view

Sampling of FTS images is  $0''.3/\text{pixel}$ . ARA 1257 has a separation of  $6''.853$  in 1920 as indicated in the WDS, which takes 23 pixels.

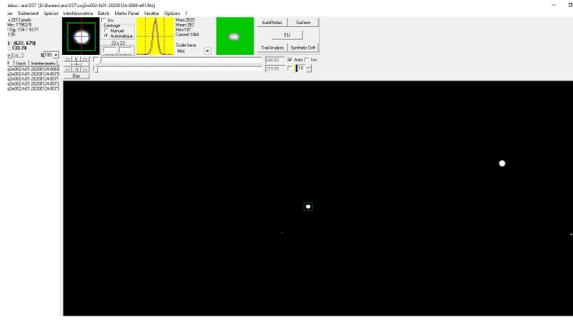


Figure 7: Image open in REDUC software

One night at FTS (five images in  $V$  band on January 24th, 2020) ARA 1257 is clearly seen as a double star with the FTS but not with a separation of  $6''.853$

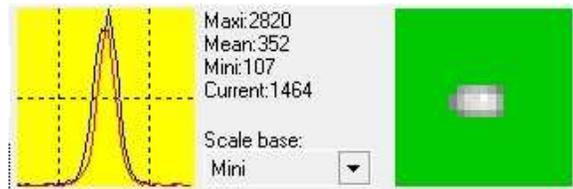


Figure 8: Profile of the target in REDUC software

The elongation of the target is clearly seen in the green window, in the yellow window we can see a double star profile.

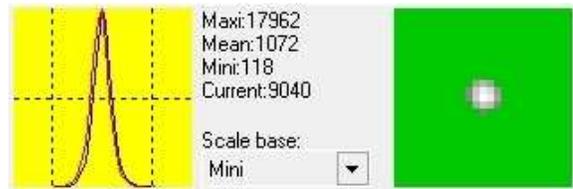


Figure 9: Profile of one star in REDUC software

There is no elongation for the other stars in the field which are seen as round, there is no shift of the telescope.

### Position

The GAIA-DR2 catalog indicates two stars with coordinates: The main component A: Gaia DR2 This star is exactly at the position indicated in the WDS:

Gaia DR2 number	RA(J2000)	Dec(2000)	$G$	$\pi$ (mas)	$\mu_\alpha$ (mas $\text{yr}^{-1}$ )	$\mu_\delta$ (mas $\text{yr}^{-1}$ )
513613344976183782	01h 50m 32s.8525495203	$-20^\circ 42' 23''.936334816$	13.1374	1.8592	12.706	$-3.189$
				0.2958	0.568	0.349
5136130494823631872	01h 50m 32s.9274250764	$-20^\circ 42' 23''.920021725$	13.4900	1.4904	11.123	0.201
				0.0503	0.176	0.444

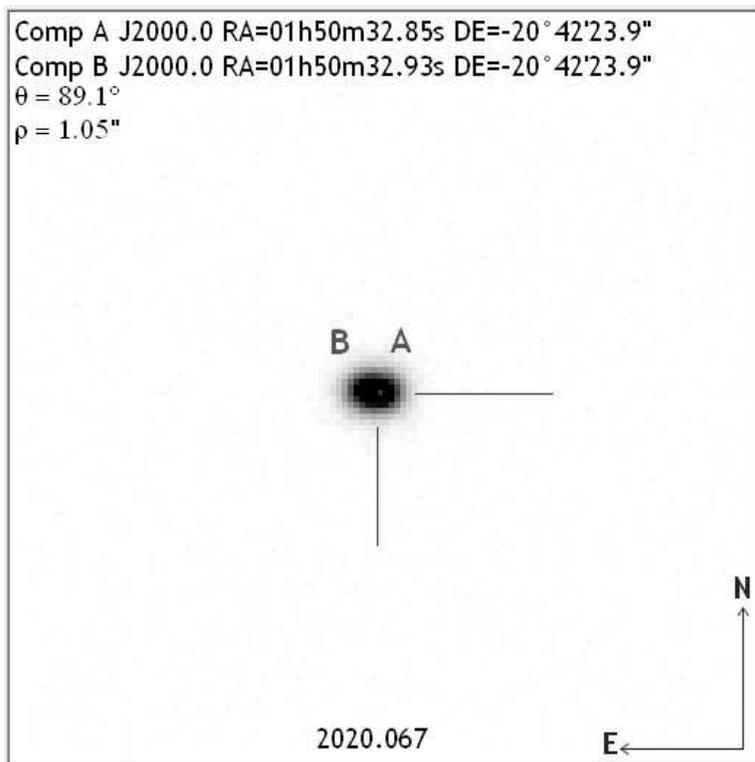


Figure 10: Extract of image open in REDUC software, zoom x4

The separation of about  $1''$  or less is too small to be measured with accuracy at FTS. Separation and position angle indicated in the WDS are wrong. It would be wise to measure this couple with suitable equipment.

#### Photometry with *Subaru* MAKALI'I Image Processor

Four best images out of five images in  $V$  band on January 24th, 2020

Measurement of the overall magnitude in  $V$  band of this pair:  $V_{AB} = 12.678 \pm 0.008$

ARA is the WDS observer code of Srinivas Aravamudan who observed at the Nizamiah Observatory located in Hyderabad, India.

## Acknowledgements

This research has made use of:

The Washington Double Star Catalog maintained at the U.S. Naval Observatory.

The VizieR catalogue access tool, CDS, Strasbourg, France (DOI: 10.26093/cds/vizier). The original description of the VizieR service was published in A&AS 143, 23

The REDUC software of Florent Losse (<http://www.astrosurf.com/hfosaf/uk/tdownload.htm#reduc>)

The *Subaru* Image Processor: MAKALI'I, a freeware which anyone can use for free only for non-commercial educational/research purpose. Software copyright is owned by both of National Astronomical Observatory of Japan (NAOJ) and AstroArts Inc. All rights reserved.

# DOUBLE STAR PHOTOMETRY - MAY 2019

Wilfried R.A. Knapp, Vienna, Austria  
wilfried.knapp@gmail.com

## Abstract

The WDS catalog contains at June 2019 about 148,500 objects. About 50,000 of these come with a magnitude for the primary with single digit precision indicating rather an estimation than a precise measurement and over 16,000 objects are listed with magnitudes in the blue or red band (WDS note codes B/K/R/I) thus in need of a measurement in the  $V$  band. After eliminating all objects not suited for resolution with the tools currently available to me (too small angular separation, too faint, too bright) about 26,000 objects remained as targets of interest for this project. The selection criterion for the objects for a specific report is then at a given point of time simply the currently highest given altitude to eliminate atmospheric effects as far as possible – so this is then a more or less random selection out of the mentioned 26,000 objects.

This report covers about 40 such objects (including some KPP objects also in need of photometry) with images taken May 2019 with  $V$ -filter to allow for visual magnitude measurement by differential photometry. This paper lists also a few WDSS objects as several newly detected likely physical pairs reported in Knapp<sup>3</sup> were meanwhile included in the WDSS catalog. All objects were additionally checked for potential gravitational relationship using GAIA DR2 data for a Monte Carlo simulation of the spatial distance between the components of a pair.

## 1 Introduction

One single image was taken for all selected objects with iTelescope iT24 with  $V$ -filter and 20 seconds exposure time and the imaging conditions were overall quite favourable. The images were plate solved with *ASTROMETRICA* using the URAT1 catalog with reference stars in the  $V$  range of 8.5 to 16.5 giving not only RA/Dec coordinates but also photometry results for all reference stars used including an average  $\epsilon_V$  error. The objects were then located in the center of the image and astrometry/photometry was then done by the rather comfortable *ASTROMETRICA* procedure with point and click at the components delivering RA/Dec coordinates and  $V$  magnitude measurements based on all reference stars used for plate solving.

## 2 Results of image processing

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

WDS/WDSS	WDS/WDSS ID
Disc	WDS discoverer code (blank for WDSS objects)
C	Components (AB if blank)
RA/Dec	Positions for primary and secondary in HH:MM:SS.sss/DD.MM.SS.ss format
$\Delta\alpha/\Delta\delta$	Plate solving errors for RA and Dec in arcseconds
$\rho$	Calculated separation in arcseconds
$\epsilon_\rho$	Separation error
$\theta$	Calculated position angle in degrees
$\epsilon_\theta$	Position angle error
$V$	$V$ mags for both components measured by differential photometry
$\epsilon_V$	Magnitude errors
SNR	Signal to noise ratio for both components
$\Delta V$	Plate solving error in $V$ mag
Epoch	Julian observation epoch
Notes	Additional comments listed below Table 1

**Table 1: Results for measured WDS objects**

WDS/WDSS	Disc	$\alpha$	$\delta$	$\Delta\alpha$	$\Delta\delta$	$\rho$	$\epsilon_\rho$	$\theta$	$\epsilon_\theta$	$V$	$\epsilon_V$	SNR	$\Delta V$	Epoch
13107+4634	BEM9002	13 10 40.936	46 34 16.80	0.03	0.03	8.96781	0.04243	223.080	0.271	11.695	0.060	170.63	0.06	2019.33406
		13 10 40.342	46 34 10.25							12.097	0.060	142.72		
13100+2840	BRT 26	13 10 07.509	28 40 01.50	0.03	0.03	4.49547	0.04243	325.391	0.541	12.209	0.071	112.62	0.07	2019.33404
		13 10 07.315	28 40 05.20							12.609	0.071	90.20		
13340+4318	ES 1549	13 33 58.813	43 15 51.65	0.06	0.04	6.86658	0.07211	300.257	0.602	10.290	0.070	255.24	0.07	2019.33417
		13 33 58.270	43 15 55.11							11.914	0.071	98.41		
13164+4202	HJ 1230	13 16 24.017	42 01 56.68	0.03	0.03	16.39004	0.04243	169.780	0.148	12.440	0.090	123.44	0.09	2019.33409
		13 16 24.278	42 01 40.55							12.848	0.091	105.43		
13532+3656	HJL1083	13 53 13.305	36 55 30.29	0.03	0.03	99.29327	0.04243	281.791	0.024	9.979	0.040	343.10	0.04	2019.33424
		13 53 05.199	36 55 50.58							10.046	0.040	325.89		
13537+4027	KPP 298	13 53 44.773	40 26 49.28	0.04	0.05	4.88759	0.06403	172.890	0.751	12.822	0.032	98.24	0.03	2019.33425
		13 53 44.826	40 26 44.43							13.060	0.033	83.04		
13438+4509	KPP 673	13 43 49.917	45 08 29.40	0.04	0.04	6.06439	0.05657	12.085	0.534	13.204	0.101	69.20	0.10	2019.33422
		13 43 50.037	45 08 35.33							14.049	0.103	45.82		
13483+3326	KPP 869	13 48 16.577	33 26 17.56	0.04	0.04	7.30716	0.05657	213.830	0.444	12.174	0.061	115.22	0.06	2019.33423

13340+4354	KPP1058	13 48 16.252	33 26 11.49	0.10	0.06	8.35398	0.11662	29.791	0.800	11.963	0.061	125.72	0.08	2019.33418
12218+3529	KPP1091	13 33 57.252	43 53 50.98	0.08	0.05	9.01465	0.09434	75.350	0.600	14.263	0.085	38.36	0.05	2019.33697
13276+3105	KPP1264	13 33 57.636	43 53 58.23	0.06	0.05	9.61555	0.07810	220.790	0.465	14.115	0.055	45.64	0.06	2019.33415
13292+4420	KPP1267	12 21 46.921	35 28 39.82	0.07	0.07	9.89939	0.09899	328.938	0.573	13.999	0.064	51.47	0.17	2019.33416
13387+4454	KPP1594	12 21 47.635	35 28 42.10	0.08	0.05	12.07649	0.09434	225.662	0.448	14.523	0.067	36.48	0.06	2019.33420
12548+4105	KPP1796	13 27 37.270	31 05 07.70	0.03	0.03	13.88700	0.04243	237.946	0.175	12.406	0.073	25.37	0.04	2019.33687
12359+3600	KPP2139	13 27 36.781	31 05 00.42	0.04	0.06	17.55619	0.07211	3.130	0.235	13.409	0.042	81.62	0.04	2019.33677
13309+4419	KPP2367	13 29 13.050	44 19 36.97	0.09	0.07	20.24473	0.11402	94.249	0.323	11.449	0.040	188.82	0.07	2019.33417
13359+4048	KPP2411	13 29 12.574	44 19 45.45	0.08	0.07	20.80976	0.10630	309.654	0.293	14.004	0.044	56.80	0.07	2019.33419
13353+4557	KPP2552	13 38 41.563	44 54 18.71	0.08	0.07	23.18684	0.10630	358.608	0.263	13.610	0.073	55.59	0.07	2019.33685
18187+355621		13 38 40.750	44 54 10.27	0.05	0.05	5.77409	0.07071	26.885	0.702	14.498	0.077	34.53	0.04	2019.33685
12299+4113	KPP3873	12 54 45.997	41 05 02.05	0.06	0.05	1.40695	0.07810	41.114	3.177	11.557	0.071	112.04	0.07	2019.33678
11573+372242		12 54 44.956	41 04 54.68	0.03	0.04	7.82898	0.05000	92.855	0.366	13.969	0.075	40.18	0.03	2019.33692
16578+321525		12 35 51.408	36 00 19.46	0.02	0.03	3.09252	0.03606	147.218	0.668	11.948	0.031	176.21	0.03	2019.33692
14479+424735		12 35 51.487	36 00 36.99	0.06	0.05	3.53610	0.07810	30.076	1.265	14.693	0.087	20.23	0.04	2019.33697
19090-015259		13 30 55.252	44 18 44.62	0.04	0.05	51.85311	0.06403	317.958	0.071	14.308	0.036	52.71	0.04	2019.33683
10276+415305		13 30 57.133	44 18 43.12	0.05	0.05	2.95370	0.07071	129.531	1.371	14.148	0.083	53.21	0.08	2019.33688
10455+330354		13 35 54.594	40 47 58.16	0.07	0.11	7.19215	0.13038	181.402	1.039	13.712	0.043	64.03	0.03	2019.33685 1)
11404+365755		13 35 53.183	40 48 11.44	0.02	0.03	3.09252	0.03606	147.218	0.668	14.759	0.088	19.92	0.06	2019.33685 1)
10523+350253		13 35 21.032	45 57 23.16	0.02	0.03	3.09252	0.03606	147.218	0.668	14.563	0.042	37.23	0.03	2019.33680
		13 35 20.978	45 57 46.34	0.06	0.05	3.53610	0.07810	30.076	1.265	14.695	0.044	33.31	0.03	2019.33680
		12 28 18.702	35 56 21.92	0.06	0.05	3.53610	0.07810	30.076	1.265	12.146	0.042	92.77	0.04	2019.33697
		12 28 18.917	35 56 27.07	0.04	0.05	51.85311	0.06403	317.958	0.071	12.804	0.043	67.09	0.04	2019.33683
		12 29 55.807	41 13 20.18	0.04	0.05	51.85311	0.06403	317.958	0.071	14.148	0.083	53.21	0.08	2019.33685 1)
		12 29 55.889	41 13 21.24	0.02	0.03	3.09252	0.03606	147.218	0.668	15.216	0.090	26.55	0.03	2019.33688
		12 31 57.151	37 22 43.48	0.05	0.05	2.95370	0.07071	129.531	1.371	13.284	0.034	66.49	0.03	2019.33685 1)
		12 31 57.807	37 22 43.09	0.07	0.11	7.19215	0.13038	181.402	1.039	13.686	0.036	51.87	0.06	2019.33685 1)
		12 36 57.730	32 15 25.17	0.02	0.03	3.09252	0.03606	147.218	0.668	14.438	0.092	15.12	0.03	2019.33680
		12 36 57.862	32 15 22.57	0.02	0.03	3.09252	0.03606	147.218	0.668	14.812	0.037	50.19	0.03	2019.33680
		12 44 47.954	42 47 36.98	0.06	0.05	3.53610	0.07810	30.076	1.265	16.141	0.057	21.82	0.04	2019.33693 1)
		12 44 48.115	42 47 40.04	0.04	0.05	51.85311	0.06403	317.958	0.071	10.035	0.041	143.96	0.04	2019.33693 1)
		12 49 09.585	33 37 03.55	0.04	0.05	51.85311	0.06403	317.958	0.071	16.926	0.129	8.40	0.04	2019.33693 1)
		12 49 06.805	33 37 42.06	0.02	0.03	3.09252	0.03606	147.218	0.668	14.563	0.042	37.23	0.03	2019.33692
		12 50 27.657	41 53 05.53	0.05	0.05	2.95370	0.07071	129.531	1.371	14.695	0.044	33.31	0.03	2019.33692
		12 50 27.861	41 53 03.65	0.07	0.11	7.19215	0.13038	181.402	1.039	14.695	0.044	33.31	0.03	2019.33692
		12 50 45.585	33 03 54.09	0.07	0.11	7.19215	0.13038	181.402	1.039	12.146	0.042	92.77	0.04	2019.33697
		12 50 45.571	33 03 46.90	0.04	0.05	51.85311	0.06403	317.958	0.071	12.804	0.043	67.09	0.04	2019.33697
		13 01 40.291	36 57 54.95	0.02	0.03	10.00245	0.03606	65.927	0.207	14.148	0.083	53.21	0.08	2019.33683
		13 01 41.053	36 57 59.03	0.02	0.03	10.00245	0.03606	65.927	0.207	15.216	0.090	26.55	0.03	2019.33688
		13 10 52.183	35 02 54.61	0.09	0.08	15.25162	0.12042	77.812	0.452	13.686	0.036	51.87	0.06	2019.33685 1)
		13 10 53.397	35 02 57.83	0.09	0.08	15.25162	0.12042	77.812	0.452	9.593	0.060	204.82	0.06	2019.33685 1)

12406+4017	HJ 2617 A	12 40 37.359	40 17 18.05	0.03	0.05	5.81365	0.05831	2.030	0.575	8.443	0.030	379.37	0.03	2019.33681
	HJ 2617 B	12 40 37.377	40 17 23.86							9.834	0.007	146.44		
12406+4017	BKO 114 A	12 40 37.359	40 17 18.05	0.03	0.05	43.69652	0.05831	343.745	0.076	8.443	0.030	379.37	0.03	2019.33681
	BKO 114 D	12 40 36.290	40 18 00.00							13.784	0.016	66.69		
13124+3908	KZA 46	13 12 23.742	39 07 37.53	0.04	0.05	48.79924	0.06403	325.838	0.075	11.608	0.031	174.86	0.03	2019.33408
		13 12 21.387	39 08 17.91							12.903	0.032	99.20		
13211+3548	KZA 50	13 21 04.032	35 48 32.75	0.03	0.04	25.13029	0.05000	254.324	0.114	10.712	0.030	249.29	0.03	2019.33411
		13 21 02.043	35 48 25.96							12.307	0.031	132.18		
13219+4416	KZA 54	13 21 51.343	44 16 00.05	0.08	0.08	19.21968	0.11314	18.373	0.337	11.584	0.007	152.87	0.09	2019.33412
		13 21 51.907	44 16 18.29							12.675	0.091	97.33		
13226+4336	KZA 56	13 22 34.939	43 36 23.94	0.05	0.05	42.57931	0.07071	210.438	0.095	11.433	0.050	176.11	0.05	2019.33413
		13 22 32.953	43 35 47.23							12.079	0.051	130.31		
13235+3534	KZA 60	13 23 30.255	35 34 45.14	0.06	0.06	11.57972	0.08485	211.151	0.420	12.929	0.051	89.74	0.05	2019.33414
		13 23 29.764	35 34 35.23							13.382	0.052	67.99		
13156+3042	LDS1375	13 15 38.077	30 42 12.99	0.03	0.03	18.22414	0.04243	217.542	0.133	13.140	0.071	83.54	0.07	2019.33408
		13 15 37.216	30 41 58.54							13.827	0.072	61.58		
13208+3748	UC 2520 A	13 20 46.545	37 48 27.67	0.09	0.04	4.03828	0.09849	224.303	1.397	13.171	0.043	73.70	0.04	2019.33411
	UC 2520 B	13 20 46.307	37 48 24.78							13.794	0.044	58.73		
13208+3748	PAL 4 A	13 20 46.545	37 48 27.67	0.09	0.04	5.44260	0.09849	19.196	1.037	13.171	0.043	73.70	0.04	2019.33411
	PAL 4 C	13 20 46.696	37 48 32.81							14.246	0.045	50.01		
13166+3818	UC 2510	13 16 37.347	38 18 17.00	0.04	0.05	6.72041	0.06403	12.544	0.546	11.862	0.051	144.26	0.05	2019.33410
		13 16 37.471	38 18 23.56							13.104	0.052	79.83		
13234+3240	UC 2529	13 23 26.017	32 40 14.64	0.06	0.08	8.94288	0.10000	3.076	0.641	11.631	0.041	147.05	0.04	2019.33413
		13 23 26.055	32 40 23.57							14.202	0.048	41.84		

### Notes

- 1) SNR B < 20
- 2) Overlapping star disks

## Cross-Match with GAIA DR2

All listed objects were additionally cross-matched with GAIA DR2 to check for potential gravitational relationship by using the DR2 data for a Monte Carlo simulation (see Appendix for details). The results are given below in Table 2 with the following structure:

Object	WDS Discoverer ID or WDSS ID
C	Components (AB if blank)
$\theta$	Position angle in degrees
$\epsilon_\theta$	Error position angle
$\rho$	Separation in arcseconds
$\epsilon_\rho$	Error separation
$\pi_1$	Parallax primary in mas
$\epsilon_{\pi_1}$	Error parallax primary
$\pi_2$	Parallax secondary in mas
$\epsilon_{\pi_2}$	Error parallax secondary
Min D(AU)	Minimum spatial distance in AU between components
Med D(AU)	Median spatial distance in AU between components
LPGR	Likelihood of potential gravitational relationship
M1(50)	DR2 StarHorse median mass value primary
M2(50)	DR2 StarHorse median mass value secondary
MinP(M50)	Minimum orbit period with DR2 StarHorse median mass values (blank for LPGR <0.5)
MedP(M50)	Median orbit period with DR2 StarHorse median mass values (blank for LPGR <0.5)
Notes	Notes given below the table

**Table 2: Results for DR2 cross-matched WDS/WDSS objects**

Object	$\theta$	$\epsilon_\theta$	$\rho$	$\epsilon_\rho$	$\pi_1$	$\epsilon_{\pi_1}$	$\pi_2$	$\epsilon_{\pi_2}$	MinD (AU)	MedD (AU)	LPGR	M1(50)	M2(50)	MinP (M50)	MedP (M50)
BEM9002	223.150	0.000	8.95026	0.00003	3.4038	0.0231	3.4356	0.0235	2601	595793	17.16	0.99139297	0.94015223	95971	332727663
BRT 26	325.293	0.001	4.49113	0.00004	3.4925	0.0356	3.4180	0.0341	1290	1289943	6.00	0.91325313	0.88097417	34765	1099804590
ES 1549	299.670	0.000	6.93191	0.00006	3.1291	0.0519	3.1029	0.0306	2196	950423	11.18	1.13237286	1.00736046	70724	636933116
HJ 1230	169.830	0.000	16.39405	0.00003	1.7562	0.0245	1.7742	0.0232	9011	1724732	6.17	1.02946723	1.02576506	600012	1588731090
HJL1083	281.811	0.000	99.41856	0.00003	3.1337	0.0288	1.4455	0.0311	64085732	76863343	0.00	1.17109084	1.12814772		
KPP 298	172.954	0.000	4.89014	0.00003	1.7184	0.0249	1.6983	0.0219	2789	1890037	5.65	1.03975987	1.01966155	103225	1820670956
KPP 673	12.143	0.000	6.04186	0.00003	5.0369	0.0213	5.0636	0.0185	1190	229370	43.99	0.73900265	0.65034574	35040	93712794
KPP 869	213.961	0.001	7.32831	0.00011	4.4783	0.1221	4.7496	0.0339	1540	2620833	1.46	0.92860049	0.90126181	44902	3153902853
KPP1058	30.422	0.000	8.42572	0.00004	3.3321	0.0375	3.2752	0.0219	2536	1087437	8.17	1.09389830	0.69939500	95885	851488411
KPP1091	74.184	0.000	8.65426	0.00005	2.4094	0.0449	2.5569	0.0293	3461	4937439	0.23	1.23772395	0.76972806		
KPP1264	221.758	0.000	9.67852	0.00004	4.5681	0.0431	4.5689	0.0220	2100	321595	32.51	0.74705315	0.69900900	80477	152499353
KPP1267	328.764	0.000	9.68829	0.00003	2.4945	0.0233	2.4760	0.0191	3844	816805	13.00	0.92904806	0.73062336	186032	576188686
KPP1594	226.014	0.002	12.10810	0.00038	9.9890	0.3527	8.7399	0.0184	8710	2949899	0.03	0.67958546	0.54737014		
KPP1796	237.865	0.000	13.91535	0.00008	3.3206	0.0387	2.9230	0.0857	17314	8458619	0.00	1.08781898	0.84588432		

KPP2139	3.067	0.000	17.50379	0.00009	2.6373	0.0546	2.9065	0.0746	6730	7252917	0.07	1.06736457	0.74674934		
KPP2367	93.870	0.000	20.33783	0.00002	4.7755	0.0164	4.7642	0.0178	4243	164655	58.83	0.73463666	0.69851589	232167	56119541
KPP2411	310.172	0.000	20.90931	0.00003	2.4109	0.0298	2.4166	0.0158	8553	815793	13.12	1.12553918	0.82976294	568790	529860638
KPP2552	358.767	0.000	23.07644	0.00006	1.6503	0.0455	2.3403	0.0335	23057471	36824884	0.00	1.05537057	0.82601243		
1228187+355621	26.943	0.000	5.79485	0.00004	9.1884	0.0382	9.1404	0.0252	632	123239	76.33	0.60222888	0.60004646	14554	39674985
KPP3873	42.115	0.003	1.51090	0.00008	16.7123	0.0725	16.9671	0.0608	90	185268	58.45	1.00000000	1.00000000	604	56700084 1)
1231573+372242	92.737	0.000	7.89628	0.00005	8.4057	0.0403	8.4260	0.0345	932	112293	77.20	0.79929084	0.59925455	24196	31995313
1236578+321525	148.750	0.001	3.22141	0.00005	9.7417	0.0378	9.7817	0.0413	328	104367	81.71	0.63000000	0.63296354	5310	30168289 2)
1244479+424735	29.779	0.001	3.55269	0.00004	10.2689	0.0356	10.2934	0.0369	345	75677	92.82	0.64922309	0.59940493	5759	18733836
1249090-015259	317.960	0.000	51.74363	0.00004	6.8842	0.0224	6.8590	0.0294	7488	136685	68.27	0.64950794	0.55066031	594717	463822950
1250276+415305	131.832	0.001	3.08080	0.00003	9.9885	0.0350	9.9959	0.0242	307	60282	97.53	0.56000000	0.53000000	5177	14255152 3)
1250455+330354	183.271	0.001	7.51253	0.00007	13.6910	0.0422	13.6237	0.0445	548	76624	96.89	0.89634675	0.49849528	10908	18058670
1301404+365755	65.799	0.000	9.92071	0.00005	9.3232	0.0280	9.3543	0.0434	1058	98471	83.74	0.55004287	0.44911414	34641	31084624
1310523+350253	76.390	0.000	15.41719	0.00005	8.9640	0.0332	9.0197	0.0414	1707	147248	66.11	0.92802906	0.34907988	62768	50275553
HJ 2617 AB	1.802	0.001	5.70000	0.00007	15.4621	0.0517	15.3911	0.0650	368	67661	97.30	1.11630666	0.90261042	4995	12455011
BKO 114 AD	343.650	0.000	43.50948	0.00006	15.4621	0.0517	15.4183	0.0512	2803	50481	99.43	2.01891708	0.50165701	93992	7183678
KZA 46	325.516	0.000	48.98732	0.00004	2.3341	0.0357	2.0159	0.0282	5360413	13944699	0.00	1.11220658	1.01851916		
KZA 50	254.356	0.000	25.25719	0.00004	4.3357	0.0298	2.2696	0.0289	38028514	43303593	0.00	1.12631285	1.02119076		
KZA 54	18.206	0.000	19.16765	0.00004	3.0813	0.0283	1.6204	0.0273	51221705	60351884	0.00	1.04697990	0.97288877		
KZA 56	210.402	0.000	42.35886	0.00003	2.4542	0.0276	2.4519	0.0259	16978	874133	12.32	1.12608540	1.02707481	1515920	560049356
KZA 60	211.352	0.000	11.48326	0.00003	2.5524	0.0321	2.4967	0.0232	4498	1812629	4.55	0.94433105	0.89852941	223459	1807655519
LDS1375	217.615	0.000	18.22326	0.00003	6.3099	0.0349	6.3080	0.0199	2869	140154	66.21	0.74982393	0.69809288	128427	43846331
UC 2520 AB	225.127	0.000	4.07999	0.00003	12.5379	0.0268	12.5162	0.0249	325	38333	99.98	0.64937556	0.60026121	5270	6751074
PAL 4 AC	11.073	0.000	5.43064	0.00003	12.5379	0.0268	1.7502	0.0222	95061584	101409805	0.00	0.64937556	0.85005802		
UC 2510	12.752	0.000	6.71319	0.00004	9.2980	0.0290	9.2927	0.0323	720	70327	94.42	0.75008655	0.65142661	16400	15840889
UC 2529	2.908	0.000	9.03028	0.00004	5.4111	0.0355	5.4685	0.0247	1649	402120	22.96	0.86693126	0.61773920	55258	210434457

## Notes

- 1) Sun mass assumed for both components
- 2) Mass primary estimated similar to secondary based on similar visual magnitudes
- 3) Mass estimations based on luminosity

All objects in table 2 were already cross-matched with GAIA data in other reports, so the values given here on separation and position angle are referenced as input for assessing the likelihood of potential gravitational relationship but not intended for updating the WDS catalog. For the objects with LPGR >50 WDS code “T” is suggested for likely physical by common parallaxes but in all these cases (may be with exception of KPP3873) the potential orbit period is far too long to detect any changes in separation and position angle by visual observation over a reasonable time frame. For the objects with LPGR < 10 WDS code “U” for likely optical is suggested.

## Summary

A part of the measured objects shows the expected magnitude difference larger than 0.5 compared with the WDS catalog data especially for the secondary but for many objects the given WDS magnitudes were simply confirmed within the given error range. 16 objects have parallaxes and angular separations allowing for a higher than 50% likelihood for a spatial distance between the components of less than 200,000 AU ( $\sim 1$  parsec) suggesting potential gravitational relationship and 24 objects are most likely optical.

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GAIA DR2 catalog  
DSS2 images  
Aladin Sky Atlas v10.0  
iTelescope iT24: 610 mm CDK with 3962 mm focal length. Resolution 0.625 arcsec/pixel. V-filter. No transformation coefficients available.  
Located in Auberry, California. Elevation 1405 m  
AAVSO VPhot  
ASTROMETRICS v4.10.0.427  
URAT1 catalog  
AstroPlanner v2.2  
MAXIM DL6 v6.08  
GAIA DR2 StarHorse catalogue available through the Gaia@AIP services hosted by the Leibniz-Institute for Astrophysics Potsdam using the ADQL query interface at `gaia.aip.de`.

## Appendix

Description of the PGR assessment procedure (according to Knapp<sup>2</sup>):

- GAIA DR2 data for RA, Dec and Plx are used for a Monte Carlo simulation assuming a normal distribution for these parameters with the given error range as standard deviation. The distance between the components is calculated from the inverted simulated parallax data and the simulated angular separation using the law of  $\cos(\sqrt{a^2 - 2 * a * b * \cos(sep)} + b^2)$  with  $a$  and  $b$  distance vectors for the stars A and B in lightyears calculated as  $(1000/Plx) * 3.261631$  and  $sep = \arccos(\sin(\delta_1) * \sin(\delta_2) + \cos(\delta_1) * \cos(\delta_2)) * \cos(abs(\alpha_1 - \alpha_2))$
- The likelihood for potential gravitational relationship (LPGR) is the percentage of simulation results  $< 200,000$  AU ( $\sim 1$  parsec) out of the simulation sample with a size of 120,000 corresponding with the likelihood that the real distance is smaller than 200,000 AU with an margin of error of 0.37% at 99% confidence
- The minimum, median and maximum distance is the smallest, median and largest result of the simulation sample
- Ignoring the likely effects of eccentricity the smallest/median/largest distance is used as estimation for the value for the semi-major axis of a potential orbit allowing for the calculation of a minimum/median/maximum orbit period assuming zero inclination using either median mass data from Anders *et al.*<sup>1</sup> or if not available mass estimation from luminosity<sup>1</sup> for assumed masses between 0.43 and 2 Sun masses or if luminosity values are not available then in total double Sun mass or other estimations.

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