The Webb Deep-Sky Society

Double Star Section Circular No 31

Contents

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Editorial

The number of measures included in these Circulars is now 87110.

Observer	WDS code	Pairs	Measures	Method/source
A. Alzner	ALZ	143	377	Lyot micrometer
J.- F. Courtot	CTT	40	151	RETEL, homemade filar, Lyot micrometer
A. Debackère	DBR	10	10	Internet astrometry
W. Knapp	KPP	247	247	Internet astrometry
TOTALS		440	785	

Bob Argyle, 2023 July

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://www.crf.usno.navy.mil` with a mirror site at `http://www.astro.gsu.edu/wds`

Journal for Double Star Observations (`www.jdso.org`)

Etoiles Doubles (in French)
A newly established on-line journal and freely available from `www.etoilesdoubles.org`

El Observador de Estrellas Dobles (in Spanish)
(`www.elobservadordeestrellasdobles.wordpress.com`)
(Unfortunately this publication has closed down. The website currently contains all 27 of the published bulletins.)

Observatori Astronòmic del Garraf (`www.oagarraf.net`)

Il Bollettino delle Stelle Doppie (in Italian)
(`https://sites.google.com/site/ilbollettinodellestelledoppie/`)

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 `http://stelledoppie.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).

MICROMETRIC MEASURES OF DOUBLE STARS IN 2022

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Introduction

The measurements presented here have been made during 2022 using two different telescopes: a homemade 205-mm (8-inch) Newtonian and either a Retel filar micrometer at a power of x508 or a Lyot double-image micrometer at x 464, and a 279-mm (11-inch) Schmidt-Cassegrain telescope at x430 up to x 640 with different homemade filar micrometers[1] and a homemade double-image micrometer at x614.

The measurement procedures have been outlined in previous circulars i.e. DSSC 23[2]. Further indications on some observed peculiarities with double-image micrometers can also be found in DSSC 24-25 (Ref. 3-4).

Measurements have been arranged as usual in Table 1. Epochs are in Julian years. In last column, "T205" denotes the 205-mm Newtonian telescope, "C11" the 11-inch Schmidt-Cassegrain, "L" is for the Lyot double-image micrometers whilst "F" indicates that a filar micrometer has been used. Table 2 gives a short comment on each measured pair.

As usual also, besides known orbital pairs, a few other pairs with uncertain status have been measured. When available, Gaia-DR2/3 proper motions, parallaxes, luminosity and radial velocity data have been used to investigate their true nature using Dommanget's criteria[5,6]. The followed procedure can be found in DSSC 28 circulars[7].

Table 1 - Measures

Pair	RA	Dec	Va	Vb	PA(°)	Sep(″)	Epoch	N	Obs.	Method
STF73AB	00550	+2338	6.1	6.5	337.7	1.22	2022.034	4	CTT	T205/L
STF180AB	01535	+1918	4.5	4.6	1.4	7.26	2022.066	4	CTT	T205/F+L
STF425AB	03401	+3407	7.5	7.6	57.8	1.91	2022.108	4	CTT	T205/F+L
STT98	05079	+0830	5.8	6.7	281.4	0.97	2022.153	4	CTT	T205/L
STF795	05480	+0627	6.0	6.0	221.2	0.99	2022.176	4	CTT	T205/L
STF932	06344	+1445	8.3	8.5	304.2	1.67	2022.194	4	CTT	T205/L
STF1037AB	07128	+2713	7.2	7.3	301.1	0.79	2022.227	5	CTT	T205/L+C11/L
STF1196AB	08122	+1739	5.3	6.3	359.4	1.18	2022.270	5	CTT	T205/L+C11/L
STF1273AB-C	08468	+0625	3.5	6.7	312.8	2.68	2022.293	4	CTT	T205/L
STT215	10163	+1744	7.3	7.5	175.0	1.52	2022.313	4	CTT	T205/L
STF1523AB	11182	+3132	4.3	4.8	143.8	2.43	2022.349	4	CTT	T205/L
STF1527	11190	+1416	7.0	8.0	308.4	0.53	2022.369	4	CTT	T205/L+C11/L
STF1547AB	11317	+1422	6.3	9.1	331.5	15.51	2022.386	4	CTT	C11/F
STF1639AB	12244	+2535	6.7	7.8	322.4	1.88	2022.393	4	CTT	T205/L+C11/F
STF1768AB	13375	+3618	5.0	7.0	96.7	1.66	2022.429	4	CTT	T205/L
STF1883	14489	+0557	7.0	7.1	277.2	1.08	2022.454	4	CTT	T205/L
STF1932AB	15183	+2650	7.3	7.4	267.8	1.63	2022.492	4	CTT	T205/L
STT298AB	15360	+3948	7.2	8.4	191.8	1.20	2022.509	4	CTT	T205/L
STT303AB	16009	+1316	7.7	8.1	175.2	1.65	2022.528	4	CTT	T205/L
STF1998AB	16044	−1122	4.8	4.9	14.6	1.20	2022.540	4	CTT	T205/L
STF2055AB	16309	+0159	4.2	5.2	47.8	1.31	2022.562	4	CTT	T205/L
STF2107AB	16518	+2840	6.9	8.5	108.7	1.51	2022.587	4	CTT	T205/L+C11/F
STF2118AB	16564	+6502	7.1	7.3	64.8	1.05	2022.601	4	CTT	C11/F+L
STF2199	17386	+5546	8.0	8.6	51.7	2.13	2022.612	4	CTT	C11/F

STF2289	18101	+1629	6.7	7.2	218.5	1.25	2022.642	4	CTT T205/L+C11/F
STF2323AB	18239	+5848	5.1	8.1	347.3	3.74	2022.651	4	CTT T205/L+C11F
STF2323AC	18239	+5848	5.1	8.0	18.9	89.18	2022.657	4	CTT T205/F+C11/F
STF2486AB	19121	+4951	6.5	6.7	202.9	6.94	2022.685	4	CTT T205/
STF2576FG	19464	+3344	8.5	8.6	153.7	3.22	2022.686	4	CTT T205/F
STF2596	19540	+1518	7.3	8.7	296.2	2.18	2022.718	4	CTT T205/F
STF2658AB	20136	+5307	7.2	9.4	105.2	5.33	2022.736	4	CTT T205/F
STF2658AC	20136	+5307	7.2	10.3	204.2	66.53	2022.736	4	CTT T205/F
HO128AB	20229	+4259	6.4	8.8	355.0	1.30	2022.770	4	CTT T205/F
STTA207AC	20229	+4259	6.4	8.0	64.4	85.45	2022.786	4	CTT T205/F
STF2725AB	20462	+1554	7.5	8.2	12.6	6.24	2022.766	4	CTT T205/F
STF2727AB	20467	+1607	4.4	5.0	265.3	8.97	2022.766	4	CTT T205/F
STT437AB	21208	+3227	7.2	7.4	18.5	2.52	2022.806	4	CTT T205/F+L
SHJ345AB	22266	−1645	6.3	6.4	103.2	1.29	2022.826	5	CTT T205/F+L
STF3050AB	23595	+3343	6.5	6.7	344.2	2.59	2022.992	3	CTT T205/L

Table 2 – Notes

Pair	ADS	Notes
STF73AB	755	Orbital pair. Direct relative motion. Second revolution since W. Struve.
STF180AB	1507	Very slow direct relative motion: 1° in 192 yrs. Getting closer: −1″.4. No Gaia-DR2 luminosity nor radial velocity data for this pair. From data published in Ref. 8 (p.106), first Dommanget criterion: 54″ (current measured separation: 7″.3). Second criterion: 9″ . The noticeable discrepancy between the two criteria likely due here to high relative error in used radial velocity data (±2 km/s i.e. 54%). After first criterion especially, possibly an orbital pair however. Relative position from Gaia-DR2 equatorial coordinates for 2015.5: 0°.8 / 7″.55, compatible with micrometric measurements.
STF425AB	2668	Orbital pair, retrograde relative motion: 48° in 192 yrs. Getting closer: −1″ .
STT98	3711	Orbital pair, retrograde relative motion: 330° since 1844. Getting wider. Nearly 1 mag. difference between both components. Clearly split with gap using the 205-mm Newtonian.
STF795	4390	Orbital pair, direct relative motion: 20° in 191 yrs. Getting closer:−0″.8.
STF932	5197	Orbital pair, retrograde relative motion: 39° in 192 yrs. Getting closer:−0″.8.
STF1037AB	58	Orbital pair, retrograde relative motion. Second revolution since W. Struve. Getting closer. Split with gap using the T205.
STF1196AB	6650	Orbital pair, retrograde relative motion. Fourth revolution since W. Struve. Getting slightly closer.
STF1273 AB-C	6993	Orbital pair, direct relative motion: 116° in 192 yrs. Getting slightly closer.
STT215	7704	Orbital pair, retrograde relative motion: 92° in 178 yrs. Near apastron.
STF1523AB	8119	Orbital pair, retrograde relative motion. Fourth revolution since W. Struve (1826).
STF1527	8128	Orbital pair, direct relative motion: 298° in 193 yrs. Getting wider. Nearly 1 magnitude difference between components. Elongated image using the T205mm. ‘8’-shaped image with the C11, no gap however.
STF1547AB	8196	Very slow orbital pair, direct relative motion: 12° in 193 yrs. Separation without any noticeable change.
STF1639AB	8539	Orbital pair, retrograde relative motion: 330° in 186 yrs. Getting slightly wider. Nearly one magnitude difference between components.
STF1768AB	8974	Orbital pair, retrograde relative motion: 339° in 191 yrs. Nearly 2 magnitude difference between components.
STF1883	9392	Orbital pair, retrograde relative motion, completing first revolution since W. Struve (1830): 354° in 192 yrs. Nearly 0.1 magnitude difference between components. Visual estimation: 7.0/7.1. WDS mentions: 7.02/8.95 (the latter not observed).
STF1932AB	9578	Orbital pair, direct relative motion, completing its first revolution since

		W. Struve (1830): 355° in 192 yrs.
STT298AB	9716	Orbital pair, direct relative motion. Fourth revolution since O. Struve (1846). Magnitude for secondary: rather 7.4 than 8.4 as mentioned in WDS.
STT303AB	9880	Orbital pair, direct relative motion: 65° in 176 yrs. Getting wider.
STF1998AB	9909	Orbital pair, direct relative motion. Fifth revolution since W. Struve (1825).
STF2055AB	10087	Orbital pair, direct relative motion. Second revolution since W. Struve (1825).
STF2107AB	10235	Orbital pair, direct relative motion. 321° in 193 yrs.
STF2118AB	10279	Orbital pair, retrograde relative motion: 179° in 190 yrs.
STF2199	10699	Orbital pair, very slow retrograde relative motion: 63° in 192 yrs.
STF2289	11123	Long period orbital pair, very slow retrograde relative motion: 25° in 193 yrs.
STF2323AB	11336	Long period orbital pair, very slow retrograde relative motion: 17° in 189 yrs.
STF2323AC	11336	Nearly fixed since W. Struve (1834).
STF2486AB	12169	Long period orbital pair, very slow retrograde relative motion: 20° in 190 yrs. Getting closer: $-3''.5$. Highly inclined orbit.
STF2576FG	12889	Orbital pair, retrograde relative motion: 344° in 191 yrs. Completing its first revolution since W. Struve.
STF2596	13082	Very long period orbital pair, retrograde relative motion: 56° in 191 yrs. Separation without any noticeable change.
STF2658AB	13560	Very long period orbital pair, retrograde relative motion: 20° in 191 yrs.
STF2658AC	13560	Certainly an optical pair. Much different parallaxes and proper motions for A and C according to Gaia-DR2. Luminosity and radial velocity missing for C. Dommanget criteria undetermined however. C brighter than B (0.1 mag. or so) at the time of observation.
HO128AB	13786	Long period orbital pair, retrograde relative motion: 39° in 136 yrs. Getting wider.
STTA207AC	13786	Important relative displacement: $12''$ in 146 yrs. Much different proper motions and parallaxes for A and C. Likely an optical pair although Dommanget criteria undetermined (no Gaia luminosity data for C component).
STF2725AB	14270	Very long period orbital pair, direct relative motion: 15° in 192 yrs, getting wider.
STF2727AB	14279	Very long period orbital pair, retrograde relative motion: 8° in 192 yrs. Getting closer.
STT437AB	14889	Very long period orbital pair, retrograde relative motion: 48° in 177 yrs, getting wider: $+1''.2$.
SHJ345AB	15934	53 Aqr. Long period orbital pair. Direct relative motion: 161° in 199 yrs. Near periastron.
STF3050AB	17149	Long period orbital pair. Direct relative motion: 153° in 190 yrs. Getting wider.

Table 3 - Residuals from known orbits

Pair	Comp	ADS	Residual(O-C) PA(°)	Sep ($''$)	Orbit	Date	Grade	Period (yrs)
STF73	AB	755	$+0°.8$	$+0''.02$	Muterspaugh	2010	2	168
STF425	AB	2668	$-1°.0$	$+0''.19$	Kiyaeva	2018	4	947
STT98		3711	$+0°.4$	$-0''.07$	Baize	1969	3	199
			$+1°.5$	$-0''.03$	Scardia	2008	2	197
			$+2°.0$	$-0''.03$	Izmailov	2019	2	198
STF795		4390	$+0°.4$	$+0''.01$	Izmailov	2019	4	1260
STF932		5197	$+5°.5$	$+0''.06$	Hopmann	1960	5	2360
STF1037	AB	5871	$+0°.6$	$+0''.01$	Scardia	2015	2	118
STF1196	AB	6650	$+3°.9$	$+0''.05$	Söderhjelm	1999	1	60
			$+2°.9$	$+0''.08$	Izmailov	2019	1	59
STF1273	AB−C	6993	$+0°.2$	$-0''.02$	Izmailov	2019	3	372
STT215		7704	$+0°.2$	$+0''.04$	Izmailov	2022	4	468
STF1523	AB	8119	$-0°.2$	$+0''.02$	Mason	1995	1	60
			$-0°.4$	$+0''.06$	Izmailov	2019	1	60

STF1527		8128	$-3^\circ.7$	$-0''.03$	Tokovinin	2012	3	415
STF1547	AB	8196	$-0^\circ.8$	$+0''.17$	Hartkopf	2013	5	3453
STF1639	AB	8539	$-0^\circ.1$	$0''.00$	Olevic	2000	4	575
			$-1^\circ.9$	$+0''.06$	Izmailov	2019	3	421
STF1768	AB	8974	$+3^\circ.8$	$+0''.02$	Söderhjelm	1999	3	228
			$+3^\circ.0$	$-0''.06$	Izmailov	2019	3	245
STF1883		9392	$+0^\circ.6$	$+0''.02$	Izmailov	2019	2	226
STF1932	AB	9578	$-0^\circ.5$	$+0''.03$	Izmailov	2019	2	197
STT298	AB	9716	$+0^\circ.1$	$+0''.03$	Söderhjelm	1999	1	55
			$+0^\circ.4$	$+0''.05$	Izmailov	2019	1	55
STT303	AB	9880	$+0^\circ.4$	$+0''.05$	Izmailov	2019	4	1114
STF1998	AB	9909	$-0^\circ.7$	$+0''.08$	Docobo	2009	1	46
STF2055	AB	10087	$+0^\circ.2$	$-0''.07$	Heintz	1993	2	129
			$+0^\circ.3$	$-0''.05$	Izmailov	2019	2	129
STF2107	AB	10235	$-1^\circ.8$	$+0''.16$	Scardia	1984	3	258
			$+1^\circ.1$	$+0''.08$	Izmailov	2019	2	274
STF2118	AB	10279	$-2^\circ.0$	$-0''.26$	Scardia	1981	4	578
			$+0^\circ.2$	$+0''.15$	Izmailov	2019	3	321
STF2199		10699	$+0^\circ.9$	$+0''.18$	Popovic	1995	5	1299
			$-1^\circ.4$	$+0''.07$	Izmailov	2019	4	1126
STF2289		11123	$+3^\circ.7$	$+0''.01$	Hopmann	1964	4	3040
			$+0^\circ.3$	$+0''.04$	Izmailov	2019	4	1959
STF2323	AB	11336	$-0^\circ.5$	$0''.00$	Novakovic	2006	5	3952
			$-0^\circ.8$	$-0''.03$	Izmailov	2019	4	2456
STF2486	AB	12169	$+0^\circ.3$	$-0''.24$	Hale	1994	5	3100
			$-0^\circ.3$	$-0''.12$	Izmailov	2019	4	1459
STF2576	FG	12889	$-0^\circ.1$	$+0''.08$	Söderhjelm	1999	2	232
STF2596		13082	$+0^\circ.3$	$+0''.20$	Izmailov	2019	4	2971
STF2658	AB	13560	$-0^\circ.2$	$-0''.04$	Izmailov	2019	5	5632
HO128	AB	13786	$-0^\circ.7$	$-0''.02$	Izmailov	2019	5	1028
STF2725	AB	14270	$+0^\circ.3$	$-0''.01$	Hopmann	1973	4	2851
			$+0^\circ.6$	$+0''.02$	Izmailov	2019	4	2107
STF2727	AB	14279	$+0^\circ.7$	$+0''.15$	Hale	1994	4	3249
STT437	AB	14889	$0^\circ.0$	$+0''.06$	Izmailov	2019	4	1218
SHJ345	AB	15934	$+1^\circ.0$	$+0''.03$	Tokovinin	2020	4	2000
STF3050	AB	17149	$+0^\circ.5$	$+0''.06$	Izmailov	2019	3	573

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Acknowledgements

Sincere thanks to Bob Argyle for arranging and editing this Circular and to our colleagues at the US Naval Observatory for maintaining the Washington Double Star Catalogue. This work makes use also of results from the European Space Agency (ESA) space mission Gaia. Gaia data are being processed by the Gaia Data Processing and Analysis Consortium (DPAC). Funding for the DPAC is provided by national institutions, in particular the institutions participating in the Gaia MultiLateral Agreement (MLA).
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 WITH A 32.5-CM F19 CASSEGRAIN AND A MECA-PRECIS DOUBLE IMAGE MICROMETER FROM 2021.14 TO 2023.14

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Results and Method

The total number of measurements is 377 on 143 double stars. In addition, nine negative observations on seven pairs were obtained. Most of the pairs are in orbital motion. All measurements were obtained by using a 32.5-cm f/19 Cassegrain sited in Hemhofen (latitude N49° 42′) close to Erlangen, Germany. The telescope was designed and constructed in 1996 by Peter Grosse, employee of Zeiss Jena. The limit for clearly resolvable stars is 0″.40.

The following micrometer was used: a MECA PRECIS Double Image Micrometer with a spar plate (type Bernard Lyot) with magnifications of 390x, 490x, 620x, 690x, 770x. Mostly, the 620x magnification was applied. On each night, the distance and the PA each are set two to ten times (mostly four times). When the distance is less than about 0″.4, the distance is measured as well as 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 118 pairs with known orbits and the corrections for precession were taken into account. In some cases, the residuals were additionally calculated for older orbit calculations that are included in the WDS Master file database.

Acknowledgements

Many thanks to R. W. Argyle for his support and the Webb Society for publishing the results. I thank R. Matson, Stephen J. Williams, W.I. Hartkopf and B. Mason for maintaining the WDS - an indispensable tool accompanying me for more than 30 years. For the calculation of the residuals mostly the orbital elements given in the 6th Catalogue of Orbits of Visual Binary Stars available from the U.S. Naval Observatory were used.
This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France and the Washington Double Star Catalog maintained at the U.S. Naval Observatory.

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Table 1 - Measures

In this table, the position angle has not been corrected for precession, and is thus based on the epoch of observation.

Col 1:	Pair = Name of star
Col 2:	Component (cL = center of luminosity)
Col 3:	RA 2000
Col 4:	DEC 2000
Col 5:	Δm = estimated magnitude difference
Col 6:	PA (°)
Col 7:	Separation (″)
Col 8:	Epoch
Col 9:	N = number of nights
Col 10:	observer
Col 11:	note indicated

Observer: Andreas Alzner, method: 325-mm Cassegrain, Double image micrometer

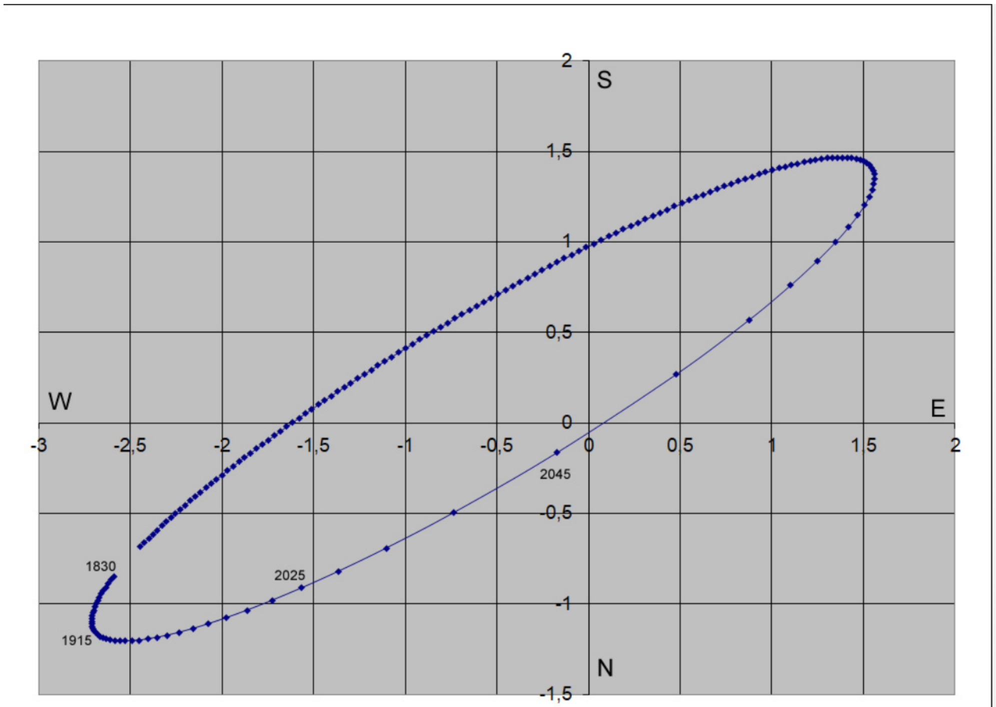
Pair	Comp	RA	Dec	Δm	PA(°)	Sep(″)	Epoch	N	Observer	
STF202		0202.0	+0246	1.1	259.7	1.87	2023.06	3	Alz	
STF299	AB	0243.3	+0314	2.5	299.5	1.93	2023.09	5	Alz	note
STF333		0259.2	+2120	0.5	210.7	1.32	2023.11	3	Alz	
STF367		0314.0	+0044	0.1	127.6	1.30	2023.11	2	Alz	
HDS509	AaAb	0401.8	+1000	1.9	53.5	0.74	2021.15	2	Alz	note
STT71		0406.9	+3327	1.9	234.7	0.75	2023.13	2	Alz	
STF460		0410.0	+8042	0.8	155.8	0.78	2022.15	2	Alz	
STT77		0415.9	+3142	0.0	306.5	0.42	2021.15	2	Alz	
STT75		0418.6	+6030	0.4	184.0	0.30	2023.13	2	Alz	
STF535		0423.3	+1123	1.2	266.8	1.08	2023.13	2	Alz	
STF554		0430.1	+1538	2.0	16.6	1.33	2021.15	2	Alz	
STF559		0433.3	+1757	0.1	276.8	2.94	2023.08	2	Alz	
STF566	AB-C	0440.0	+5328	1.3	156.8	0.79	2022.15	2	Alz	
STF577		0442.2	+3731	0.1	314.6	0.71	2023.12	4	Alz	
HU612		0447.8	+5318	1.0	6.8	0.71	2022.15	2	Alz	
STT95		0505.5	+1948	0.6	291.9	0.93	2022.15	2	Alz	note
STT98		0507.9	+0830	0.8	280.4	0.97	2022.15	2	Alz	
STF657		0518.8	+5250	0.5	312.0	0.94	2023.12	5	Alz	
WNC2	A-BC	0523.9	−0052	0.3	158.7	3.11	2021.14	1	Alz	
DA5	AB	0524.5	−0224	1.3	75.9	1.82	2022.16	3	Alz	note
STF677		0524.7	+6323	0.7	105.9	1.19	2022.17	2	Alz	
STF728		0530.8	+0557	1.1	44.1	1.30	2022.18	4	Alz	

DA3		0535.9	−0538	0.8	171.3	0.86	2022.17	1	Alz	
STF742		0536.4	+2200	0.4	275.1	4.17	2023.12	3	Alz	
STF774		0540.7	−0157	2.0	166.9	2.47	2022.20	2	Alz	note
STF787		0546.0	+2119	0.6	56.9	0.67	2021.15	2	Alz	
STT119		0547.9	+0758	0.4	354.6	0.71	2021.15	2	Alz	
STF795		0548.0	+0627	0.0	222.8	1.00	2021.16	1	Alz	note
				0.0	219.9	0.96	2022.16	2	Alz	
				0.0	221.5	0.97	2023.14	1	Alz	
STF3115		0549.1	+6248	0.9	329.6	0.78	2023.14	3	Alz	
STT124		0558.9	+1248	1.2	297.9	0.63	2022.16	2	Alz	note
STT121		0605.3	+7400	0.8	202.5	0.38	2023.14	1	Alz	
BU1008		0614.9	+2230	2.8	256.2	1.90	2021.16	2	Alz	note
STF881		0622.1	+5922	0.8	154.1	0.66	2023.14	1	Alz	
STT139		0625.6	+2227	1.2	262.9	0.82	2022.18	2	Alz	
STF932		0634.4	+1445	0.2	303.4	1.59	2022.18	2	Alz	
STT150		0639.3	+4200	0.9	5.8	0.31	2022.18	2	Alz	
STT157		0647.8	+0020	0.4	157.1	0.63	2022.18	2	Alz	
STF981		0655.5	+3010	0.4	109.6	0.71	2022.18	3	Alz	
STT159		0657.3	+5825	1.3	238.7	0.75	2022.18	2	Alz	
STF1037		0712.8	+2713	0.1	299.5	0.81	2022.20	3	Alz	
STT520		0713.8	+2830	1.7	32.8	0.63	2021.24	2	Alz	note
STF1110	AB	0734.6	+3153	0.7	51.5	5.42	2021.25	4	Alz	
				0.7	50.2	5.50	2022.22	3	Alz	
STF1126		0740.1	+0514	0.5	176.0	0.83	2021.26	2	Alz	
STF1157		0754.6	−0248	0.1	168.4	0.66	2021.25	3	Alz	
STF1165		0802.1	+5437		single		2021.27	1	Alz	note
STF1175		0802.4	+0409	1.4	289.7	1.47	2022.20	3	Alz	
STT186		0803.3	+2616	0.2	74.0	1.04	2022.22	3	Alz	
STF1187		0809.5	+3213	1.0	20.5	3.09	2021.15	2	Alz	
				0.6	20.0	3.03	2022.22	3	Alz	
COU47		0839.7	+2005		(companion not seen)		2022.20	1	Alz	
STF1273	cL(AB)-C	0846.8	+0625	2.7	313.7	2.70	2022.21	2	Alz	
A2473		0850.7	+1800	0.0	113.4	0.26	2022.23	2	Alz	note
VDK3		0850.7	+0752	0.5	204.3	0.99	2022.23	2	Alz	
STF1318		0913.6	+4659	1.4	227.5	2.46	2022.23	2	Alz	
STF1338		0921.0	+3811	0.4	316.9	1.18	2021.15	2	Alz	note
STT200		0924.9	+5134	2.1	334.1	1.21	2021.24	2	Alz	
STF1355		0927.3	+0614	0.0	357.0	1.73	2021.29	2	Alz	
STF1374		0941.4	+3857	1.0	312.9	2.73	2022.21	3	Alz	
STF1406		1005.6	+3105	1.1	216.6	0.77	2022.27	2	Alz	
A2142		1005.7	+4103	0.8	293.8	1.11	2022.30	1	Alz	
STT215		1016.3	+1744	0.3	174.8	1.48	2021.25	3	Alz	
STF1424		1020.0	+1951	1.4	126.6	4.70	2022.35	3	Alz	
STF1426		1020.5	+0626	0.4	312.6	0.92	2021.31	2	Alz	
STT216		1022.7	+1621	2.5	230.5	2.30	2021.26	2	Alz	
STT217		1026.9	+1713	0.3	150.0	0.84	2021.24	2	Alz	
STT220		1029.2	+1009		(companion not seen)		2021.27	1	Alz	
STF1457		1038.7	+0544	0.5	334.3	1.85	2022.34	2	Alz	
STT228		1047.3	+2235	0.8	166.6	0.66	2021.31	2	Alz	
A2773		1052.6	+0500	1.7	345.8	1.74	2021.30	3	Alz	
STF1517		1113.7	+2008	0.1	133.2	0.74	2022.34	2	Alz	

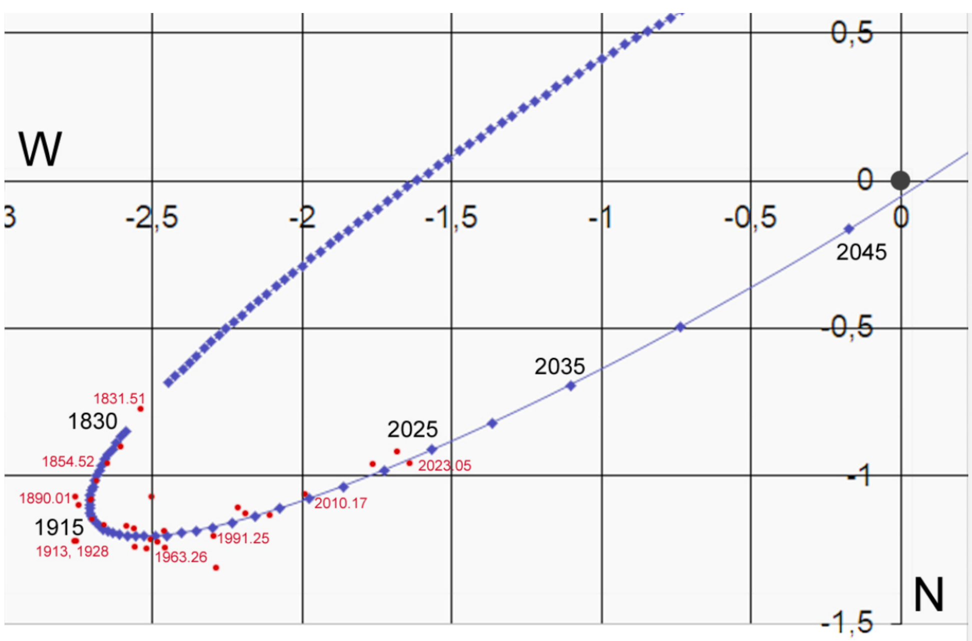
STF1523	AB	1118.2	+3132	0.5	147.9	2.24	2021.27	2	Alz	note
				0.5	142.7	2.30	2022.34	2	Alz	
STF1527		1119.0	+1416	1.0	314.4	0.62	2022.34	2	Alz	
STT235		1132.3	+6105	1.3	51.8	0.93	2021.24	2	Alz	
STF1555		1136.3	+2747	0.1	149.0	0.70	2021.25	3	Alz	
				0.1	150.7	0.71	2022.35	3	Alz	
BU602		1146.8	+1500		(companion not seen)		2021.32	1	Alz	
BU794		1153.7	+7345	1.1	79.0	0.55	2021.27	2	Alz	
STF1606		1210.8	+3953	0.6	137.4	0.68	2022.34	2	Alz	
STF1639		1224.4	+2535	1.0	323.3	1.88	2022.39	2	Alz	
STT251		1229.1	+3123	0.8	60.8	0.80	2021.31	2	Alz	
				0.8	62.2	0.74	2022.38	2	Alz	
STF1668		1240.9	+0850	0.5	187.4	1.06	2021.32	1	Alz	
				0.5	184.7	1.05	2022.38	2	Alz	
STF1670		1241.7	−0127	−0.1	355.4	3.05	2021.36	3	Alz	
				0.0	353.7	3.17	2022.37	5	Alz	
STF1687	AB	1253.3	+2114	1.4	205.4	1.22	2021.27	1	Alz	
				2.0	204.6	1.11	2022.38	1	Alz	
MET9		1254.7	+2206		too faint		2021.27	1	Alz	
STT261		1312.0	+3205	0.1	337.7	2.58	2022.40	3	Alz	
STF1734		1320.7	+0257	0.6	173.0	1.11	2022.40	3	Alz	
STF1742		1324.3	+0124	0.4	0.0	0.95	2022.39	2	Alz	
STT266		1328.4	+1543	0.3	358.0	1.97	2022.39	3	Alz	
STF1757		1334.3	−0019	1.1	146.9	1.54	2022.40	3	Alz	
STF1781		1346.1	+0507	0.7	199.0	1.08	2022.40	3	Alz	
STF1819		1415.3	+0308	0.1	152.8	0.91	2022.41	5	Alz	
STF1834		1420.3	+4831	0.1	104.7	1.72	2022.41	3	Alz	
STF1865		1441.1	+1344		round		2021.45	2	Alz	
STF1877		1445.0	+2704	2.4	345.1	2.84	2021.13	3	Alz	
				2.5	344.9	2.83	2022.43	4	Alz	
STF1888		1451.4	+1906	2.3	295.2	5.08	2021.45	2	Alz	
				1.9	293.7	5.01	2022.46	2	Alz	
STT287		1451.5	+4456	−0.1	8.3	0.54	2021.45	2	Alz	
STF1909		1503.8	+4739	−	172.6:	0.23 :	2021.45	2	Alz	note
				0.8	195.1	0.29	2022.43	3	Alz	
STF1926		1514.9	+3818	−	191.6	elong.?	2022.44	1	Alz	
STT295		1515.0	+3649		round		2021.45	2	Alz	
STF1937		1523.2	+3017	0.5	316.0	0.36	2021.45	2	Alz	
				0.3	331.6	0.50	2022.44	2	Alz	
STF1938	BC	1524.5	+3723	0.5	1.5	2.22	2022.45	4	Alz	
HU149		1524.6	+5413	0.0	271.0	0.69	2022.44	2	Alz	
STF1944		1527.7	+0605	0.6	289.0	0.65	2022.44	3	Alz	
STF1954		1534.8	+1032	1.4	170.5	4.04	2022.45	3	Alz	
STF1985		1555.9	−0210	1.5	354.6	5.94	2022.45	1	Alz	
STT303		1600.9	+1316	0.4	174.0	1.66	2021.47	2	Alz	
				0.4	174.1	1.65	2022.46	2	Alz	
STF2052		1628.9	+1825	0.2	117.2	2.48	2022.52	3	Alz	
STF2055		1630.9	+0159	1.1	48.8	1.35	2022.51	2	Alz	
STF2091		1642.2	+4112	−	336.7	0.31	2021.46	3	Alz	
D15		1643.9	+4329	0.2	318.9	0.65	2021.45	2	Alz	
STF2107		1651.8	+2840	1.5	107.5	1.44	2022.56	1	Alz	

STF2118		1656.4	+6502	0.3	66.3	0.92	2022.54	2	Alz	
STF2130		1705.3	+5428	0.0	355.9	2.58	2022.55	3	Alz	
STF2161		1723.7	+3708	1.1	320.1	3.99	2021.48	1	Alz	
STF2207		1737.1	+6707	0.4	106.2:	0.32	2022.19	3	Alz	note
STF2199		1738.6	+5546	0.7	53.2	2.08	2021.60	2	Alz	
				0.8	53.1	2.11	2022.56	1	Alz	
H 1 41		1739.7	+7256	0.5	337.5	0.95	2022.54	2	Alz	
STF2218		1740.3	+6341	1.3	305.9	1.49	2022.54	1	Alz	
STF2215		1747.1	+1742	1.2	245.4	0.48	2022.56	1	Alz	
STT349		1753.0	+8354	0.5	49.2	0.55	2022.54	2	Alz	
AC15		1807.0	+3034	3.8	337.7	1.55	2022.56	1	Alz	
HU674		1809.7	+5024	0.7	210.6	0.78	2022.19	3	Alz	
STT353		1820.8	+7120	1.3	262.6	0.57	2021.60	2	Alz	
STT363		1837.4	+7741	0.3	339.6	0.66	2022.63	2	Alz	
STF2384		1838.4	+6708	0.5	303.1	0.35	2022.54	2	Alz	note
STF2382	AB	1844.3	+3940	0.7	344.0	2.21	2021.76	3	Alz	
STF2383	CD	1844.4	+3937	0.1	74.1	2.33	2021.76	3	Alz	
AG366		1858.1	+4711	0.0	181.0	1.36	2022.76	2	Alz	
STT380		19426	+1150	1.0	74.7	0.36	2021.74	2	Alz	
STF2579		1945.0	+4508	3.8	213.6	2.78	2022.76	2	Alz	
STT387		1948.7	+3519	0.5	92.4	0.49	2021.74	2	Alz	
				0.7	87.8	0.39	2022.78	2	Alz	
STF2583		1948.7	+1148	0.6	104.4	1.44	2021.74	3	Alz	
HDS2828		1951.3	+4723	–	162:	0.26 :	2022.76	2,3	Alz	note
DJU4		1953.5	+2405	3.0	244.6	1.50	2021.74	2	Alz	
STF2606		1958.5	+3317	0.7	144.8	0.68	2021.75	4	Alz	
STF2609		1958.6	+3807	0.8	22.9	1.94	2021.75	4	Alz	
STT395		2002.2	+2456	0.2	128.2	0.76	2021.76	5	Alz	
				0.1	127.2	0.74	2022.81	3	Alz	
STF2723		2044.9	+1219	1.1	139.9	1.02	2021.76	2	Alz	
STT413		2047.4	+3629	1.2	0.9	0.96	2021.76	3	Alz	
STT418		2054.8	+3242	0.0	283.6	0.95	2021.76	3	Alz	
STF2783		2114.1	+5818	0.2	348.9	0.68	2022.76	2	Alz	
AGC13		2114.8	+3803	3	171.7	0.94	2022.76	2	Alz	
STT437		2120.8	+3227	0.2	18.6	2.44	2021.77	1	Alz	
				0.3	19.2	2.49	2022.84	2	Alz	
BU688		2142.6	+4103	0.3	197.1	0.41	2022.85	2	Alz	
STF2822		2144.1	+2845	1.3	325.4	1.55	2022.82	4	Alz	
STF2843		2151.6	+6545	0.3	151.3	1.30	2022.85	2	Alz	
STF2854		2204.4	+1339	0.1	83.7	1.49	2022.84	2	Alz	
STF2881		2214.6	+2934	0.4	74.9	1.31	2022.84	3	Alz	note
STF2944		2247.8	−0414	0.5	310.0	1.79	2022.88	2	Alz	
STF2950		2251.4	+6142	1.1	269.8	1.06	2022.87	3	Alz	
STF3001		2318.6	+6807	3.3	223.1	3.35	2022.89	1	Alz	
STF3017		2327.7	+7406	0.8	18.5	1.22	2022.89	1	Alz	

Table 2 - Notes to individual stars



WDS02433+0314=STF299. P=914, a=5.60. Orbital arc from 1830 to 2705, Δt=5y



WDS02433+0314=STF299. P=914, a=5.60. Normal places used for calculation, all in the 4th quadrant.

Pair	ADS	Note
STF299	2080	A first orbit (see above) was calculated by the author for this long period pair (IAU Comm. G1, Binary and Multiple Star Systems, Double Stars Information, Circular No. 209). Orbital elements are as follows: P = 914 yrs, a = $5''.6$, i = $85°.2$, node(2000) = $122°.7$, T = 2046.7, e = 0.90, omega = $274°.7$. Ephemerides for epoch t: 2023.0: $300°.0$, $1''.886$, 2024.0: $300°.2$, $1''.849$, 2025.0: $300°.3$, $1''.811$, 2026.0: $300°.5$, $1''.772$, 2027.0: $300°.6$, $1''.730$
HDS509		0401.8+1000 (no ADS designation) Very few measurements of AaAb since the Hipparcos discovery 1991 (HIP 18805). AB is the wide pair STT70, which I have seen several times but have not measured. The close pair was discovered 143 years after AB; since "AB" denoted the wide pair, "AaAb" is listed for the close. The main star is of spectral type B5V, so the motion is very slow. AB = STT70: $5^m.8$ - $11^m.2$, $\rho = 11''$ was measured in the 19th century among others 1848.52 by Otto Struve, 1879.03 by S.W. Burnham, and 1898.66 by W.J. Hussey, two of four times by the latter with the 36-inch Lick refractor. AaAb was therefore too close at that time.
STT95	3672	Jasinta's orbit (1996) predicts an increase in distance over the next few years, while Izmailov's solution (2019) predicts a slow decrease. The distance measurements of the last 30 years tend to follow the new calculation.
DA5	4002	For AB, there is a rectilinear solution given by Hartkopf *et al.* (2012).
STF774	4263	Orbital elements by W. Knapp, JDSO, Vol 17, No 4, October 19, 2021
STF795	4390	The orbit presented by Zirm in 2015 better represents the early 19th century measurements than Izmailov's 2019 solution as the latter calculation shows systematic positive residuals of the distances.
STT124	4562	Baize's provisional orbit from 1988 fails as the distance continues to increase. W. Knapp has discussed this pair in JDSO, Vol17, No 4, October 19, 2021 but did not communicate orbital elements as he considers the pair 'most likely optical'. But Otto Struve obtained two consistent measurements in 1845 and 1846 with the companion in the 4th quadrant. W.J. Hussey could not see it in 1899 with the 36-inch Lick refractor and other observers recorded it single at the end of the 19th century, so this pair is likely physical moving in a high inclination orbit.
BU1008	4841	Rectilinear solution given by Scardia *et al.* (2018) and by Hartkopf, Matson and Mason in LIN2
STT520	5893	Indeterminate orbit, very slow motion.
STF1165	6516	The last positive measurement is from 2012 (WDS precise last)
A2473	7039	Stars not separated, measurements at the limit of the 13-inch. Because of the low magnitude difference the quadrant of the 2022.23 measurement was indeterminate.
STF1338	7307	Residuals have been calculated for three older orbits, all are listed in the WDS Master file database and for the latest orbit Sca2023 (IAU, Commission G1, Double Star Information Circular No. 209 (February 2023)).
STF1523	8119	AB: P = 59.84 yrs (Heintz 1996, grade 1) Aa-A: P = 1.834 yrs(Heintz 1996, grade 9). Residuals have been calculated combining AB (Heintz 1996) and Aa-A (Heintz 1996).
STF1909	9494	2021 measurements uncertain.
STF2207	10690	Measurements difficult, position angles scattered.
STF2384	11568	Measurements with a large telescope are desirable.
HDS2828		1951.3+4723 (no ADS no). Stars not separated. Measurements with a large telescope are desirable to confirm the increasing distance.
STF2881	15769	Provisional orbit, growing residuals.

Table 3 - Residuals from known orbits or from rectilinear solutions

Pair	Comp.	ADS	Residual(O-C) PA(°)	Sep($''$)	Orbit	Date	Grade	Period (yrs)
STF202		1615	+1.4	+0.03	Scardia	2015	4	3267.4
			+0.3	+0.01	Izmailov	2019	4	1946.9984

STF299		2080	−0.6	+0.05	Alzner	2023	TBD	914
STF333		2257	+0.3	+0.02	Rica Romero	2012	4	1215,913
			+0.3	+0.02	Izmailov	2019	4	710.5425
STF367		2416	−0.6	+0.03	RAO	2014	3	753
			−1.0	+0.02	Kiyaeva	2016	3	419.9
			−0.9	+0.02	Izmailov	2019	3	370.1079
STF460		2963	−5.8	+0.11	Scardia	2003	3	372.42
STT77		3082	+1.1	−0.07	Scardia	1983	3	190.919
			−1.7	−0.05	Starikova	1985	3	187.925
			−1.3	−0.03	Scardia	2023	3	188.81
STT75		3105	−5.1	0.00	PkO	2018	4	862
STF535		3174	+2.3	−0.04	Izmailov	2019	4	532.2226
STF554		3264	+1.5	−0.09	Torres	2019	3	172.5
STF566	AB−C	3358	+0.7	−0.07	Tokovinin	2021	4	660
STF577		3390	+0.9	+0.06	RAO	2015	4	564
HU612		3434	+2.5	−0.02	Docobo	2019	4	233.7
STT95		3672	−3.2	−0.04	Jasinta	1996	4	760.34
			−1.7	+0.02	Izmailov	2019	4	897.7634
STT98		3711	+0.5	−0.03	Scardia	2008	2	197.45
			+0.8	−0.03	Izmailov	2019	2	197.5577
WNC2	A−BC	3991	+0.5	−0.05	Rica Romero	2013	5	923
DA5	AB	4002	−0.8	−0.03	Hartkopf	2012	LIN2 (Rectilinear solution)	
STF677		3956	−0.4	+0.02	Hartkopf	2008	4	361.89
			−1.0	+0.04	Izmailov	2019	4	430.1707
STF728		4115	+0.3	−0.08	Seymour	1999	4	613.69
STF742		4200	−1.7	0.00	Hopmann	1973	5	2959
STF774		4263	−0.0	+0.32	Hopmann	1967	5	1508.6
			−1.5	+0.07	Knapp	2021	5	15805
STF787		4349	+3.8	+0.03	Zirm	2014	5	920
STT119		4388	−2.8	+0.02	PkO	2018	5	944
STF795		4390	+1.8	+0.01	Zirm	2015	4	1140
			−1.3	−0.02				
			0.0	−0.01				
			+2.2	+0.01	Izmailov	2019	4	1260.0996
			−0.9	−0.02				
			+0.5	0.00				
STF3115		4376	+3.3	+0.05	Novakovic	2007	4	976.83
			−1.5	0.00	Scardia	2007	4	1370
			+1.7	+0.01	Hartkopf	2013	4	1503.7
STT124		4562	−9.1	+0.33	Baize	1988	5	140
STT121		4603	+2.8	−0.04	Docobo	1995	3	180.18
BU1008		4841	0.0	+0.02	Scardia	2018	Rectilinear solution	
			+0.4	+0.04	Hartkopf	2022	LIN2 (Rectilinear solution)	
			+1.0	+0.14	Izmailov	2019	5	1031.163
STF881		4950	+1.9	+0.04	Zirm	2013	4	503
STT139		5042	−1.8	+0.12	Heintz	1962	5	514.3
			−0.5	+0.22	Scardia	2001	5	360.3
STF932		5197	+5.4	−0.01	Hopmann	1960	5	2360
STT150		5280	−5.0	+0.01	Docobo	2012	3	231.9
STT157		5455	−1.6	+0.03	Docobo	2018	4	500
STF981		5570	−4.2	−0.13	Kiyaeva	2017	5	1089.7

STT159		5586	+0.9	+0.04	Alzner	2000	3	262
STF1037		5871	−1.1	+0.03	Scardia	2015	2	118.35
STT520		5893	+2.1	+0.02	PkO	2018	5	1279
STF1110	AB	6175	−0.1	−0.03	Docobo	2014	3	459.8
			−0.9	−0.02				
STF1126		6263	−3.0	+0.01	Zirm	2015	4	752
			−3.0	+0.02	Izmailov	2019	4	1252.2788
STF1157		6454	−2.3	−0.02	Ling	2010	4	1448
STF1175		6532	+0.3	+0.02	Izmailov	2019	4	2929.3326
STF1187		6623	+1.0	+0.11	Olevic	2001	5	1385.156
			+0.7	+0.05				
STF1273	cL(AB-C)	6993	+1.2	0.00	Izmailov	2019	3	371.8983
A2473		7039	−203.8	+0.03	Docobo	2016	3	113.4
			−23.8	+0.03	(companion in the 4th quadrant)			
			+8.0	+0.02	Tokovinin	2023		234.8
VDK3		7044	+0.7	−0.03	Izmailov	2019	4	223.9709
			+2.2	−0.04	Josties/Mason	2019	4	221.2
STF1338		7307	+1.4	−0.02	Scardia, orbitII	2002	3	444.27
			−1.1	+0.02	Mason	2018	3	424.2
			+0.4	+0.03	Izmailov	2019	3	413.4528
			+0.2	+0.02	Scardia	2023	3	381.5
STF1355		7380	+0.8	0.00	Ling	2011	4	591
			−1.4	+0.02	Izmailov	2019	4	1073.7339
STF1374		7477	+0.6	−0.07	Ling	2013	4	1377
			+0.2	−0.05	Izmailov	2019	4	1815.6124
STT215		7704	−1.0	−0.03	Scardia	2018	4	702.4
			−0.3	0.00	Izmailov	2019	4	467.9925
STF1424		7724	−0.1	−0.03	PkO	2014	4	554
STF1426		7730	−1.2	+0.03	Izmailov	2019	4	775.6553
STT216		7744	+2.4	−0.02	Scardia	2009	3	314.93
STT217		7775	+0.8	+0.04	Scardia	2015	3	138.789
STF1457		7864	+0.1	+0.01	RAO	2015	4	488
STT228		7926	−1.9	+0.03	PkO	2018	4	1229
STF1517		8094	−1.6	−0.02	Rica Romero	2015	4	924
STF1523	AB	8119	+0.4	+0.03	Heintz	1996	1	59.84
			−0.7	−0.02				
STF1527		8128	+1.9	+0.02	Scardia	2011	3	551.36
			+2.3	+0.06	Tokovinin	2012	3	415
STT235		8197	+2.8	−0.04	Soderhjelm	1999	1	72.7
			+1.2	−0.04	Izmailov	2019	1	72.9339
STF1555		8231	−2.0	+0.06	Docobo	2017	4	1730
			−0.5	+0.08				
BU794		8337	+4.8	+0.04	Soderhjelm	1999	2	76.7
STF1606		8446	−0.4	+0.03	Mason	1999	4	1431
STF1639		8539	+0.8	0.00	Olevic	2000	4	575.44
STT251		8569	−1.3	+0.10	Scardia	2003	5	540.56
			−0.4	+0.04				
STF1670		8630	−0.3	−0.04	Scardia	2007	2	169.104
			−0.9	−0.03				
STF1687	AB	8695	+3.7	+0.03	Izmailov	2019	3	486.3482
			+2.1	−0.09				

STT261		8814	−0.5	−0.06	Izmailov	2019	4	772.2055
STF1734		8864	+0.1	+0.04	Izmailov	2019	4	973.8333
STT266		8914	−0.5	0.00	Izmailov	2019	4	949.2369
STF1757		8949	−0.3	−0.05	Izmailov	2019	3	344.1128
STF1781		9019	−0.9	+0.02	Izmailov	2019	2	253.7049
STF1819		9182	+0.4	+0.03	Scardia	2012b	2	223.5
STF1834		9229	+1.2	+0.07	Hartkopf/Mason	2015	3	413.4
STF1888		9413	+0.7	0.00	Soderhjelm	1999	2	151.6
			+0.8	+0.03				
			+0.2	−0.14	Izmailov	2019	2	152.9614
			+0.1	−0.12				
STT287		9418	+3.1	−0.09	Heintz	1997	4	340
STF1909		9494	+4.5	−0.02	Zirm	2011	2	209.8
			+0.9	−0.06				
			+12.3	0.00	Izmailov	2019	2	214.7628
			+5.1	+0.02				
STF1937		9617	+0.8	−0.03	Muterspaugh	2010	1	41.63
			−1.4	+0.03				
STF1938	BC	9626	−0.2	−0.02	Kiyaeva	2014	2	265
HU149		9628	−1.2	+0.03	Zirm	2015	4	770
STF1944		9647	−1.6	+0.06	Zirm	2015	4	1030
STF1954		9701	−0.7	+0.01	Izmailov	2019	4	1150.1045
STF1985		9842	−0.5	−0.10	Izmailov	2019	5	2307.2358
STT303		9880	−0.5	+0.03	Zirm	2015	4	1460
			−0.4	+0.02				
			−0.6	+0.06	Izmailov	2019	4	1114.4707
			−0.6	+0.05				
STF2052		10075	+0.1	−0.04	Prieur	2017	2	230.06
			+0.1	−0.03	Izmailov	2019	2	229.4999
STF2055		10087	+1.4	−0.01	Izmailov	2019	2	129.0034
STF2091		10169	+1.4	+0.02	Zirm	2014	4	888
D15		10188	+1.8	+0.04	Alzner	2007	2	120.05
STF2107		10235	0.0	+0.01	Izmailov	2019	2	274.0879
STF2118		10279	+0.3	−0.20	Scardia	2002	3	422.22
			+1.8	+0.02	Izmailov	2019	3	321.3131
STF2130		10345	+2.5	−0.01	Heintz	1981	3	672
			0.0	−0.06	Prieur	2012	3	812
			+0.2	−0.01	Izmailov	2019	3	424.2713
STF2199		10699	0.0	+0.03	Izmailov	2019	4	1126.0007
			+0.1	+0.05				
STF2218		10728	−0.1	+0.09	Zirm	2015	4	2130
			+0.1	+0.11	Izmailov	2019	4	1051.1579
STF2215		10795	+3.2	+0.05	Cvetkovic	2006	4	1062.47
STT349		11006	−6.9	+0.02	Heintz	1996	4	433
AC15		11077	−1.3	+0.02	Jao	2016	2	55.91
HU674		11128	−0.6	+0.06	Mason	2017	4	773.2
STT353		11311	−1.7	+0.01	Andrade	2005	3	307.8
STT363		11584	−2.8	+0.06	Scardia	2009	4	641.9
STF2384		11568	−0.4	−0.03	Heintz	1996	3	133.5
STF2382	AB	11635	+0.2	−0.08	Mason	2004b	4	1725
	AB	11635	+0.7	+0.07	Docobo	2020	4	2802.8

STF2383	CD	11635	+0.7	−0.06	Docobo	2020	4	724.3
AG366		11899	−1.1	+0.02	WSI	2021	5	1260.888
STF2579		12880	+0.1	−0.01	Izmailov	2019	4	657.1722
STT387		12972	−0.4	+0.05	Mason	2006	2	165
			−1.6	−0.03				
			+0.1	+0.06	Josties/Mason	2021	2	165.0
			−1.2	−0.04				
DJU4		−-−	−2.4	+0.11	Cvetkovic	2008	5	615.25
STF2606		13196	−2.9	+0.05	Zirm	2015	4	455
STT395		13277	+0.3	+0.04	Izmailov	2019	4	709.37
			−0.8	+0.03				
STF2723		14233	−1.1	+0.01	Izmailov	2019	4	782.1910
STT413		14296	+1.2	+0.05	Izmailov	2019	4	800.7968
STT418		14421	+0.6	+0.02	Zirm	2013	4	787
			+0.6	+0.02	Izmailov	2019	4	709.1513
STF2783		14784	+0.6	+0.03	Zirm	2014	4	1760
AGC13		14787	−0.9	−0.08	Muterspaugh	2010	2	49.626
STT437		14889	+0.4	−0.01	Izmailov	2019	4	1218.0962
			+0.7	+0.03				
BU688		15251	−1.3	−0.02	Josties/Mason	2018	3	106.9
STF2822		15270	+0.1	+0.07	Izmailov	2019	3	692.0588
STF2881		15769	+5.0	+0.11	Izmailov	2019	4	1345.3304
STF2944		16270	−0.1	+0.05	Zirm	2007	4	1160.28
			+0.5	−0.01	Izmailov	2019	4	602.8834
STF2950		16317	0.0	−0.01	Zirm	2015	4	804
			+0.1	+0.08	Izmailov	2019	4	817.1898
STF3001		16666	−0.6	−0.10	Izmailov	2019	4	2198.7243
			−1.2	−0.05	Docobo	2021	4	1500

MEASUREMENTS OF DOUBLE STARS WITH ROBOTIC TELESCOPES IN 2022

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Abstract

These observations and measurements were made with the LCO Global Telescope Network. I have used the Gaia EDR3 catalogue since December 3rd, 2020 and the Gaia DR3 catalogue since June 13th, 2022. This is how I added the parallax of the components of each observed pairs when it is known, the *G*-band magnitude (specific to Gaia), and the precise coordinates of each component. The aim of this work is to measure the polar coordinates of the observed pairs but also to determine whether they are optical or physical couples. In the latter case, when the components have same parallax and if they have common proper motion within the errors, one can conclude their probable physicality.

Explanation of Table 1

Col.1:	WDS designation (based on 2000 coordinates)
Col.2:	Discoverer & Number
Col.3,4:	Components and Gaia-EDR3 Absolute stellar parallax (mas) & standard error of parallax (mas)
Cols.5-8:	Gaia-EDR3 proper motion in RA direction (mas/yr), standard error of proper motion in right ascension direction (mas/yr), proper motion in declination direction (mas/yr), standard error of proper motion in declination direction (mas/yr)
Col.9:	Mean date of observation (2022+)
Col.10:	Number of Observations
Col.11:	Position Angle (°)
Col 12:	Error in PA (°)
Col.13:	Separation (″)
Col.14:	Error in separation (″)
Col.15:	Mag. of star A (above); mag. of star B (below)
Col.16:	Observatory code
Col.17:	Notes

Table 1: Measures

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
04192+2914	A	2.4675	0.0245	6.573	0.032	-6.425	0.023	0.920	2	238.28	0.96	2.722	0.036	11.5	V38	1
	B	2.4888	0.0206	6.537	0.026	-6.417	0.019							12.2		
04550+3026	A	8.5430	0.0419	226.401	0.048	-124.775	0.027	0.919	2	27.83	0.63	5.456	0.034	13.4	T04	1
	B	8.5249	0.0298	224.105	0.035	-123.082	0.020							14.4		
04552+3022	A	0.7693	0.0312	2.769	0.041	-2.787	0.024	0.919	2	22.65	0.01	27.748	0.177	11.3	T04	2
	B	6.3248	0.0490	3.748	0.059	-24.298	0.035							11.7		
06508+2927	A	4.6963	0.0185	12.436	0.021	-24.910	0.018	0.929	2	20.62	0.64	6.481	0.181	10.5	Z24	2
	B	0.4231	0.0168	0.212	0.019	-6.634	0.016							11.3		
11079−7727	A	5.9195	0.1845	-23.045	0.215	1.185	0.224	0.210	2	118.03	0.11	1.835	0.001	12.6	E10	2
	B	5.4906	0.0870	-23.066	0.098	0.748	0.116							13.9		
11083−7734	A	5.3381	0.0352	-23.574	0.042	0.530	0.044	0.218	1	284.09	0.12	2.443	0.008	10.5	E10	2
	B	4.9792	0.2194	-24.710	0.246	-2.398	0.260							12.5		

11089−7732	A	5.2868	0.0557	-23.255	0.064	0.597	0.067	0.210	2	19.50	0.07	20.788	0.036	16.5	E10	2
	B	2.0839	0.0148	-12.843	0.017	-3.147	0.018							12.7		
11092−7729	A	5.4248	0.0508	-23.237	0.066	0.212	0.055	0.210	2	17.72	0.18	1.254	0.013	13.0	E10	
	B	5.4216	0.0453	-23.491	0.061	2.352	0.044							13.5		
11092−7729	A	5.4248	0.0508	-23.237	0.066	0.212	0.055	0.210	2	68.61	0.27	4.528	0.008	13.0	E10	
	C	5.4368	0.0254	-23.165	0.029	2.492	0.029							14.0		
11092−7729	B	5.4216	0.0453	-23.491	0.061	2.352	0.044	0.218	1	86.8		3.85		13.5	E10	1
	C	5.4368	0.0254	-23.165	0.029	2.492	0.029							14.0		

Table 2: Catalogue names and positions

Pair	Comp	EDR3 catalogue	EDR3 co-ordinates
TVB 69	A	164857891549222400	041914.50+291423.1
	B	164857887255386240	041914.32+291421.6
LDS 5616	A	56912025954435840	045456.57+302536.5
	B	156912025956834432	045456.77+302541.3
KSA 30	A	156907902785833984	045510.16+302133.2
	B	156907907082740480	045510.98+302159.4
HDS 949	A	888443882447477760	065046.06+292711.3
	B	888443882447476992	065046.27+292717.2
AGE 3	A	5201155402038028672	110755.74−772725.5
	B	5201155406332032000	110756.24−772726.3
GHE 27	A	5201153035509861888	110815.50−773353.4
	B	5201153035509862784	110814.77−773352.8
KSA 51	A	5201152760634067712	110854.20−773211.7
	B	5201152790697913728	110856.26−773152.0
REP 20	A	5201154444259173632	110911.64−772913.1
	B	5201154444261256704	110911.76−772911.9
REP 20	A	5201154444259173632	110911.64−772913.1
	C	5201154444259359488	110912.94−772911.6
REP 20	B	201154444261256704	110911.76−772911.9
	C	5201154444259359488	110912.94−772911.6

Observatory codes

- MPC code V38:T0.40m, McDonald Observatory, Fort Davis, Texas, USA, LCO
- MPC code T04:T0.40m, Haleakala Observatory, Haleakala, Hawaii, LCO
- MPC code E10: FTS Faulkes Telescope South T2m, Siding Spring, Australia, LCO
- MPC code Z24: T1m, Teide Observatory, Tenerife, Canary islands, Spain, LCO

Notes

1 - Physical pair (same parallax and common proper motion within the errors)
2 - Optical pair

Explanation of Table 2

Col.1:	usual name
Col.2,3:	difference between our measures of $\theta(^\circ)$ and $\rho('')$ called 'O' and the oldest measures of $\theta(^\circ)$ and $\rho('')$ listed into the WDS catalogue.
Col.4:	date of the first reliable measure into the WDS catalogue.
Col.5:	interval (in years) between the earlier reliable measures and our measures

Table II: Residuals from the WDS

Name	(O-WDS)°	(O-WDS)″	Date	Interval(yrs)
TVB 69	+0.28	+0.022	2001	21
LDS 5616	−9.17	−0.544	1960	62
KSA 30	+1.65	−1.752	1954	68
HDS 949	+0.62	+0.081	1991	31
AGE 3 AB	+0.03	−0.065	1994	28
GHE 27 AB	−0.91	+0.043	1989	33
KSA 51	+0.50	−0.112	1996	26
REP 20 AB	−4.78	+0.154	1989	33
REP 20 AC	−3.39	+0.028	1989	33
REP 20 BC	+12.8	−0.45	1998	24

Note in WDS

Daemen *et al.* (2013) derive component properties for REP 20 A, B and C as follows:

Comp.	Spectral Type	Teff (K)	Luminosity $L_\odot$	Age (million yrs)	Mass $M_\odot$	Radius $R_\odot$
A	M2.5±0.5	3490±70	0.25±0.05	2.7+0.7/-0.5	0.36±0.05	1.37±0.03
B	M2±0.5	3560±70	0.20±0.04	4.0+1.3/-0.8	0.38±0.05	1.17± 0.02
The B component is also an SB1 (single lined spectroscopic binary)						
C:	M2.5±0.5	3490±70	0.14±0.03	4.7+2.3/-1.2	0.34±0.05	1.04± 0.02

This WDS note for components B and C gives possible common properties (spectral type, effective temperatures, luminosity, age, masses and radius) which are identical within the margin error for both components. This confirms the predicted binarity due to the identical parallaxes and common proper motions indicated above.

References

Daemgen, S., Petr-Gotzens, M. G., Correia, S. *et al.*, 2013, *A&A*, **554**, A43, 20.

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. The original description of the VizieR service was published in A&AS **143**, 23
- the Gaia EDR3 Catalogue and the Gaia DR3 Cataloue
- the REDUC software
- the WDSTOOL data base

Special thanks to - Florent Losse, REDUC software (http://www.astrosurf.com/hfosaf/uk/tdownload.html#REDUC)
- David Chiron, WDSTOOL data base (http://wdstool.com/)
- Paul Roche, *Faulkes Telescope* project, Cardiff University

PHOTOMETRIC AND ASTROMETRIC MEASUREMENTS FROM CCD IMAGES TAKEN IN 2022 WITH REMOTE TELESCOPES

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Method

This article reports photometric and astrometric measurements obtained by processing CCD images taken in 2022 with the remote telescopes iT24 in Auberry, California and iT32 in Siding Spring, New South Wales, Australia with a V filter.

The main focus is on precise measurement of visual magnitudes. The WDS catalogue contains currently (Mar 2023) about 155,500 objects. Approximately 50,000 of these are listed with single-digit magnitudes, which is indicative of estimates rather than accurate measurements, and over 16,000 objects are listed with magnitudes in the blue or red band (WDS codes B/K/R/I) and therefore require measurements in the V band. The selected objects for this report are faint and wide pairs with the highest possible altitude during nights without Moon to eliminate atmospheric imaging effects as far as possible - so this is then a more or less random selection out of the mentioned 66,000 objects. This report covers about 260 such objects, including some WDS objects that happened to be by chance in close visual proximity to the selected targets.

The intention was, to take two or more images in different nights for all selected objects, but unfavourable imaging conditions often reduced this to a single image. The images were plate solved with Astrometrica using the Gaia DR2 catalogue with reference stars in the magnitude range of 8.5 to 16.5 for astrometric measurements (i.e. calculating theta and rho). In a second step the images were again plate solved with Astrometrica using the URAT1 catalog for objects in the northern skies and the UCAC4 catalog for objects in the southern skies for photometry in the visual band. The objects were located in the centre of the image and astrometry/photometry was done by the rather comfortable Astrometrica procedure with point and click at the components delivering RA/Dec coordinates and V mag measurements based on all reference stars used for plate solving. The error range of the reported visual magnitudes is calculated from the average plate solving V mag error of the image and the signal-to-noise ratio of the components. The error ranges for separation and position angle of the components are calculated from the average plate solving RA/Dec position errors.

Results

Table 1: Results for measured WDS objects

WDS_ID	Date	PA(°)	e_PA	Sep(″)	e_Sep	M_1	e_M_1	M_2	e_M_2	N
07597−3324	2022.07566	183.540	0.689	5.88122	0.07071	12.063	0.070	13.998	0.072	1
08147−3051	2022.10421	222.963	0.890	5.47961	0.08515	10.155	0.070	12.644	0.075	2
08151−2819	2022.10427	173.084	0.547	9.26742	0.08852	10.527	0.065	11.383	0.065	1
08171−2704	2022.47459	148.071	0.726	6.16236	0.07810	14.303	0.080	14.521	0.086	1
08205−3411	2022.10424	261.869	1.048	4.63862	0.08485	10.615	0.060	12.278	0.066	2
08220−3358	2022.10424	138.049	1.297	3.74888	0.08485	11.024	0.061	12.208	0.063	2
08225−3024	2022.10430	124.084	0.680	7.45963	0.08852	10.875	0.060	11.242	0.060	2
08243−3329	2022.10558	203.519	0.739	5.48571	0.07071	10.229	0.060	10.902	0.060	1
08246−3240	2022.10438	174.753	1.738	3.03775	0.09220	12.339	0.060	12.695	0.061	2
08248−3240	2022.10438	49.535	0.325	16.25620	0.09220	12.013	0.060	12.462	0.060	2
08253−3340	2022.10558	23.189	1.869	2.60006	0.08485	12.173	0.061	12.308	0.061	1

08254−3249		2022.10440	177.172	0.456	11.11855	0.08852	12.734	0.060	11.779	0.060	2	
08254−3546		2022.09472	145.553	0.836	5.49710	0.08034	11.101	0.067	12.239	0.067	3	
08267−2658	AB	2022.07566	177.970	1.693	2.64166	0.07810	9.502	0.070	12.893	0.071	1	1)
08267−2658	AC	2022.07566	103.193	0.475	9.42010	0.07810	9.502	0.070	16.909	0.176	1	
08269−2658		2022.07566	78.753	1.302	3.43515	0.07810	11.993	0.070	13.628	0.072	1	
08312−3233		2022.10436	328.336	0.541	9.36984	0.08852	11.549	0.065	10.966	0.065	2	
08343−2900		2022.07567	235.267	0.817	5.47598	0.07810	10.678	0.070	12.215	0.070	1	
08353−2923		2022.10303	355.886	0.667	7.28878	0.08485	11.472	0.070	12.050	0.070	1	
08378−3228		2022.10561	237.186	0.686	7.69492	0.09220	10.164	0.060	12.534	0.061	1	
08392−3413		2022.10562	130.562	0.765	6.35112	0.08485	10.348	0.060	12.379	0.061	1	
08395−2852		2022.10437	131.254	0.596	8.50018	0.08852	11.447	0.070	11.920	0.070	2	
08408−3226		2022.09477	153.884	0.576	8.90600	0.08957	10.820	0.067	12.024	0.067	3	
08432−2826		2022.10301	30.120	0.511	9.51475	0.08485	11.902	0.070	12.918	0.070	1	
08534−3353		2022.10435	220.337	0.616	7.94573	0.08544	11.180	0.060	12.319	0.060	2	
08545−2805		2022.10431	140.601	0.824	6.15522	0.08852	12.947	0.065	13.961	0.066	2	
08581−3243		2022.10428	260.725	0.757	6.70114	0.08852	10.369	0.060	12.670	0.062	2	
08591−3203		2022.10433	46.907	0.561	8.32139	0.08145	12.112	0.060	12.174	0.060	2	
09083+3641		2022.31405	229.627	0.703	3.45808	0.04243	11.661	0.030	11.801	0.030	2	
09360+4511		2022.32909	316.362	0.719	4.50453	0.05657	12.106	0.050	12.646	0.051	1	
09426+2908		2022.32907	20.954	1.084	3.73715	0.07071	12.234	0.031	12.555	0.031	1	
09454+2935		2022.32907	145.540	0.606	5.34859	0.05657	9.964	0.030	12.004	0.033	1	
09470+3513		2022.15288	55.796	0.047	65.35484	0.05361	10.082	0.030	13.430	0.030	2	
09477+3508		2022.15288	298.323	0.022	38.00101	0.05361	14.128	0.031	16.521	0.042	2	
09538+2738		2022.31405	327.339	0.512	4.03861	0.03606	12.432	0.045	12.643	0.045	2	
09545+2736		2022.31405	190.249	0.490	4.21731	0.03606	12.325	0.045	15.073	0.051	2	
09561+2741		2022.32909	242.425	1.380	3.52123	0.08485	12.172	0.041	12.644	0.041	1	2)
09573−3140		2022.16017	16.539	0.932	4.79854	0.07810	10.459	0.050	11.445	0.051	1	
09574−3314		2022.16027	205.171	0.603	8.76201	0.09220	14.811	0.061	14.979	0.061	1	
09582−2943		2022.16021	138.355	0.298	16.31235	0.08485	11.092	0.060	11.251	0.060	1	
09590+3206		2022.15426	314.304	0.428	9.46352	0.07071	15.768	0.045	16.637	0.053	1	
10027+3615		2022.15428	340.946	0.066	24.71400	0.02828	10.901	0.040	11.595	0.040	1	
10034+3935		2022.15427	110.725	0.443	8.27980	0.06403	11.931	0.040	12.191	0.040	1	
10041+3949		2022.32906	209.613	0.397	5.19910	0.03606	11.389	0.040	12.433	0.040	1	
10044+3611		2022.15428	259.924	0.079	20.51898	0.02828	14.469	0.041	14.748	0.041	1	
10064−3541		2022.16017	43.964	0.664	6.73819	0.07810	10.512	0.050	12.465	0.051	1	
10069+3539		2022.32905	336.301	0.770	4.76155	0.06403	11.666	0.040	12.665	0.041	1	
10071−3514		2022.16024	37.134	0.244	16.58270	0.07071	14.123	0.050	14.711	0.051	1	
10078+3155		2022.15429	289.835	0.345	11.96535	0.07211	11.449	0.050	14.463	0.051	1	
10083−2951		2022.16023	80.508	0.768	5.27579	0.07071	12.564	0.061	11.908	0.060	1	
10093+3536	AB	2022.15430	32.404	0.047	94.78569	0.07810	12.108	0.060	16.483	0.068	1	
10093+3536	AC	2022.15430	201.731	0.407	11.00191	0.07810	12.108	0.060	14.562	0.061	1	
10110+2835		2022.32908	188.190	1.052	4.25338	0.07810	10.728	0.060	12.625	0.060	1	
10147−3641		2022.16015	95.981	0.830	5.85389	0.08485	11.500	0.050	12.336	0.050	1	
10148−3056		2022.16021	265.694	0.652	7.45845	0.08485	12.287	0.060	13.886	0.061	1	
10160+3034		2022.15431	21.018	0.770	11.16265	0.15000	13.417	0.040	13.700	0.040	1	
10176+3449		2022.15698	291.251	0.396	11.31147	0.07810	10.535	0.060	14.789	0.064	1	
10191−2733		2022.16026	275.575	0.693	7.61694	0.09220	14.886	0.051	15.580	0.052	1	
10198−3152		2022.19039	159.161	0.330	13.11852	0.07562	11.370	0.060	13.311	0.060	3	
10221−3019		2022.19040	185.021	0.216	20.02016	0.07562	11.332	0.060	11.686	0.060	3	
10246+4158		2022.15699	12.801	0.226	14.79774	0.05831	13.348	0.054	14.218	0.062	1	
10248−3006		2022.20551	245.772	0.154	29.10721	0.07811	12.666	0.060	12.758	0.060	2	

10256−3449		2022.19044	111.554	0.341	13.52327	0.08032	15.313	0.058	15.904	0.060	3	
10258−3412	AB	2022.16017	10.519	0.386	12.60226	0.08485	10.812	0.055	11.051	0.055	2	
10258−3412	BC	2022.16017	4.896	0.213	22.81860	0.08485	11.051	0.055	12.910	0.055	2	
10287−3206		2022.20969	303.184	0.197	26.81274	0.09220	14.654	0.051	14.955	0.051	2	
10297−3249		2022.20138	323.385	0.583	7.31324	0.07438	14.154	0.050	16.042	0.054	2	
10298−3618		2022.16015	58.410	0.205	23.67211	0.08485	10.130	0.060	14.583	0.061	1	
10307−3422		2022.16014	289.977	0.263	20.05048	0.09220	10.019	0.060	14.867	0.061	1	
10329−3459		2022.24252	113.479	0.141	17.24316	0.04243	11.639	0.050	16.765	0.057	1	
10341−3107		2022.16018	255.881	0.791	5.12434	0.07071	11.064	0.051	11.584	0.050	1	
10355−2941		2022.20968	36.140	0.981	5.16979	0.08852	13.545	0.061	13.574	0.061	2	
10357−2606		2022.25916	197.547	0.751	7.55135	0.09899	14.661	0.071	16.893	0.079	1	
10372−3356		2022.22153	61.677	0.565	10.04328	0.09899	15.061	0.058	15.145	0.058	3	
10406−3257		2022.20966	271.536	0.654	6.52904	0.07438	11.854	0.050	13.736	0.051	2	
10445−2801		2022.22151	13.691	0.023	96.91452	0.08032	13.834	0.054	16.686	0.059	3	
10451−2757		2022.22151	280.792	0.723	6.36705	0.08032	13.242	0.054	13.779	0.054	3	
10457+3949		2022.15705	38.400	0.776	16.19249	0.21932	11.833	0.111	13.156	0.117	1	
10459−3634		2022.25908	121.006	1.080	4.89190	0.09220	13.424	0.050	15.242	0.055	1	
10480−3401		2022.25077	218.405	0.408	9.94719	0.07071	10.877	0.060	13.061	0.060	2	
10490−3428		2022.24246	293.876	0.366	8.84472	0.05657	13.227	0.050	14.205	0.050	1	
10504−3111		2022.25917	286.618	0.513	11.04921	0.09899	10.556	0.060	17.561	0.104	1	3)
10513−2624		2022.25906	321.254	0.954	5.53896	0.09220	12.439	0.051	13.705	0.054	1	
10515−3019		2022.25912	267.819	0.515	10.25016	0.09220	11.292	0.060	12.553	0.060	1	
10553+3419		2022.22805	186.928	0.313	14.27424	0.07810	11.348	0.050	12.594	0.050	1	
10565−3209		2022.25913	94.459	0.309	17.10690	0.09220	12.327	0.060	15.873	0.062	1	
10572−3322		2022.25913	9.125	0.495	10.66497	0.09220	12.613	0.060	13.524	0.060	1	
10587−3520		2022.25914	83.551	0.360	14.69036	0.09220	12.431	0.050	13.377	0.050	1	
10591−3244		2022.25915	70.223	0.392	13.47706	0.09220	13.500	0.050	16.691	0.056	1	
11015+3816		2022.22812	1.514	0.124	19.61685	0.04243	11.953	0.030	15.104	0.032	1	
11035−3245		2022.25915	345.422	0.547	10.37401	0.09899	11.564	0.060	14.008	0.060	1	
11071−3154		2022.24247	248.508	0.492	4.94040	0.04243	10.967	0.050	12.686	0.051	1	
11072+3204		2022.22816	77.929	0.104	23.28787	0.04243	12.377	0.030	13.000	0.030	1	
11091+4231	AB	2022.22807	267.225	0.086	14.86921	0.02236	13.055	0.050	13.569	0.050	1	
11091+4231	AC	2022.22807	5.269	0.043	29.62515	0.02236	13.055	0.050	15.977	0.054	1	
11091+4231	AD	2022.22807	238.106	0.028	45.19882	0.02236	13.055	0.050	15.630	0.052	1	
11131+4011		2022.23095	138.938	0.046	31.54147	0.02532	10.513	0.030	10.647	0.030	2	
11140+3635		2022.22815	61.016	0.105	23.05148	0.04243	11.919	0.030	16.901	0.050	1	
11141+3926		2022.23372	49.503	0.065	31.92042	0.03606	16.260	0.044	17.028	0.064	1	
11152+3521	AB	2022.22811	137.852	0.043	18.91003	0.01414	13.738	0.021	14.170	0.021	1	
11152+3521	AC	2022.22811	352.625	0.043	18.87613	0.01414	13.738	0.021	15.213	0.023	1	
11152+3628		2022.22815	280.669	0.037	21.98393	0.01414	13.105	0.030	15.157	0.032	1	
11187+3759		2022.23096	343.789	0.031	33.57992	0.01825	11.293	0.025	11.766	0.025	2	
11202+3426		2022.23094	68.776	0.091	26.66964	0.04243	11.969	0.030	16.888	0.050	2	
11246+3752		2022.22808	29.424	0.176	16.26847	0.05000	10.775	0.030	10.818	0.030	1	
11248+4128	AB	2022.22809	278.970	0.177	17.44478	0.05385	10.683	0.040	13.850	0.040	1	
11248+4128	AC	2022.22809	210.821	0.067	46.21797	0.05385	10.683	0.040	12.833	0.040	1	
11266+3946		2022.22817	293.910	0.033	24.42626	0.01414	11.595	0.030	11.749	0.030	1	
11280+3403		2022.22814	88.579	0.059	21.77811	0.02236	11.535	0.030	12.262	0.030	1	
11281+3940		2022.23093	92.498	0.093	26.04274	0.04243	10.689	0.040	13.402	0.040	2	
11401+3758		2022.22810	196.331	0.131	18.54837	0.04243	12.229	0.030	16.231	0.036	1	
11403+3750		2022.22810	347.212	0.286	8.51110	0.04243	12.360	0.030	12.033	0.030	1	
11414+3624		2022.32127	171.251	0.323	11.35209	0.06403	11.754	0.050	14.602	0.057	1	4)

11507+3312	2022.32119	106.064	0.435	7.44463	0.05657	12.208	0.020	12.354	0.021	1	
11512+3708	2022.32113	16.573	1.254	4.56985	0.10000	11.910	0.080	15.809	0.130	1	5)
11538−3348	2022.33021	208.898	0.525	10.80549	0.09899	12.180	0.050	14.671	0.051	1	
11559−3005	2022.33018	266.929	0.724	7.83850	0.09899	11.918	0.060	13.575	0.061	1	
11567+3201	2022.32122	177.763	0.597	8.14621	0.08485	13.654	0.041	14.209	0.042	1	
11577+3206	2022.32130	131.175	0.709	13.03250	0.16125	13.406	0.059	14.277	0.075	1	
11580+3230	2022.32120	18.082	0.492	7.45834	0.06403	13.342	0.041	14.114	0.041	1	
11582−3421	2022.33027	7.236	0.660	6.78404	0.07810	15.551	0.052	17.074	0.063	1	
12003+4124	2022.32124	60.289	0.404	11.07693	0.07810	11.195	0.060	12.267	0.060	1	
12007−3247	2022.33028	103.826	0.517	8.66185	0.07810	15.535	0.062	16.305	0.063	1	
12010+4058	2022.32115	63.932	0.825	5.00636	0.07211	14.055	0.061	14.986	0.065	1	
12032−3637	2022.33021	167.190	0.624	8.47084	0.09220	13.420	0.060	14.406	0.061	1	
12041−3531	2022.33029	301.700	0.422	8.69705	0.06403	16.009	0.053	16.512	0.055	1	
12056−3237	2022.33023	251.156	0.358	14.73718	0.09220	13.965	0.050	13.915	0.050	1	
12057−3237	2022.33023	21.958	0.379	13.91983	0.09220	15.382	0.052	18.169	0.142	1	6)
12062−3459	2022.33026	206.347	0.582	9.08355	0.09220	15.481	0.052	16.624	0.056	1	
12071−2830	2022.33030	57.298	0.322	15.08534	0.08485	16.275	0.055	17.309	0.063	1	
12083+4153	2022.47465	65.132	0.443	11.91365	0.09220	12.085	0.041	14.732	0.059	1	
12093+3031	2022.32122	43.398	0.473	7.74841	0.06403	11.882	0.050	13.571	0.051	1	
12093−3316	2022.33019	54.753	0.308	17.15485	0.09220	12.313	0.060	13.991	0.060	1	
12107−3604	2022.33024	305.176	0.908	5.81509	0.09220	14.445	0.061	15.099	0.062	1	
12110−2702	2022.33019	282.731	0.698	8.12251	0.09899	12.580	0.070	14.294	0.072	1	
12133+3013	2022.32121	177.079	0.481	7.62991	0.06403	10.993	0.040	11.907	0.040	1	
12169−2942	2022.33020	199.344	0.869	6.52854	0.09899	13.519	0.061	13.670	0.061	1	
12191−2726	2022.33017	139.634	0.369	15.35580	0.09899	10.920	0.060	11.410	0.060	1	
12197+3000	2022.32117	181.545	0.518	6.26228	0.05657	11.193	0.060	13.831	0.066	1	
12198+3523	2022.32116	295.433	1.612	5.72818	0.16125	12.487	0.060	15.732	0.077	1	
12226−3103	2022.33022	37.881	0.532	9.92037	0.09220	13.613	0.050	13.060	0.050	1	
12239−2812	2022.33015	272.544	0.300	16.22299	0.08485	10.596	0.060	15.354	0.062	1	
12247+4116	2022.32125	233.752	0.978	10.89160	0.18601	12.035	0.050	14.819	0.055	1	
12271−2726	2022.33016	59.135	0.562	8.65473	0.08485	11.912	0.061	11.959	0.061	1	
12308+3640	2022.32114	173.551	1.051	5.14254	0.09434	11.463	0.071	11.928	0.072	1	
12322+3148	2022.32123	311.226	0.384	10.56100	0.07071	13.560	0.051	15.158	0.054	1	
12332−3427	2022.33030	141.430	0.187	25.98944	0.08485	16.092	0.063	16.151	0.064	1	
12340−2725	2022.33031	315.453	0.192	23.34880	0.07810	17.138	0.061	17.168	0.062	1	
12381+4155	2022.32118	256.164	0.910	6.69042	0.10630	12.180	0.100	16.283	0.132	1	7)
12397+3714	2022.32116	271.836	0.662	6.24096	0.07211	11.608	0.060	12.531	0.060	1	
12400+4102	2022.32129	209.713	0.372	12.03203	0.07810	13.045	0.041	13.185	0.042	1	
12406+3444	2022.32125	105.752	0.828	11.89802	0.17205	15.808	0.101	15.987	0.098	1	8)
12424+3653	2022.32134	2.881	0.116	21.00655	0.04243	12.385	0.040	13.969	0.041	1	
12454−3054	2022.33017	88.861	0.352	16.09126	0.09899	11.400	0.060	12.494	0.060	1	
12456−3059	2022.33028	15.984	0.560	8.68580	0.08485	15.849	0.052	16.248	0.053	1	
12461−3105	2022.33025	267.874	0.502	10.51536	0.09220	14.978	0.051	18.027	0.082	1	9)
13276+3105	2022.38968	221.980	0.300	9.56443	0.05000	14.023	0.041	14.457	0.041	1	
13303+4024	2022.38975	46.703	0.215	17.06056	0.06403	16.636	0.058	16.699	0.055	1	
13304+4010	2022.38975	210.668	0.518	7.08026	0.06403	15.829	0.044	17.106	0.061	1	
13309+4419	2022.38967	93.898	0.102	20.30043	0.03606	13.587	0.031	14.327	0.031	1	
13340+4354	2022.38965	31.500	0.502	8.23322	0.07211	11.174	0.030	14.239	0.032	1	
13359+4048	2022.38963	309.597	0.194	20.86625	0.07071	11.510	0.040	13.905	0.041	1	
13426+3701	2022.38972	293.593	0.235	19.01378	0.07810	11.996	0.050	15.757	0.054	1	
13455+3643	2022.38973	38.372	0.568	7.88261	0.07810	16.355	0.056	16.446	0.055	1	

13465+3443	2022.38970	178.235	0.655	5.60266	0.06403	14.403	0.051	17.880	0.209	1	10)
13483+3326	2022.38960	213.748	0.333	7.30020	0.04243	12.149	0.040	11.949	0.040	1	
13510+3030	2022.38964	145.115	0.765	5.40048	0.07211	11.702	0.040	13.910	0.044	1	
13531+3100	2022.38963	266.081	0.243	16.97389	0.07211	13.016	0.040	13.372	0.040	1	
13537+4027	2022.38962	172.990	0.578	4.95706	0.05000	12.818	0.030	13.043	0.031	1	
13550+3135	2022.38971	141.330	0.426	7.60805	0.05657	13.697	0.050	15.088	0.052	1	
14007−3053	2022.33304	280.781	1.033	4.70460	0.08485	13.204	0.062	13.721	0.062	1	
14025+3743	2022.38977	79.441	0.189	12.87900	0.04243	16.844	0.051	16.966	0.057	1	
14078−2621	2022.33306	129.546	1.148	4.60188	0.09220	12.036	0.061	12.291	0.061	1	
14095+3549	2022.38966	211.624	0.381	8.51433	0.05657	9.534	0.030	10.037	0.030	1	
14098+3544	2022.38966	33.441	0.385	5.36875	0.03606	12.463	0.030	14.359	0.032	1	
14103+4008	2022.38966	182.040	0.247	8.37531	0.03606	12.483	0.030	14.448	0.031	1	
14111+3454	2022.38969	39.049	0.138	11.71750	0.02828	13.113	0.040	14.801	0.042	1	
14120−2234	2022.33302	169.490	1.199	4.40389	0.09220	12.511	0.061	12.433	0.061	1	11)
14123+3646	2022.38961	66.656	0.263	12.34079	0.05657	13.033	0.040	12.607	0.040	1	
14128−3754	2022.33304	328.991	1.266	4.48029	0.09899	12.156	0.061	12.746	0.062	1	
14183−3149	2022.33302	247.071	1.302	4.05548	0.09220	12.730	0.061	12.987	0.062	1	
14230+3708	2022.38976	294.200	0.138	20.83292	0.05000	12.789	0.040	16.563	0.055	1	
14243−2200	2022.33305	133.611	1.054	4.61031	0.08485	11.738	0.065	10.548	0.061	1	
14252−3112	2022.12254	72.255	0.292	18.07866	0.09220	11.309	0.050	12.320	0.050	1	
14272−3251	2022.12253	146.343	0.694	7.00407	0.08485	12.623	0.060	13.145	0.060	1	
14278−3231	2022.12253	156.195	0.413	12.78792	0.09220	13.032	0.050	13.044	0.050	1	
14283−3425	2022.33299	267.438	1.389	3.80251	0.09220	11.914	0.061	11.985	0.060	1	
14290−3040	2022.33299	111.248	1.293	4.08375	0.09220	11.041	0.051	11.329	0.051	1	
14325−3102	2022.12255	79.259	0.434	12.18034	0.09220	15.632	0.052	16.410	0.054	1	
14469−3636	2022.33306	122.224	1.118	4.72590	0.09220	11.215	0.051	11.766	0.051	1	
14473−3634	2022.33306	179.247	0.155	36.65317	0.09899	17.299	0.063	16.361	0.055	1	
14475−3030	2022.33307	191.303	1.097	4.81336	0.09220	11.503	0.060	12.491	0.061	1	
14488−2857	2022.33300	264.504	1.367	3.86344	0.09220	12.280	0.050	12.547	0.050	1	
14516+3807	2022.11929	323.156	0.169	24.85035	0.07317	11.057	0.040	16.920	0.061	3	
14523−3424	2022.33301	97.334	1.249	4.23029	0.09220	10.684	0.060	11.991	0.063	1	
15043+3628	2022.11926	333.362	0.352	10.80733	0.06627	15.701	0.044	16.637	0.055	3	
15124+3650	2022.11788	269.834	0.634	6.72503	0.07441	11.199	0.035	14.259	0.041	2	
16459−3205	2022.48080	85.664	0.269	12.03642	0.05657	12.406	0.060	12.582	0.060	1	
16461−3140	2022.48087	126.115	0.666	4.86925	0.05657	12.432	0.070	13.025	0.071	1	
16463−3006	2022.48079	204.214	0.732	4.42972	0.05657	10.889	0.060	10.993	0.060	1	
16472−2733	2022.48081	313.431	0.563	5.09105	0.05000	12.749	0.060	12.578	0.060	1	
16472−3301	2022.48082	112.399	0.792	5.11736	0.07071	10.445	0.060	12.059	0.061	1	
16499−3603	2022.48090	45.593	0.801	5.05896	0.07071	12.396	0.062	12.421	0.063	1	
16509−2758	2022.48085	151.059	0.632	5.80492	0.06403	14.513	0.071	14.309	0.071	1	
16520−2640	2022.48074	140.876	0.397	10.19618	0.07071	11.326	0.070	11.788	0.070	1	
16523−2640	2022.48074	35.041	0.257	15.78045	0.07071	12.733	0.070	12.305	0.070	1	
16523−2641	2022.48074	211.674	0.569	7.12057	0.07071	11.405	0.070	14.021	0.071	1	
16525−2642	2022.48074	33.297	0.206	19.65698	0.07071	13.096	0.070	13.154	0.070	1	
16529−3718	2022.48083	136.476	0.856	4.73049	0.07071	11.438	0.071	11.519	0.071	1	
16550−3715	2022.48073	197.852	0.675	5.99881	0.07071	10.636	0.070	11.486	0.070	1	
16554+4029	2022.47450	266.328	0.072	22.48596	0.02828	12.115	0.030	14.231	0.031	1	
16555+3558	2022.47451	284.138	0.188	8.63835	0.02828	13.048	0.040	14.909	0.042	1	
16558+3513	2022.47451	237.426	0.177	9.17568	0.02828	13.195	0.040	14.291	0.041	1	
16586+3619	2022.47452	238.189	0.166	19.54041	0.05657	16.401	0.057	16.514	0.059	1	
16590−2610	2022.48081	110.817	0.666	4.86807	0.05657	11.925	0.070	12.285	0.070	1	

17005−2528		2022.48089	305.186	0.395	10.25641	0.07071	12.800	0.061	15.670	0.068	1	
17029+3423		2022.47453	233.183	0.073	22.32804	0.02828	15.901	0.047	16.756	0.067	1	
17032−3247		2022.48085	47.598	0.544	5.96146	0.05657	12.658	0.070	12.153	0.070	1	
17033−2439		2022.48078	141.339	0.871	4.64874	0.07071	12.245	0.071	12.463	0.070	1	
17046+3900	AB	2022.47454	232.511	0.265	6.11239	0.02828	10.912	0.040	11.569	0.040	1	
17046+3900	AC	2022.47454	173.296	0.019	84.28654	0.02828	10.912	0.040	13.108	0.040	1	
17046+3900	AD	2022.47454	138.121	0.017	94.43752	0.02828	10.912	0.040	12.822	0.040	1	
17051+3418		2022.47455	22.920	0.393	8.24059	0.05657	12.003	0.040	14.805	0.043	1	
17052−2602		2022.48075	218.550	0.863	4.69272	0.07071	11.251	0.070	11.479	0.070	1	
17066+3215		2022.47456	268.022	0.165	19.70057	0.05657	10.330	0.040	13.186	0.040	1	
17076+3823		2022.47456	219.564	0.215	15.09906	0.05657	12.189	0.040	12.748	0.040	1	
17077+3337		2022.47457	263.796	0.637	5.08908	0.05657	11.513	0.030	15.275	0.048	1	
17079+3530		2022.47458	182.210	0.512	6.33471	0.05657	12.939	0.040	14.055	0.041	1	
17084−3155		2022.48084	276.524	0.868	4.66461	0.07071	11.445	0.070	12.538	0.072	1	
17089+3647		2022.47459	21.146	0.570	5.02861	0.05000	11.732	0.040	16.595	0.093	1	12)
17092+3342		2022.47459	218.492	0.184	8.80291	0.02828	11.480	0.040	12.152	0.040	1	
17092+3648		2022.47459	312.011	0.518	5.52833	0.05000	13.771	0.041	14.810	0.042	1	
17093+3645		2022.47459	63.001	0.524	5.46278	0.05000	14.175	0.041	14.850	0.042	1	
17100−3641		2022.48079	358.226	0.802	5.05242	0.07071	12.289	0.060	12.377	0.061	1	
17101+4130		2022.47460	123.757	0.263	7.86437	0.03606	12.801	0.030	14.332	0.032	1	
17104+3752		2022.47461	266.799	0.339	7.16404	0.04243	13.183	0.040	15.355	0.045	1	
17112+3314		2022.47462	8.928	0.278	5.82052	0.02828	14.065	0.041	13.998	0.041	1	
17112+3345		2022.47462	81.471	0.421	6.80984	0.05000	13.326	0.040	14.250	0.041	1	
17118+3406		2022.47464	335.438	0.319	5.07963	0.02828	10.980	0.030	15.085	0.062	1	
17145+3833		2022.47465	187.096	0.289	5.60292	0.02828	13.253	0.050	13.723	0.051	1	
17176+3532		2022.47465	240.059	0.697	4.64824	0.05657	11.772	0.040	14.444	0.048	1	
17177+3537		2022.47465	279.736	0.403	8.04183	0.05657	9.296	0.040	12.385	0.041	1	13)
17179+3533		2022.47465	259.865	0.679	4.77340	0.05657	13.617	0.041	15.077	0.044	1	
17193−2949		2022.48089	316.536	0.340	11.91783	0.07071	14.051	0.071	14.407	0.071	1	
17262+3604		2022.47467	99.766	0.140	11.61417	0.02828	15.706	0.046	16.826	0.065	1	
17273−2759		2022.48087	59.732	0.810	4.99958	0.07071	13.938	0.070	16.148	0.080	1	14)
17313−3327		2022.48075	84.954	0.869	4.66136	0.07071	11.588	0.050	12.496	0.050	1	
17328−2856		2022.48088	38.937	0.165	22.26721	0.06403	13.332	0.060	14.158	0.061	1	
17344−3421		2022.48077	110.508	0.668	4.85255	0.05657	11.317	0.070	12.913	0.070	1	
17355−3009		2022.48076	76.968	0.711	6.29720	0.07810	9.850	0.070	11.830	0.070	1	
17365−3212		2022.48086	253.399	0.665	4.30510	0.05000	12.589	0.060	13.010	0.061	1	
18060−3018		2022.41538	267.172	0.651	8.71389	0.09899	11.622	0.070	15.902	0.095	1	15)
18082−3127		2022.41541	60.629	1.441	3.93504	0.09899	10.873	0.072	12.022	0.090	1	
18137−1410		2022.41533	317.255	1.117	5.07913	0.09899	11.200	0.070	11.772	0.071	1	
18153−3413		2022.41538	12.198	1.208	4.69602	0.09899	12.164	0.071	12.669	0.072	1	
18167−3047		2022.41537	183.738	1.304	4.34925	0.09899	12.489	0.081	12.593	0.082	1	
18188−3325		2022.41534	204.648	1.138	4.98411	0.09899	12.435	0.070	12.646	0.070	1	
18190−3357		2022.41539	67.311	1.420	3.99247	0.09899	9.592	0.050	10.496	0.054	1	
18207−3245		2022.41534	350.879	1.273	4.45634	0.09899	10.952	0.070	11.868	0.071	1	
18241−3058		2022.41536	130.402	1.059	5.35376	0.09899	13.981	0.071	14.042	0.071	1	16)
18244−3054		2022.41536	249.053	1.200	4.72728	0.09899	11.809	0.060	13.186	0.060	1	
18287−3017		2022.41540	162.226	1.087	5.21912	0.09899	10.485	0.090	10.485	0.091	1	

Explanation of table

WDS_ID	WDS Designator
Comp	left justified component designator. If blank this is AB
Date	observation date in years
PA	position angle theta, in degrees
e_PA	formal theta error, in degrees
Sep	separation rho, in arcseconds
e_Sep	rho error, in arcseconds
M_1	primary magnitude, in V mag
e_M_1	primary magnitude error, in V mag
M_2	secondary magnitude, in V mag
e_M_2	secondary magnitude error, in V mag
N	number of nights averaged into mean measure
Note	notes - see below

Notes

1.	08267−2658	DAM 471AC:	SNR C <10
2.	09561+2741	BRT 22:	WDS precise position wrong. Correct is 095620.36+274131.9
3.	10504−3111	UC 2008:	SNR B<20
4.	11414+3624	UC 2190:	Last WDS measurement erroneous
5.	11512+3708	NSN 50:	SNR B <20
6.	12057−3237	TSN 84:	SNR B <10
7.	12381+4155	SKF2651:	SNR B <20
8.	12406+3444	UC 2383:	SNR A and B <20
9.	12461−3105	UC 2403:	SNR B<20
10.	13465+3443	CBL 597:	SNR B <5
11.	14120−2234	BRT1490:	Similar parallax and proper motion suggest a physical pair. *WDS note code "T" suggested*
12.	17089+3647	DAM 899:	SNR B <20
13.	17177+3537	HO 67:	A likely brighter than $V = 9.3$ (star disk saturated)
14.	17273−2759	VVV 42:	Quadrant issue. Precise position is due to fast proper motion currently 172716.40−275923.8
15.	18060−3018	BRT3059:	Most likely false positive, spurious assumed. However, something is here. *X-mark first measurement as erroneous*
16.	18241−3058	BRT3069:	False positive or wrong WDS position (correct would be 182407.50-305820.9). *X-mark last WDS measurement as erroneous*

Three objects remained without measurements due to lack of resolution:

08155−2820 TDS5652: No resolution, not even hint of elongation. Spurious.
08170−2705 TDS5671: No hint of a double. Spurious.
17200+3640 LDS4739: No resolution. Secondary fainter than mag 17.

Summary

About one third of the objects measured show the expected significant magnitude difference >0.5 compared to the WDS catalogue data, especially for the secondary but often also for the primary. For another third of the objects, the given WDS magnitudes are simply confirmed within the measurement error range and the rest is in between.

Acknowledgements

The following tools and resources have been used for this research:
Washington Double Star Catalog
Gaia DR2 and DR3 catalog
UCAC4 and URAT1 catalog
Remote telescopes
iT24: 610mm CDK with 3962mm focal length. Resolution 0.625 arcsec/pixel. V-filter. Located in Auberry, California. Elevation 1405m
iT32: 430mm CDK with 2912mm focal length. Resolution 0.64 arcsec/pixel. V-filter. Located in Siding Spring, Australia. Elevation 1122m
Aladin Sky Atlas v11.0
AAVSO VPhot
Astrometrica v4.10.0.427
AstroPlanner v2.2
MaxIm DL6 v6.08

UNCONFIRMED TYCHO DOUBLE STARS VERSUS GAIA DR3 – I

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Abstract

“Absence of evidence is not evidence of absence" is a well-known adage used to defend claims that something exists without providing substantive evidence. Such statements are of limited scientific value as falsification is difficult, if not impossible. On the other hand, a well-documented absence is sufficient reason to declare that something does not exist - this is a valid scientific statement, falsifiable by the mere proof of existence.

This report takes a closer look at a subset of 2,149 unconfirmed Tycho Double Stars (henceforth TDS/TDT objects) with angular separation >1.45 arcseconds based on the assumption that Gaia DR3 should resolve any such object with ease. With a combination of automatic cross-matching and manual checking of potential candidates we found 10 TDS/TDT objects confirmed with reasonable small differences between WDS Catalogue and Gaia DR3 data and 44 objects potentially confirmed with very generous allowances for significant data deltas. A further ten TDS/TDT objects are special cases that required some detective work to get conclusive results.

The remaining TDS/TDT objects are clearly spurious, with 655 cases of them with very faint Gaia DR3 companions outside the Tycho magnitude limit. However, ‘something’ acceptable as a visual double star exists here at these positions. The remaining 1,431 unconfirmed TDS/TDT objects are considered spurious due to a missing Gaia DR3 companion within a 5 arc second search radius.

Method

The WDS Catalogue contained in September 2022 in total 14,173 TDS/TDT objects with 3,059 confirmed pairs (which means with two or more observations) and 339 marked with WDS note code ‘X’, which means ‘spurious’ (we prefer this term, which indicates technical reasons, over the terms ‘dubious’ or ‘bogus’ used in the WDS Catalog, as these terms seem to imply an intention to mislead).

The remaining 10,776 of these TDS/TDT objects are still only listed with the initial measurement. This number includes four objects listed with a first observation after 1991/1992 for additional components to existing TDS/TDT pairs detected later.

Out of the 3,059 confirmed TDS/TDT pairs, 1,384 are listed with a separation range of $1''.45$ and above, which means 36% of the corresponding in total 3,851 TDS/TDT objects in this separation range. In contrast, only 16% of the pairs with a separation smaller than $1''.45$ are listed as confirmed. This bias towards the pairs with larger separation might be explained by the fact that such pairs are relatively easy to observe even with amateur equipment and for this reason well researched.

The basic idea for this work is the assumption that Gaia with a telescope aperture of 1.0 m should (together with the technological progress in the last 30 years) easily confirm any double star discovered by Tycho with a telescope aperture of 0.3 m. The TDS/TDT objects are listed in the WDS catalogue with an angular separation of 0.3 arcseconds or larger, magnitudes fainter than 7 and brighter than 15 and a magnitude delta of up to 3.3. Gaia DR3 covers this range very well with a resolution limit of 0.18 arcseconds according to Torra *et al.* (2021). Even with the caveat that this proposed resolution limit is a best-case scenario under favourable conditions, this means that virtually any TDS/TDT object has to be confirmed by Gaia DR3 to be considered as existing and that any such Tycho Double Star not confirmed by Gaia can be considered 'spurious'.

To stay on the very safe side regarding the Gaia resolution limit we restricted this research to the TDS/TDT objects with a separation of 1.45 arcseconds or more resulting in a total of 2,149 such objects. This separation range also allowed cross-checking with various sky surveys, particularly *2MASS*, where this level of resolution can be achieved. Checks against the WDS also revealed a number of cases where a TDS/TDT double was in fact a rediscovery of a previously known double, usually from many years earlier.

This data set was cross-matched with Gaia DR3 with a search radius of five arcseconds. Proper motion since 1991 should not give a noticeable large change in position or in separation to get a companion outside the search radius.

All objects without any Gaia DR3 companion after cross matching are clearly spurious due to evident absence of a secondary. Next step is the check of all objects with an existing potential companion for matching the values for separation, position angle and magnitudes. All objects with reasonably matching data are considered confirmed, all objects with unreasonably large data deltas are considered false positives as well as all objects with magnitudes outside the Tycho limit.

To verify the validity of this approach we decided to check this method, using a confirmed data set from the WDS catalogue with parameters similar to the selected set of TDS/TDT objects.

Additional checks were made against the WDS catalogue, to see if some Tycho pairs were re-discoveries of previously known doubles, some found much earlier in time than Tycho. A number of Tycho pairs proved to be re-discoveries of known doubles. This effort was complicated by the presence in the WDS of some doubles found by data-mining of general star catalogues of various types, including earlier than DR3 versions of Gaia.

Supplementary checks were done by Gould using sky survey images from various sources. The intention was to use these as a 'reality check', as some sky surveys had sufficient resolution to show doubles in the Tycho magnitude range, either as extended images or closely separated images, for many of the doubles listed by Tycho as having separations from $1''.45$ or wider. This figure, $1''.45$, represents an approximate resolution limit for sky survey images from *2MASS*. Similarly, images generated by the SkyMapper (ANU) program of the Southern and part of the Equatorial zones of the sky, with the benefit of multi-wavelength images, were used. These sometimes showed need for further data checks; and sometimes simply confirmed data already to hand.

Proof of concept

No star catalogue is error-free. This also applies to Gaia DR3 and the Gaia Consortium provides a list of known issues (`https://www.cosmos.esa.int/web/gaia/dr3-known-issues`). All measurements listed in the Gaia DR3 catalogue are given with indications for the reliability of the given data, not only in the form of measurement error range, but also in the form of a renormalized unit weight error value (RUWE). In addition, there are indications of a possible lack of reliability due to missing important data such as proper motion and parallax. Therefore, it seems necessary to assess the risk of erroneous Gaia catalogue data for the planned method.

Proof of concept for the presented method is done by cross matching a sample of confirmed WDS objects with a separation from $1''.45$ to $3''$ and with five or more observations against the Gaia DR3 Catalogue.

Out of 5,790 objects, three were completely missed in the cross-match results and 32 lacked a potential companion within the search radius of five arcseconds.

This means that 99.4% of the selected objects were attempted to be matched with potential secondaries. A closer look at the misses revealed that about half of these misses were due to magnitude and proper motion issues of no relevance for cross matching Gaia DR3 with TDS/TDT objects. However, in further 12 cases the cause for mis-hits are WDS catalogue data issues like erroneous most recent observations and wrong precise positions (meanwhile cleared up by private communication with USNO).

In the next step, we checked the objects in more detail by calculating position angle and separation with Gaia DR3 data and comparing these values with the current WDS data. All objects with a delta of less than 15° in position angle and less than $0''.2$ in separation were considered as confirmed by Gaia DR3 observation. Finally, we checked the 110 objects with larger deltas for the possible reasons. In seven cases proper motion issues caused significant changes since the last measurement (Appendix B, Table 6), 99 pairs were listed in the WDS catalogue with an imprecise last measurement (Appendix B, Table 7) and in two cases the currently WDS catalogue precise position is erroneous (Appendix B, Table 8). Additionally three objects popped up with obvious magnitude issues (Appendix B, Table 9). One object (WDS21522+3252, ES 2321) remains slightly questionable due to insufficient Gaia DR3 data regarding proper motion and magnitudes.

Overall, including manual checks, this reduces the error range of the selected procedure to 0.1%. A likelihood of 99.9% for correct assessment is considered sufficient for an acceptable evidence of absence, especially if the referenced data set contains only a small number of positive objects, as is the case with the selected set of TDS/TDT pairs.

Results for TDS/TDT objects

Beginning with Knapp & Gould (2016) we made several attempts for cleaning up Tycho Double Star issues in the WDS Catalogue. The release of the 3rd Gaia source catalogue (Gaia Collaboration 2022) gives the basis for a next step.

The selected subset of 2,149 unconfirmed TDS/TDT objects with a separation of $1''.45$ or larger was cross-matched with the Gaia DR3 catalogue with a search radius of five arcseconds around the given WDS precise position with a hit rate of 100% for the primaries. This step was supplemented by a manual check of all objects with a separation larger than three arcseconds to avoid issues with the search radius of five arcseconds.

For 1,431 objects, we found simply no Gaia DR3 companion within the search radius of 5 arcseconds, which means spurious due to sufficient evidence of non-existence (Appendix A, Table 1). *Suggested WDS catalogue update: Add WDS note code 'X'.*

For ten objects, we found fairly good matching Gaia DR3 pairs (Appendix A, Table 2). Magnitudes, separation and position angle of Gaia DR3 pairs at the given position are (with some allowances for the effects of proper motion since 1991) with a delta in position angle up to ∼30 degrees and a delta in separation up to ∼0.8 arcseconds close enough to WDS Catalogue data to be considered as genuine confirming observations. This number is modest compared with the overall confirmation rate of 36% in this group of TDS/TDT objects, which might be explained by the intense efforts already invested in the confirmation of these pairs over the last 30 years. *Suggested WDS catalogue update: Add Gaia DR3 measure as the second observation. WDS note code 'T' for TDS2124 with similar parallax and proper motion.*

Side note regarding the accuracy of Tycho measurements of doubles: Records of non-Tycho (not TDS nor TDT) doubles, where these were measured in the same era by Hipparcos and by speckle interferometry using large telescopes, show many examples where the Tycho measurements are not consistent with Hipparcos and speckle measures and where the two non-Tycho measures agree and are a better fit for the trend-line of change with the particular doubles.

For 44 objects, we found at the given position Gaia DR3 pairs potentially detectable by Tycho but with separation and position angle not even similar to the WDS data, and for this reason considered most likely false positives (Appendix A, Table 3). However, if we accept the TDS/TDT data as non-binding proposal then we can take these Gaia DR3 measurements as confirmations if the magnitude of the secondary is brighter than $G = 15$. This magnitude limit to accept a Gaia DR3 companion as potential secondary is reasonably generous as the faintest TDS/TDT secondary is listed with visual magnitude 14.72 and G-band magnitudes should always be brighter than visual magnitudes. There are a few TDS/TDT objects listed with even fainter magnitudes but these are all first observations not from Tycho. This gives together with the ten positive objects a meagre confirmation rate of 2.5% of the checked 2,149 objects. *Suggested WDS Catalogue update: Either add Gaia DR3 measure as second observation or X-mark Tycho measure as erroneous and add Gaia DR3 measure as first observation.*

For 650 objects, we found Gaia DR3 pairs with companions too faint by far to be detectable by Tycho and for two cases we found an unreasonably large separation delta, which means false positives for certain (Appendix A, Table 4). However, something has been found here and such pairs are valid visual double stars. The original Tycho measurement is obviously erroneous but a new first observation can be recorded, which could allow us to keep the corresponding TDS/TDT designations. In case of several components besides the primary, the brightest was selected as secondary for this purpose. *Suggested WDS Catalogue update: X-mark TDS/TDT measure as erroneous and add Gaia DR3 measure as first observation.*

Finally, ten objects are special cases that required some detective work to get conclusive results (Appendix A, Table 5):

Pair	Notes
TDS3375Aa,Ab:	Gaia DR3 pair found at this position corresponds with RST 158AB. This is the third measurement for this neglected pair after 73 years without observation. No matching Gaia DR3 objects for TDS3375Aa,Ab available. *Suggested WDS catalogue update: Add WDS note code 'X' for TDS3375Aa,Ab and add Gaia DR3 measurement for RST 158AB*
TDS5152AB:	Seems with some allowances confirmed by a Gaia DR3 pair at this position. However, this is indeed the match for BRT2682AC. Gaia DR3 lists a third component without G for a 158° and 2″.49 pair but the faint $R = 16.75$ companion (no G given) suggests spurious for TDS5152AB. Overall this could mean that the Tycho object is just a rediscovery of BRT2682 with the delta in theta and rho just another example of the usual Tycho measurement imprecision. *Suggested WDS catalogue update: X-mark the Tycho measurement for TDS5152AB as erroneous and add the Gaia DR3 observation with the R = 16.75 component as first observation of that companion. Add the Gaia DR3 measurement for BRT2682AC*
TDS5171AB:	Possible match with Gaia DR3 $G = 11.7 + 12.4$ pair at this position. However, this measure corresponds with BRT1609AC. Gaia DR3 lists no other companion for a potential match with TDS5171AB. *Suggested WDS catalogue update: Add WDS note code 'X' for TDS5171AB, and change component designation BRT1609AC to AB and add Gaia DR3 measurement for BRT1609*
TDS7016AB:	Gaia DR3 pair at this position matches the data for DAM2006AB,C. No other Gaia DR3 object for a match with TDS7016AB. *Suggested WDS catalogue update: X-mark the Tycho measure as erroneous, delete DAM2006AB,C and take the DAM measure as first observation of TDS7016AB*
TDS8418AB:	Gaia DR3 measure corresponds with DAM 579AC. Another potential companion offered by Gaia DR3 is with $G = 17.8$ too faint by far for a match with TDS8418AB. *Suggested WDS catalogue update: X-mark the Tycho measure as erroneous, delete the DAM 579AC object, take the DAM measure as first observation of TDS8418AB and list the Gaia DR3 measure as second observation with precise magnitudes*
TDT 563:	With some allowances positive. Possible match with Gaia DR3 $G = 11.4 + 11.6$ pair with 292° and 0″.50. *Suggested WDS catalogue update: X-mark the Tycho measure as erroneous and list the Gaia DR3 measure as first observation*
TDT2232AB:	With some allowances match with Gaia DR3 $G = 10.7 + 13.5$ pair with 356° and 3″.23. However, this measure corresponds with GII 51AC. Gaia DR3 offers no companion for a match with TDT2242AB. *Suggested WDS catalogue update: WDS note code 'X' for TDT2232AB, change component designation GII 51AC to AB*

TDT2548AB: Gaia DR3 $G = 11.1 + 11.2$ pair at this position with 327° and 0″.56 is a match for COU 827Aa,Ab. No other Gaia DR3 companion matching TDT2548B. *Suggested WDS catalogue update: WDS note code 'X' for TDT2548AB. Change COU 827 component designations from Aa,Ab to AB*

TDT2738CD: The Gaia DR3 measure for TDT2738CD matches the data for nearby HEI 78AB. This means TDT 2738 is clearly a rediscovery of HEI 78AB. However, the WDS precise position for HEI 78AB points obviously to component C and there is only one single Gaia DR3 object at this position. In consequence the measurements listed in the WDS catalogue for HEI 78AC have a quadrant issue. *Suggested WDS catalogue update: Change HEI 78AB and AC precise position to 210536.05+144158.0 and add WDS note code 'T' to AB for similar parallax and proper motion. Declare TDT2738CD as rediscovery of HEI 78AB (maybe X-mark as imprecise measurement) and mark the HEI 78AC measures in the observation history with a 'q' for quadrant issue*

TDT3626: Positive match with Gaia DR3 $G = 11.7 + 14.8$ pair with 228° (quadrant issue) and 1″.7. Slight position error due to high proper motion. *Suggested WDS Catalogue update: Correct precise position to 223802.8+491351.7. Either add Gaia DR3 measurement as second observation or X-mark Tycho measure as erroneous and add Gaia DR3 measurement as first observation. Add WDS note code 'T' for similar parallax and proper motion*

Potential further research

Gaia DR3 is expected to resolve double stars with a moderate delta in magnitude and moderate brightness down to a separation potentially as close as 0″.18. Therefore, it should be possible to extend the research presented here to all Tycho Double Stars with a separation below 1″.45, which would cover the rest of 8,625 so far unconfirmed TDS/TDT objects.

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Acknowledgements

The following tools and resources have been used for this research:
Washington Double Star Catalog
Gaia DR3 Catalogue (via CDS VizieR)
CDS X-Match tool
UCAC4 catalogue (CDS VizieR)
Tycho Double Star Catalog
Aladin Sky Atlas v11
SIMBAD, VizieR
2MASS All Sky Catalog
CDS DSS2 colour image composition

Appendix A

Tables with Gaia DR3 cross-match results for 2,149 unconfirmed TDS/TDS objects

Table 1 - 1,431 TDS/TDT objects with no Gaia DR3 companion

(Stub with 10 rows, full table available for download from
`https://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_I/`)
Suggested WDS Catalogue update: Add WDS note code 'X'.

WDS	DD	Theta	Rho	M1	M2	Comment
00003+6024	TDS1237	217.2	1.77	11.98	12.17	No Gaia DR3 companion
00046+5833	TDS128	227.9	2.57	9.55	12.67	No Gaia DR3 companion
00056+5753	TDS1288	15.8	1.72	11.71	12.02	No Gaia DR3 companion
00064+4938	TDS1292	120.2	2.03	12.07	12.2	No Gaia DR3 companion
00065−5224	TDS1295	287.5	2.78	12.42	13.2	No Gaia DR3 companion
00074+5218	TDS1302	127.3	1.61	12.25	13.03	No Gaia DR3 companion
00092+5217	TDS1318	115.0	1.96	11.67	12.07	No Gaia DR3 companion
00102+5016	TDS1328	108.5	1.83	11.05	12.39	No Gaia DR3 companion
00182+5911	TDS1389	12.4	2.12	11.54	12.45	No Gaia DR3 companion
00185+6735	TDS1391	167.0	2.02	11.56	12.21	No Gaia DR3 companion

Table 2 - ten positive matches of TDS/TDT objects with Gaia DR3 (Delta Theta $<31^\circ$ and delta Rho $< 0''.85$)

(Stub. Full table with comments available for download from
`https://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_I/`)
Suggested WDS Catalogue update: Add Gaia DR3 measure as the second observation. Add WDS note code 'T' for TDS2124 with similar parallax and proper motion.

		Tycho				Gaia 2016			
WDS	DD	Theta	Rho	M_1	M_2	Theta	Rho	G_1	G_2
02073−0754	TDS2124	168.6	1.53	12.03	12.40	146.590	1.48057	11.988	13.146
06330−2430	TDS3914	268.0	2.35	10.53	12.51	237.303	2.51817	10.393	14.158
06527+0742	TDS 295	189.3	1.56	10.72	11.78	202.074	1.03984	10.917	12.526
07078−0647	TDS4499	214.8	2.42	10.86	12.13	218.702	2.34460	10.723	12.030
08040−2404	TDS5493	280.9	2.34	10.99	12.55	304.301	2.06631	10.962	12.786
12540−6324	TDS8575	167.1	2.27	11.30	12.00	174.658	2.21053	10.626	11.949
18053+7217	TDT 668	42.5	1.99	11.10	12.24	41.055	1.90364	11.273	11.948
18201−1631	TDT 802	348.7	1.76	11.33	12.19	358.626	1.58497	10.831	12.014
19417+5424	TDT1639	257.0	2.24	11.26	12.42	261.487	2.34019	10.821	12.427
19452+1823	TDT1708	211.8	1.83	11.12	12.50	199.261	0.98001	11.103	12.547

Table 3 - 44 potentially positive matches of TDS/TDT objects with Gaia DR3, but most likely false positives

(Stub with 10 rows, full table available for download from
`https://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_I/`)
Suggested WDS Catalogue update: Either add Gaia DR3 measure as second observation (beware of quadrant issues) or X-mark Tycho measure as erroneous and add Gaia DR3 measure as first observation

		Tycho				Gaia 2016			
WDS	DD	Theta	Rho	M_1	M_2	Theta	Rho	G_1	G_2
02076+6318	TDS2126	241.7	1.82	11.34	12.97	199.101	4.79355	10.904	14.407
02519+4713	TDS2376	26.8	1.96	12.06	12.09	179.459	1.46975	11.408	14.643
02519+4713	TDS2376	26.8	1.96	12.06	12.09	179.459	1.46975	11.408	14.643
03482−8946	TDS2656	203.5	2.10	11.04	12.06	51.358	1.76384	10.854	14.511
04190+7241	TDS2819	116.4	1.90	11.02	12.36	235.964	4.14563	10.907	14.995
06093−6518	TDS3590	228.2	1.55	10.46	12.43	184.892	2.85255	10.226	13.631
06368−0009	TDS3967	314.0	1.96	11.52	12.31	158.835	0.71731	11.236	12.728
07159+0029	TDS4645	356.6	1.61	10.80	12.38	59.599	3.36688	10.238	13.925
07463−2619	TDS5185	187.1	2.50	12.32	12.46	147.868	3.51102	12.221	14.903
08091−4445	TDS5572	111.8	2.11	11.36	11.92	272.171	2.40511	11.142	14.795

Table 4 - 655 false positive matches of TDS/TDT objects with Gaia DR3 objects fainter than G=15

(Stub with 10 rows, full table available for download from
`https://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_I/`)
Suggested WDS Catalogue update: X-mark Tycho measure as erroneous and add Gaia DR3 measure as first observation

			Tycho				Gaia 2016			
WDS	DD	Comp	Theta	Rho	M_1	M_2	Theta	Rho	G_1	G_2
00014+6347	TDS1249		201.8	1.89	10.48	12.13	356.394	3.35415	10.283	15.913
00081+6414	TDS1306		177.4	2.48	11.66	12.41	43.431	2.06856	11.634	17.782
00151+5407	TDS1359		198.9	1.76	11.03	12.92	156.658	4.50852	10.643	17.699
00156+5534	TDS1364		7.2	2.41	11.42	12.22	309.813	4.76788	11.323	15.644
00279+6217	TDS1473	AB?	215.6	1.94	11.43	12.44	217.713	3.49907	11.258	19.565
00313+5000	TDS1507		65.0	1.95	10.33	11.56	336.974	3.33839	9.538	20.266
00332+5248	TDS1517		13.4	2.46	11.48	12.28	153.835	5.00345	11.447	19.123
00425+5735	TDS1575		141.5	2.10	11.82	12.60	98.112	4.88238	11.306	17.129
00443+5846	TDS1593		103.9	2.30	12.62	13.25	309.545	2.13111	12.138	19.585
00466+6006	TDS1607		203.7	1.51	11.71	12.27	227.596	2.17934	11.317	19.462

Table 5 - ten special cases

(Stub. Full table with comments available for download from
`https://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_I/`)
Suggested WDS Catalogue update: See report text

			Tycho 1991				Gaia 2016			
WDS	DD	Comp	Theta	Rho	M1	M2	Theta	Rho	G_1	G_2
05508−465	TDS3375	Aa.Ab	209.1	2.17	10.90	12.32	261.031	0.52363	11.323	11.822
07446−1341	TDS5152	AB	253.0	1.51	11.76	11.98	239.057	3.61740	11.825	13.558
07455−3322	TDS5171	AB	249.3	2.10	11.59	12.34	28.258	3.51205	11.743	12.382
10061−5718	TDS7016	AB	331.2	1.73	12.03	12.26	178.567	2.08078	11.805	14.899
12313−6042	TDS8418	AB	269.8	1.67	12.03	12.73	343.060	4.22686	11.913	14.892
17539+1413	TDT 563		61.5	1.67	11.07	12.37	292.485	0.49836	11.434	11.634
20236+3854	TDT2232	AB	210.6	1.45	11.12	11.37	355.778	3.22912	10.697	13.509
20482+2622	TDT2548	AB	212.3	2.53	10.55	11.52	326.817	0.55541	11.084	11.241
21056+1443	TDT2738	CD	189.7	1.93	11.85	12.04	233.838	1.82304	11.881	12.323
22380+4914	TDT3626	AB	43.8	2.98	11.71	11.99	228.005	1.70643	11.685	14.848

Appendix B

Tables with proof of concept side results

Table 6 - Seven proof of concept pairs with imprecise last measurement due to proper motion issues

						Gaia DR3			
WDS	DD	Theta	Rho	M1	M2	Theta	Rho	G_1	G_2
01388−1758	LDS 838	338	1.9	12.70	13.20	190.475	2.25894	10.818	10.508
04132+5032	CHR 15	39	1.9	14.00	14.60	51.088	1.64341	12.698	13.261
08582+1945	LDS3836	248	2.6	13.37	13.37	230.903	2.17474	11.966	12.486
16077−3802	COO 193	224	1.9	8.97	8.99	45.931	4.08300	8.690	8.720
19034+2343	J 2937	57	2.1	11.50	12.10	62.485	2.45728	12.141	13.154
19552−0051	BU 830	112	2.4	8.46	11.79	114.663	2.06118	8.259	11.254
23296+1548	NSN 770	309	2.0	13.69	13.88	303.036	1.58277	13.102	13.207

Note to J 2937: Third component $G = 15.9$ nearby most likely physical with primary

Table 7 - 99 proof of concept pairs with imprecise last measurements

(Stub with 10 rows, full table available for download from `https://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_I/`)

						Gaia DR3			
WDS	DD	PA	Sep	M1	M2	theta	rho	G_1	G_2
00073+2058	HDS 12	6	2.2	9.22	11.53	2.785	2.59544	8.910	11.210
00105+5540	ES 930	339	2.7	11.24	11.33	339.073	3.06997	11.084	11.156
00309+2135	J 634	249	2.3	9.80	11.80	247.004	2.67694	11.622	13.195
01203+2122	A 1905	332	1.8	9.65	11.21	331.511	0.96271	9.493	
01529+2152	J 671	153	2.7	11.60	11.80	153.328	3.01786	11.579	12.133
02223+6131	NSN 17	65	2.7	14.80	15.80	69.379	3.49990	14.082	15.269
02289+0044	J 648	154	2.3	10.50	11.00	155.475	2.73557	10.330	11.074
02586−4444	DON 44	345	2.3	10.10	11.46	327.934	2.20403	9.916	11.486
03048+0807	J 303	39	2.5	10.29	11.83	39.891	3.00693	10.178	11.240
03120+1538	BRT1175	143	2.4	12.10	12.30	138.967	2.88408	12.016	12.260

Table 8 - Two proof of concept pairs with erroneous WDS precise positions

						Gaia DR3			
WDS	DD	PA	Sep	M1	M2	theta	rho	G_1	G_2
18461+1000	J 1215	128	1.7	12.14	12.40	127.810	1.81867	11.044	11.309
19585+2202	L 47	303	2.4	10.20	11.20	303.332	2.41264	11.130	12.433?

Note to J 1215 - No such pair at the given precise position. Position error. Correct position is identical with WDS 18462+1001 HEI 804 at 184609.30+100106.8 (which means HEI 804 is a 1990 rediscovery of J 1215 lost since 1983)

Note to L 47 - No such pair at this position. Looks like a WDS precise position error - nearby at 195841.11+220333.9 a matching Gaia DR3 $G = 11.1/12.4$ pair with 303° and $2''.41$

Table 9 - Three proof of concept pairs with magnitude issues in relation to Gaia DR3 G mags

						Gaia DR3			
WDS	DD	PA	Sep	M1	M2	theta	rho	G_1	G_2
04332+1746	LDS2254	82	2.6	19.00	20.60	81.927	2.63688	16.953	16.854
17560+0827	J 457	219	2.6	9.50	11.00	217.396	2.63958	12.105	13.082
19316+0555	ELP 44	182	2.5	7.84	10.33	182.399	2.48441	10.562	14.396

UNCONFIRMED TYCHO DOUBLE STARS VERSUS GAIA DR3 - II

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Abstract

As follow up to our paper 'Unconfirmed Tycho Double Stars versus Gaia DR3 - I', this report takes a closer look at the remaining subset of 8,625 unconfirmed TDS/TDT objects with angular separation below 1.45 arcseconds based on the assumption that Gaia DR3 should most likely resolve such close double stars. With a combination of automatic cross-matching and manual checking of potential candidates we found 547 TDS/TDT objects confirmed by Gaia DR3 companions within the search radius of 3 arcseconds with reasonable data differences and 178 pairs with significant Rho and Theta data deltas.

Of the remaining TDS/TDT objects 440 have very faint Gaia DR3 companions outside the Tycho magnitude limit. However, 'something' acceptable as double star exists here at these positions.

The rest of the TDS/TDT objects have no companion within the search radius of 3 arcseconds and are thus considered spurious.

Method

The method used is the same as in our first paper 'Unconfirmed Tycho Double Stars versus Gaia DR3 - I' (Gould & Knapp, 2023), which basically means matching the TDS/TDT objects against the Gaia DR3 catalog.

As the proposed separation of the selected TDS/TDT objects goes down to just under $0''.4$, we expected a slightly weaker cross-match performance, as this comes close to the proposed Gaia DR3 resolution limit of $0''.18$ (Torra et al. 2021), which is in practice a best-case value under very favourable conditions. The Gaia documentation (https://gea.esac.esa.int/archive/documentation/GEDR3/index.html) offers some advice in this regard as follows:

For sources that are separated on the sky by $0.2 - 0.3$ arcsec, such that they are only occasionally resolved in the Gaia transits, ambiguity in the observation-to-source matching can lead to spurious parallax values that are very large (positive or negative) and appear highly significant

The spatial resolution of Gaia EDR3 has improved with respect to Gaia DR2 and incompleteness in close pairs of stars starts below separations of ∼1.5 arcsec. Below ∼0.7 arcsec, the completeness in close source pairs decreases very rapidly. Nonetheless, the treatment of such sources has been improved and close pairs with separations between 0.18 and 0.4 arcsec which were erroneously considered duplicate sources in Gaia DR2 appear as two sources in Gaia EDR3 (although such pairs may still represent spurious solutions). New quality indicators in Gaia EDR3 that are related to the image parameter determination step provide useful indications whether, for instance, a source is one of a close pair (and possibly a binary) or whether it suffers from nearby disturbing sources.

Fabricius et al. (2021) show, for instance, that the parameter `ipd_gof_harmonic_amplitude` is useful for identifying spurious solutions of resolved doubles, which are not correctly handled in the Gaia EDR3 astrometric processing.

The resolution success for WDS double stars is according to Fabricius *et al.* (2021) in Gaia EDR3 significantly better than in DR2, but drops sharply below $0''.7$.

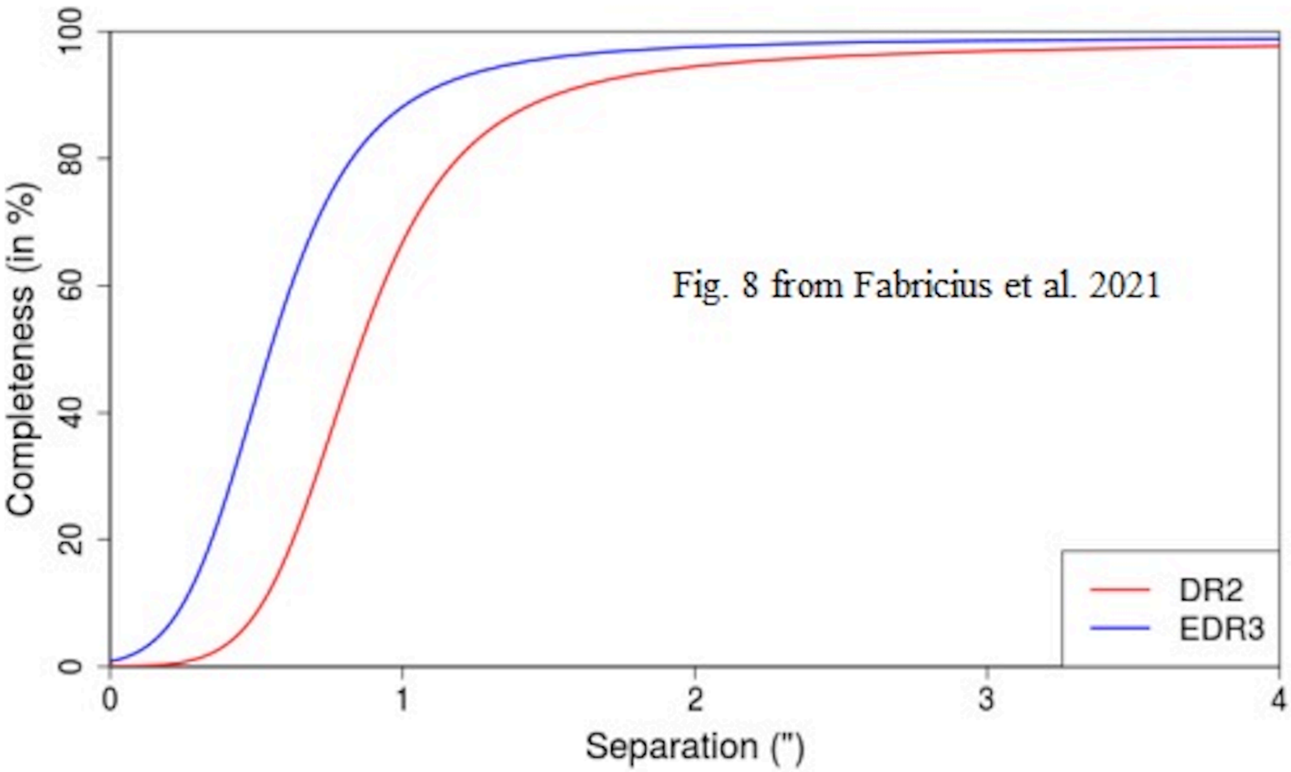

Figure 1: Completeness diagram from Fabricius *et al.* (2021)

There are no details given, how this 'completeness' assessment was done, so it is unclear, if this relationship is restricted to confirmed pairs. If not, then by itself the huge number of unconfirmed TDS/TDT objects would have a significant influence on the outcome. It is also unclear, if this result is valid for pairs restricted to properties typical for TDS/TDT objects - there are many reasons for unresolved pairs in Gaia DR3 such as very bright components or high proper motion, which are not relevant for this project. Therefore, we decided to check our method again in detail, using again a confirmed data set from the WDS Catalogue with parameters similar to the TDS/TDT objects in question.

Proof of concept

Proof of concept for the presented method is done by cross-matching a sample of confirmed WDS objects with a separation from 0.4 to 1.44 arc seconds and magnitude data comparable with TDS/TDT pairs with five or more observations against the Gaia DR3 Catalog. High proper motion objects and pairs with a very bright component nearby were excluded to avoid known Gaia issues. The number of WDS objects matching these restrictions is with 687 examples small (∗) with the following distribution in angular separation:

Rho	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
%	6.6	7.1	8.0	9.3	10.5	10.9	9.6	8.9	9.6	11.2	8.3

Table A

The cross-match of these 687 pairs with Gaia DR3 with a search radius of 3″ found all primaries but left 43 objects without a companion indicating a rather modest overall hit rate of 93.7% (see also Appendix B, Table 8) with the following distribution in angular separation for successful matches:

Rho	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
%	60.0	71.4	92.7	95.3	97.2	100.0	98.5	98.4	100.0	100.0	100.0

Table B

This result indicates that the hit rate is down to an angular separation of 0″.7 indeed quite good, and the drop below is significant but not as sharp as proposed.

A closer look at the misses (Appendix B, Table 9) identified 12 KOI pairs (Kepler Object of Interest, observed by the Kepler space telescope looking for stars hosting one or more transiting planets), which seem somehow hard to resolve in the visual band. Another 21 misses are pairs without observation in the last 10 up to 60 years - it might be a good idea to have a closer look at these objects with a high performance telescope. Even if we might exclude some of the misses as not relevant for our project there remains an increased risk for false negatives compared to our first paper ‘Unconfirmed Tycho Double Stars versus Gaia DR3’.

The fact of this modest Gaia double star resolution rate especially in the range of 0″.4 to 0″.5 poses a dilemma for our project because a significant part of the selected subset of the TDS/TDT objects falls into this range:

Rho	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
% TDS/TDT	13.1	28.5	20.2	11.0	8.6	6.9	3.7	2.9	1.8	1.6	1.6

Table C

The seemingly obvious solution would be to simply restrict our project to separations ∼0″.6 to avoid the critical separation range. However, the lack of precision in the given Tycho measurements would necessarily lead to the inclusion of a significant number of pairs in this range as well to the exclusion of a significant number of pairs outside this range. So we decided to stick with the given subset and to use the known bad Gaia resolution rate in the range below 0″.6 to possibly best estimate the resulting error range (see Summary).

It seemed also of interest to have a closer look at the proposed Gaia DR3 resolution limit of 0.18 arcseconds, as every technical limit is often difficult to realize in reality even under favourable conditions. A reference data set of 475 confirmed WDS pairs with separation between 0.15 and 0.34 arcseconds (in the magnitude range comparable to TDS/TDT pairs and without a known fast proper motion issue) was cross-matched with Gaia DR3 with a search radius of 1″ with an expected low hit rate of overall about 12.5% (20.9% in the range of 0″.3 and a mere 4.9% in the range of 0″.2 separation). Nevertheless, this demonstrates that Gaia DR3 is under very favorable conditions indeed able to resolve double stars down to separations of 0.2 arcseconds (Appendix B Table10). However, resolution in this separation range is obviously not the rule but the exception (see list of 415 unresolved pairs in Appendix B Table 11).

How can these results be compared with Tycho?

Høg *et al.*, 2000 state regarding Tycho-2 catalog: Good quality Tycho-2 solutions were often obtained for separations above 0.43 arcsec and, surprisingly, realistic results were sometimes derived at separations as close as 0.25 arcsec. For the Tycho-2 Catalogue the safer limit of 0.8 arcsec was however adopted, drastically reducing the number of resolved doubles.
Høg *et al.*, 1997 state regarding Tycho catalog: Double stars were subject to dedicated data reductions, resulting in the resolution of pairs with separation down to about 1.5 arcsec. Detection of the effects of duplicity was effective down to separations of about 0.5 arcsec.
These remarks suggest some caution that we fully share - as we have already shown in our first paper there is little reason to fully trust Tycho double star measurements even for angular separations above 1″.45 The effective risk that Gaia (with a telescope aperture of 1.0 m and contemporary technology) is not able to re.solve pairs resolved by Tycho (with a telescope aperture of 0.3 m and technology 30 years older) seems most likely close to zero.

Results for TDS/TDT objects

The WDS catalogue contains 10,296 TDS/TDT objects with a separation of 1.44 or smaller with first observation 1991/1992 with 83.8% of them so far not confirmed by at least a second observation. This subset of 8,625 unconfirmed TDS/TDT objects was cross-matched with the Gaia DR3 catalogue with a search radius of three arcseconds around the given WDS precise position with a hit rate of 100% for the primaries. 26 objects were missed in the first run with position 2016 due to very high proper motion but found in a second run with proper motion calculated back to position 2000

For 7,435 objects, we found simply no Gaia DR3 companion within the search radius of 3″ , which means spurious due to sufficient evidence of non-existence (Appendix A, Table 1). *Suggested WDS Catalogue update: Add WDS note code 'X'.*

For 269 objects, we found well matching Gaia DR3 pairs with a delta in separation <0″.2 and in position angle <15° and magnitudes (if given) for the secondary brighter than G=15 (Appendix A Table 2). The average delta in separation is −0″.03 and the standard deviation is 0″.10. About 12% of the matched pairs are potentially questionable due to missing magnitude data for the secondary and about 31% of the these pairs are currently listed with a quadrant issue. However, the risk of false positives seems negligible. *Suggested WDS catalogue update: Add Gaia DR3 measure as the second observation.*

For 191 other objects we found fairly well matching Gaia DR3 pairs with a delta in separation <0″.3 and in position angle <30° and magnitudes (if given) for the secondary brighter than G=15 (Appendix A Table 3). The average delta in separation is −0″.03 and the standard deviation is 0″.19. About 20% of the matched pairs are potentially questionable due to missing magnitude data for the secondary and about 34% of the these pairs are currently listed with a quadrant issue. However, the risk of false positives still seems negligible. *Suggested WDS Catalogue update: Add Gaia DR3 measure as the second observation.*

For 83 objects, we found with some allowances matching Gaia DR3 pairs with a delta in separation <0″.4 and in position angle <60° and magnitudes (if given) for the secondary brighter than G=15 (Appendix A Table 4). The average delta in separation is −0″.03 and the standard deviation is 0″.29. About 33% of the matched pairs are potentially questionable due to missing magnitude data for the secondary and about 38% of the these pairs are currently listed with a quadrant issue. However, the risk of false positive results appears to be still relatively low. *Suggested WDS Catalogue update: Add Gaia DR3 measure as the second observation or X-mark the Tycho measurement as erroneous and add Gaia DR3 measure as first observation.*

For 175 objects, we found at the given position within the search radius of $3''$ Gaia DR3 pairs potentially detectable by Tycho (which means secondaries brighter than G=15) but with separation and position angle not even similar to the WDS data, and for this reason considered most likely false positives (Appendix A, Table 5). About 37% of the found pairs are potentially questionable due to missing magnitude data for the secondary. *Suggested WDS Catalogue update: X-mark Tycho measure as erroneous and add Gaia DR3 measure as first observation.*

For 436 objects, we found Gaia DR3 pairs with companions too faint by far to be detectable by Tycho and in most cases also with large deltas in separation and position angle, which means false positives for certain (Appendix A, Table 6). In case of several components besides the primary, the brightest companion was selected as secondary. *Suggested WDS Catalogue update: X-mark Tycho measure as erroneous and add Gaia DR3 measure as first observation.*

Finally, 36 objects are special cases that required some detective work to get conclusive results (Appendix A Table 7). *Suggested WDS Catalogue updates are given for each object individually.*

Summary

From 8,625 unconfirmed TDS/TDT objects with separation $<1''.45$ we found:

7,435 spurious objects (no companion within the search radius of 3 arcseconds)

269 pairs with ΔTheta$<15^\circ$ and ΔRho$<0''.2$

191 pairs with ΔTheta$<30^\circ$ and ΔRho$<0''.35$

83 pairs with ΔTheta$<60^\circ$ and ΔRho$<0''.4$

175 pairs with a companion beyond allowances

436 pairs with a companion fainter than G=15

36 special cases, of them

25 objects without matching companion

4 pairs with ΔTheta$<60^\circ$ and ΔRho$<0''.4$

3 pairs with a companion beyond allowances

4 pairs with faint companion.

Using the statistics from the proof of concept part, we estimate the number of false misses as follows:

In total we found 547 pairs confirmed within the allowance thresholds up to ΔTheta$<60^\circ$ and ΔRho$<0''.4$.

From these pairs 87 are listed with separation up to $0''.4$ and 93 up to $0''.5$. Applying the Gaia DR3 hit range of 60% and 71.4% in these groups (see Fig. 3) suggests a number of 95 misses. This estimate is a bit on the pessimistic side, as we ignore the fact that several of the missed proof of concept objects seem a bit questionable. Together with all other separation groups, we estimate a total number of 100 cases of missing Gaia DR3 companions in the cross-match of the TDS/TDT subset examined in this report. What looks like a large number is in relation to the number of objects in question actually tiny with a projected false negative risk of 1.2%. In comparison, the false positive rate in the Tycho Double Star Catalogue for this group of unconfirmed TDS/TDT objects is >85% even when counting the 'something is here' as hits.

Overall, this means:

86.49% of the checked TDS/TDT objects are assessed as spurious with a projected error rate of about 1.2%

6.34% are considered confirmed within defined thresholds

7.17% objects were found with 'something is here', which means companions beyond the defined thresholds or with very faint companions.

There remains the question, how many of the confirmed TDS/TDT objects might be just lucky hits. To find an answer to this question we selected a random sample of 10,000 Gaia DR3 objects with G=11 and checked for objects with a companion within a search radius of 3″ (corresponding with the search radius used for cross-matching the TDS/TDT objects with Gaia DR3). We found here in total 1,094 pairs including 90 triples, which gives a hit rate of 10.9% slightly below the hit rate in the TDS/TDT sample of in total 13.51% including the 'something is here' objects. However, the number of objects with a separation below 1″.5 is with 207 cases significantly below the number of confirmed TDS/TDT objects in this separation range and also the distribution in the separation bins is very different.

This is an interesting statistical anomaly of TDS/TDT objects with separation below 1″.5 in comparison with the sample of confirmed WDS objects in this range and also with the random sample that has a quite different distribution in the various separation bins with an obvious bias towards the smaller separations:

Rho	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
% WDS sample	6.6	7.1	8.0	9.3	10.5	10.9	9.6	8.9	9.6	11.2	8.3
% Random sample	11.6	5.3	4.3	5.8	7.7	7.2	9.7	9.7	14.0	14.5	11.1
% TDS/TDT	13.1	28.5	20.2	11.0	8.6	6.9	3.7	2.9	1.8	1.6	1.6

Table D

Interestingly, the group of 269 confirmed TDS/TDT pairs with Theta<15° and Rho<0″.2 reflect this anomaly:

Rho	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
% Table 2	13.5	20.4	23.8	19.3	8.9	5.9	3.7	2.9	0.7	0.0	0.0

Table E

These values make clear that the number of confirmed TDS/TDT objects is far beyond a potential random hit rate. The re-reduction method used for the creation of the Tycho Double Star catalogue (Fabricius *et al.*, 2002) was obviously very well suited to identify double stars down to a separation below 0″.4. However, it is also evident that this procedure had also a heavy tendency for false positives in the range of separation 0″.6 and below.

Together with our 'Unconfirmed Tycho Double Stars versus Gaia DR3 - I' paper we have covered in total over 10,000 so far unconfirmed TDS/TDT objects and found the vast majority of them to be spurious. There is due to unavoidable star catalogue errors a risk to have declared about 100 of these objects erroneously as spurious but we consider this a fair price to be able to declare over 9,000 of such proposed pairs correctly as spurious.

(∗) Historically, the great double star discovery surveys of the 19th and 20th centuries were typically limited to stars brighter than magnitude 10 or 11, and were known to be incomplete among fainter stars, in part due to the limited apertures of the visually-used telescopes. Also, surveys to a particular visual magnitude were preferred for statistical reasons to aim at completeness to the resolution limit of the telescopes used. Tycho stars claimed as double are mostly dimmer than the irregular magnitude cut-off for the earlier surveys, hence the rather modest number of long-known both close and faint doubles available for comparison.

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Acknowledgements

The following tools and resources have been used for this research:
Washington Double Star Catalog
Gaia DR3 Catalogue (via CDS VizieR)
CDS X-Match tool
Tycho Double Star Catalog
Aladin Sky Atlas v11
SIMBAD, VizieR

Appendix A

Tables with Gaia DR3 cross-match results for 8,625 unconfirmed TDS/TDS objects

Table 1 - 7,435 TDS/TDT objects with no Gaia DR3 companion

(Stub with 10 rows, full table available for download from
`https//www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_II/`)
Suggested WDS Catalogue update: Add WDS note code 'X'

WDS	TDS	Theta	Rho	M1	M2	Comment
00005+4556	1239	126	0.6	11.93	12.12	No Gaia DR3 companion
00006−2916	1240	288	0.6	11.54	12.12	No Gaia DR3 companion
00007+5417	1243	109	0.5	11.04	11.05	No Gaia DR3 companion
00007+5600	1242	359	0.5	11.29	11.41	No Gaia DR3 companion
00007+5614	1241	236	0.6	11.31	11.62	No Gaia DR3 companion
00007−0601	1245	356	0.5	10.82	11.15	No Gaia DR3 companion
00011+5622	1247	114	0.6	11.60	11.98	No Gaia DR3 companion
00014−0920	1251	106	0.8	12.12	12.12	No Gaia DR3 companion
00019+5257	1255	52	0.6	11.40	11.94	No Gaia DR3 companion
00020+1720	1256	242	0.4	10.95	11.15	No Gaia DR3 companion

Table 2 - 270 TDS/TDT objects with matching Gaia DR3 pairs with a delta in separation <0″.2 and delta in position angle <15° and magnitude for the secondary brighter than G=15

(Stub with 10 rows, full table available for download from
`https://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_II/`)
Suggested WDS Catalogue update: Add Gaia DR3 measure as second observation

			Tycho				Gaia DR3				
WDS	TDS	Comp	Theta	Rho	M1	M2	Theta	Rho	G_1	G_2	Notes
00017+5905	1252	Aa,Ab	63	0.9	10.90	11.97	60.935	0.77423	10.882	11.650	
00164+5722	1375	Aa,Ab	123	0.8	11.63	11.98	128.564	0.71375	11.422	11.682	
00171+5807	1381		299	0.8	11.57	11.72	289.049	0.68014	11.062	11.590	
00219−3908	1421		1	0.7	10.94	11.23	173.061	0.61093	10.833	10.944	Q
00268−3707	1464		315	0.8	11.87	11.93	130.656	0.63568	11.427	11.999	Q
00292+4043	1488		110	0.5	10.79	10.93	123.646	0.68386	9.800		M
00306+5412	1499		296	0.7	11.57	11.77	122.643	0.71447	11.416	12.062	Q
00360+5034	1541		321	0.8	11.23	11.54	319.706	0.62603	10.873	11.565	
00383−6405	1555		271	0.4	10.78	10.85	280.104	0.38581	10.382	10.845	
00470−6932	28		292	0.9	10.94	12.00	296.302	0.95013	10.652	11.690	

Q - quadrant issue
M - no magnitude for secondary

Table 3 - 192 TDS/TDT objects with matching Gaia DR3 pairs with a delta in separation <0″.3 and delta in position angle <30° and magnitude for the secondary brighter than G=15

(Stub with 10 rows, full table available for download from
`https://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_II/`)
Suggested WDS Catalogue update: Add Gaia DR3 measure as second observation

WDS	TDS	Tycho Theta	Rho	M_1	M_2	Gaia DR3 Theta	Rho	G_1	G_2	Notes
01370+6344	1929	299	0.4	10.63	10.65	118.945	0.68182	9.753		Q,M
04128+5808	2787	30	0.4	10.51	10.61	4.326	0.46864	10.193	10.461	
06530−2951	4247	75	0.4	10.44	10.83	66.534	0.60497	10.043	11.245	
07071+6659	4487	149	0.4	10.75	10.80	166.823	0.22551	10.060	10.468	
09191−4838	6466	160	0.4	10.51	10.53	161.697	0.65388	9.643	11.470	
09253−2439	6547	175	0.4	10.49	10.73	193.311	0.41444	10.043	10.663	
10438−5409	7439	164	0.4	10.73	10.77	343.999	0.69768	10.193		Q,M
12017−5214	8179	135	0.4	10.73	11.01	152.043	0.63619	10.223	11.727	
14388+6857	9258	230	0.4	10.64	10.78	78.370	0.45786	10.295	10.709	Q
14485−7558	9313	320	0.4	10.59	10.66	304.034	0.67466	10.025		M

Q - quadrant issue
M - no magnitude for secondary

Table 4 - 85 TDS/TDT objects with matching Gaia DR3 pairs with a delta in separation <0″.4 and delta in position angle <60° and magnitude for the secondary brighter than G=15

(Stub with 10 rows, full table available for download from `http://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_II/`)
Suggested WDS Catalogue update: Add Gaia DR3 measure as second observation or X-mark the Tycho measurement as erroneous and add Gaia DR3 measure as first observation

WDS	TDS	Tycho Theta	Rho	M_1	M_2	Gaia DR3 Theta	Rho	G_1	G_2	Notes
00209−5534	1413	148	0.8	12.11	12.15	332.155	0.45398	11.448	12.022	Q
00239+5322	1438	17	0.8	11.11	11.63	334.614	1.10029	10.773	12.106	
00586+6254	1694	357	1.2	11.64	12.00	15.844	0.83500	11.724	11.864	
00590+6110	1703	277	0.6	11.42	11.53	265.050	0.90258	10.733		M
01015+5458	1723	196	0.7	12.01	12.31	50.755	0.38184	11.463	12.482	Q
01022+5702	1734	212	0.4	10.92	11.15	256.018	0.37245	10.849	11.007	
01248+6414	1870	304	0.5	11.28	11.35	281.364	0.81532	10.465		M
01360−8438	1924	313	0.7	11.88	11.90	355.271	0.58405	11.418	12.678	
01551−7401	2054	115	0.6	11.38	11.41	60.099	0.45578	10.926	11.127	
02154+5517	2176	91	0.5	11.04	11.39	125.213	0.33441	10.894	11.550	

Q - quadrant issue
M - no magnitude for secondary

Table 5 - 178 TDS/TDT objects with Gaia DR3 pairs at the given position within the search radius of 3″ , potentially detectable by Tycho (which means secondaries brighter than G=15) but with separation and position angle not even similar to the WDS data, and for this reason considered most likely false positives

(Stub with 10 rows, full table available for download from `https://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_II/`)
Suggested WDS Catalogue update: X-mark Tycho measure as erroneous and add Gaia DR3 measure as first observation

WDS	TDS	Tycho Theta	Rho	M_1	M_2	Gaia DR3 Theta	Rho	G_1	G_2	Notes
00100+5530	1326	27	0.4	11.01	11.08	206.287	0.82127	10.431		M
00177+4934	9	108	0.9	11.19	11.62	212.751	1.00476	10.922	14.898	
00365+5341	1546	159	0.7	11.70	11.79	311.628	2.99232	11.038		M
00526+5636	1651	84	0.6	11.49	11.63	211.679	1.14491	10.849	14.048	
00593+5113	1706	151	0.3	10.55	10.70	157.617	0.83372	10.013		M
01133+6339	1804	342	0.6	11.15	12.06	331.187	1.18765	10.520	13.313	
01180+6550	1835	278	0.5	11.14	11.28	263.274	1.48196	10.419	12.091	
01460−6523	1995	97	0.4	9.52	10.13	61.246	3.18001	9.046	14.468	
01547−3714	2051	134	0.8	11.64	12.02	137.133	0.33253	11.150	11.770	
02017+5649	2089	242	0.5	11.39	11.41	72.739	1.19862	10.862	13.398	

Q - quadrant issue
M - no magnitude for secondary

Table 6 - 440 TDS/TDT objects with Gaia DR3 pairs with companions too faint by far to be detectable by Tycho and in most cases also with large deltas in separation and position angle, which means false positives for certain

(Stub with 10 rows, full table available for download from `https://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_II/`)
Suggested WDS Catalogue update: X-mark Tycho measure as erroneous and add Gaia DR3 measure as first observation

WDS	TDS	Comp	Tycho Theta	Rho	M_1	M_2	Gaia DR3 Theta	Rho	G_1	G_2
00017−2348	1253		204	0.5	11.35	11.40	125.120	2.38664	10.292	18.266
00077+7839	1304		317	0.5	11.15	11.18	197.016	2.93352	10.306	18.695
00091+5938	1315	Ba,Bb	256	0.4	10.45	10.45	280.658	2.82847	9.616	16.576
00125+5415	1341		310	0.6	11.87	11.95	307.286	1.31461	11.207	15.210
00173+5346	1383		46	0.6	11.43	11.68	24.440	1.61767	11.063	16.685
00212+6239	1415		316	0.6	11.60	11.61	112.546	1.97555	10.799	16.929
00250+6212	1450		281	0.7	11.75	11.89	96.197	2.10734	11.001	17.709
00253−7000	1455		126	0.5	11.42	11.47	174.084	1.77073	10.645	16.806
00255+5858	1458		131	0.8	12.00	12.30	56.729	2.63988	11.493	19.168
00272+5110	1468		284	0.8	11.98	12.69	75.690	1.28815	11.654	17.602

Table 7 - 36 TDS/TDT objects with special issues

(Stub with 5 objects, full table available for download from `https://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_II/`)
Suggested WDS Catalogue update: Given per object

WDS	DD	Comp	Gaia DR3 Theta	Rho	G_1	G_2
00475+1237	TDS1613	AB	338.772	0.36287	11.047	11.089
03020−3101	TDS2418	Aa,Ab	311.996	1.57147	10.169	13.079
03580+5136	TDS2697	AC	327.068	0.41707	10.650	10.732
04078−2513	TDS2756	Aa,Ab	350.114	2.33473	10.235	17.126
05000−1623	TDS3035	AC	199.023	0.35911	10.971	11.075

Pair	Notes with suggested WDS Catalogue update
00475+1237	Gaia DR3 measure is for HEI 303Aa,Ab. No match for TDS1613AB - spurious. *WDS note code 'X' for TDS1613AB. Change HEI 303 component designation to AB*
03020−3101	Gaia DR3 measure is for RST1251AB. No Gaia DR3 component match for Aa,Ab match. TDS2418Aa,Ab spurious. *WDS note code 'X' for TDS2418Aa,Ab*
03580+5136	Gaia DR3 measure is for COU2359AB listed with last observation 1990. No Gaia DR3 component for C. *WDS note code 'X' for TDS2697AC. Add Gaia DR3 measure for COU2359AB*
04078−2513	Gaia measure is for TOI 954AB. No match for TDS2756Aa,Ab. WDS note code 'X' for TDS2756Aa,Ab
05000−1623	Hard to decide due to missing proper motion data for one component. However, it seems that TDS3035 is a badly measured rediscovery of RST3409 missed since 1951. The Gaia DR3 measure looks like a match for RST3409 with a quadrant issue. *Delete TDS3035AC object. Add Tycho measure to RST3409 observation history and X-mark as erroneous. Add Gaia DR3 measurement to RST3409 observation history*

Appendix B

Tables with Gaia DR3 cross-match results for 687 proof of concept objects

Table 8 - 644 proof of concept pairs out of 687 objects confirmed in Gaia DR3

(Stub with 10 rows, full table available for download from `https://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_II/`)
612 objects are confirmed with a delta in Theta <15° and a delta in Rho $<0''.2$ and 24 objects are considered confirmed with a delta in Theta up to 60° and a delta in Rho up to $0''.6$ and eight objects are special cases requiring some detective work. 111 of these objects come with a quadrant issue and ten objects are listed in Gaia DR3 without G for the secondary.

WDS	DD	Theta	Rho	M_1	M_2	Theta	Rho	G_1	G_2	Notes
00004+2749	TDS1238	88	0.8	11.70	11.71	268.126	0.83719	11.393	11.529	Q
00112+3331	COU 648	308	0.4	11.00	11.30	131.543	0.26559	10.813	10.954	Q
00112+5034	TDS 5	133	1.2	11.15	13.05	135.438	1.20988	11.155	12.352	
00114−4701	RST 2	67	0.6	11.00	11.30	67.350	0.64187	10.678	10.935	
00132−3942	RST1181	216	0.8	11.36	11.62	215.822	0.80887	10.951	11.364	
00156+3751	COU 848	296	0.8	11.51	11.84	296.639	0.78710	11.163	11.440	
00171−5551	RST2237	267	0.5	11.10	11.61	267.478	0.51574	10.819	11.378	
00181+5255	TDS 10	75	1.2	11.88	11.91	255.619	1.25916	11.901	11.982	Q
00195+3544	POP 35	296	0.7	11.23	11.05	296.714	0.72970	10.525	11.420	
00202−2437	RST2240	347	1.3	11.34	11.76	346.603	1.29004	11.073	11.529	

Q - quadrant issue

Table 9 - 43 proof of concept pairs out of 687 objects not resolved in Gaia DR3

(Stub with 10 rows, full table available for download from `https://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_II/`)
The combination of not observed for 10 or more years and not resolved by Gaia DR3 suggests a closer look at these objects with a high performance telescope

WDS	DD	Comp	First	Last	Obs	Theta	Rho	M1	M2	Note
00155−1537	HU 403		1901	1991	7	50	0.7	11.12	11.49	1
00246−1255	HU 4		1899	1963	10	53	0.5	12.30	12.30	2
00465+1558	HEI 19		1978	2016	7	244	0.7	11.01	11.06	

01385+3448	COU1059		1973	2011	9	133	0.4	11.30	11.80	3
01588+3730	COU1364		1975	2012	5	53	0.5	11.39	11.01	4
02212+2751	COU 457		1970	2011	7	161	0.5	11.40	12.00	5
02503+3230	COU 675		1971	2009	7	55	0.6	11.10	11.40	6
03549−1058	RST3389		1939	1990	6	96	0.4	11.10	11.10	7
04327+2553	GHE 11	Aa,Ab	1990	2012	21	12	0.4	14.20	14.60	8
04518+3047	JOY 4		1944	2012	19	230	0.8	12.80	12.00	9

1. Not observed since 1991
2. Not observed since 1963
3. Not observed since 2011
4. Not observed since 2012
5. Not observed since 2011
6. Not observed since 2009
7. Not observed since 1990
8. Gaia measures matches JOY 3 with much brighter components than listed. No match for GHE 11 Not observed since 2012
9. Not observed since 2012

Table 10 - Gaia resolution limit test: 60 resolved pairs

Cross-match of 475 pairs with confirmed separation between 0.15 and 0.34 arcseconds with a search radius of 1″ (Stub with 10 rows, full table available for download from `https://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_II/`)

WDS	DD	Comp	Theta	Rho	M_1	M_2	Theta	Theta	Rho	G_1	G_2	Note
00479+5555	MLR 652		354	0.3	10.1	10.1	13.981	340.019	0.22811	9.414	9.652	
00519+6101	MLR 516		272	0.3	10.7	11.0	1.896	273.896	0.29940	10.529	10.744	
01255+0225	A 2315		313	0.3	10.8	10.8	22.350	110.650	0.30617	10.374	10.434	Q
01328+3551	A 1911	Ea,Eb	359	0.3	10.3	10.7	14.755	13.755	0.27572	10.071	10.159	
01557−4351	I 452		322	0.3	10.2	10.3	2.863	324.863	0.29991	9.727	10.021	
02456−2004	DON 40		283	0.2	10.5	10.6	4.055	98.945	0.38781	10.291	10.304	Q
02524−0755	RST4215		150	0.2	11.2	11.2	54.903	204.903	0.27173	10.656	10.749	
03333+3522	COU1079	AB	39	0.3	10.0	10.3	1.443	40.443	0.30959	9.748	10.219	
04217−0300	RST4238		272	0.3	11.5	12.0	0.079	271.921	0.83967	11.077	11.958	
04308+4550	A 1007		162	0.3	10.3	10.8	0.350	161.650	0.34138	10.083	10.379	

Q - quadrant issue

Table 11 - Gaia resolution limit test: 415 unresolved pairs

Cross-match of 475 pairs with confirmed separation between 0.15 and 0.34 arcseconds with a search radius of 1″ (Stub with 10 rows, full table available for download from `https://www.webbdeepsky.com/dssc/dssc31/Tycho_Gaia_II/`)

WDS	DD	Comp	Theta	Rho	M_1	M_2
00059−3020	RST5180	AB	340	0.3	10.00	10.20
00101+3825	HDS 23	Da,Db	146	0.2	11.42	12.85
00229−2852	RST1186		224	0.3	11.60	11.60
00288+5541	MLR 624		337	0.2	9.90	10.10
00302−1221	RST3345		248	0.3	10.25	10.72
00321−3614	RST2246		274	0.3	11.11	11.72
00365+3724	A 1505	AB	39	0.2	10.50	10.50
00390+4037	WOR 31	AB	124	0.3	10.50	10.50
00390+4040	BU 1159		158	0.2	9.90	10.10
00397−2135	HDS 91		224	0.2	10.02	10.55

Cumulative index of the contents of Double Star Section Circulars

DSSC11 (ctd)
Measures of double stars with a CCD camera and 35.−cm Newtonian telescope in 2002 (Ernő Berkó, Tamás Ladányi, and Gyórgy Vaskúti)
Pp. 94, 2003

DSSC12:
Micrometric measures of double stars from 2003.0 to 2004.0 (J- F. Courtot & R. W. Argyle)
Measures of double stars made with an eyepiece micrometer (Magne Tollefsen)
Measures of double stars made with an eyepiece micrometer (Tim Leese)
CCD measures of double stars 2003 (Doug West)
Measures of double stars with a CCD camera and 35.-cm reflector from 2002.953 to 2003.394 (Ernő Berkó, Tamás Ladányi, and György Vaskúti)
Data mining the Two Micron All Sky Survey 2MASS) for double stars (Martin Nicholson)
777 double stars in the Two Micron All Sky Survey (2MASS) (Martin Nicholson)
On double identities, recovered pairs, and optical imposters - investigations into some neglected double stars of the Washington Double Star Catalogue (Richard Harshaw)
New measures for some neglected double stars of the Washington Double Star Catalogue (Richard Harshaw)
Measures of some neglected southern double stars using the superCOSMOS database (Richard Jaworski)
Pp. 96, 2004

DSSC13:
Micrometric measures of double stars from 2004.0 to 2005.0 (Bob Argyle)
Micrometer measurements from 2002.97 to 2004.94 (Andreas Alzner)
Measures of double stars with a CCD camera and 35.−cm reflector from 2003.934 to 2003.942 (Ernő Berkó, Tamás Ladányi, and György Vaskúti)
Measures of neglected John Herschel southern double stars using o−line databases (Richard Jaworski)
Measures of selected John Herschel pairs between RA 0 h and 6 h using the SuperCOSMOS database (Richard Jaworski)
Suggested additional double stars to the Catalogue (Richard Jaworski)
The John Herschel multiple stars HJ 2116, HJ201 and HJ202 (Richard Jaworski)
Measures of neglected John Herschel southern double stars using the SuperCOSMOS database (Richard Jaworski)
Measures of 396 neglected southern double stars (Tòfol Tobal)
Possible anonymous southern visual double stars (Tòfol Tobal)
Measures of 622 neglected northern double star RA 00h− 12h 55m (Tòfol Tobal)
Measures of double stars made with an eyepiece micrometer (Magne Tollefsen)
Common proper motion pairs from the Sloan Digital Sky Survey (John Greaves)
HJ 327AC, HJ 2002 & HJ 9001 (Richard Jaworski and Bob Argyle)
Possible additional components to double stars (Richard Jaworski)
A search for ‘missing’ Luyten double stars (Richard Jaworski)
Pp. 88, 2005

DSSC14:
Micrometric measures of double stars from 2005.0 to 2006.0 (Bob Argyle)
Micrometer measures from 2004.94 to 2005.96 (Andreas Alzner)
Measures of double stars made with an eyepiece micrometer (Tim Leese)
2520 previously unreported double stars (Martin Nicholson & Hannah Varley)
Updated measures of neglected pairs in the Washington Double Star Catalogue (Richard Harshaw)
BKO161 in place of STI 1445 (Gyorgy Vaskúti & Tamás Ladányi)
CCD measures of double stars at Palmer Divide Observatory - 2006.112 to 2006.238 (Brian D. Warner)
A modified industrial micrometer project - preliminary report (Morgan Spangle)
Some recent measures using a CCD camera (Morgan Spangle)
A search for ‘missing’ Luyten double stars - II (Richard Jaworski)

DSSC14 (ctd) Measures of Luyten double stars using data from the 2MASS survey and SUPERCOSMOS image database (Richard Jaworski)
Measurement of the positions of Milburn (MLB) pairs from Sky Surveys (Richard Jaworski)
Measures of the neglected double star HJ2302 AB using the chronometric method (Ian Coster)
Pp. 68, 2006

DSSC15: Micrometric measures of double stars from 2006.0 to 2007.0 (Bob Argyle)
Measures of double stars with a CCD camera and 25 - cm Cassegrain reflector in 2006 (Tamás Ladányi)
CCD observations of double stars at Waverley Observatory (Andrew Soon)
An analysis of errors in the measurement of visual double stars using the Celestron Micr-Guide with an SCT and Al-Azimuth mount (Tim Napier-Munn)
Measures of 1027 neglected northern double stars RA 13h - 24h (Tòfol Tobal)
Measurement of the positions of Milburn (MLB) pairs from Sky Surveys - II (Richard Jaworski)
Some measures of double stars using the chronometric method, an eyepiece micrometer and the Aladin database (Ian Coster)
Candidate binary star systems in the Sloan Digital Sky Survey Data Release Five (Martin Nicholson) Pp. 70, 2007

DSSC16: Micrometric measures of double stars in 2007 (Bob Argyle)
Micrometer measurements from 2006.21 to 2008.12 (Andreas Alzner)
Micrometric measures of double stars in 2007 (Jean - François Courtot)
Measures of double stars with a DSLR camera and 35.5-cm reflector from 2007.109 to 2007.194 (Ernő Berkó & György Vaskúti)
SDSS Data Release 6 proper motion information (John Greaves)
A trapezium in the field of Chevalier 138 (Thom Gandet)
Measurements of Selected Southern Double Stars - 1 (Richard Jaworski)
Measures of 1024 neglected visual double stars (Tòfol Tobal & Xavier Miret)
Pp. 84, 2008

DSSC17: Micrometric measures of double stars in 2008 (Bob Argyle)
Micrometer measures of the multiple system ES 1089 (Jean-François Courtot)
Measurement of some neglected southern multiple stars in Pavo (Tim Napier-Munn & Graham Jenkinson)
Measures of double stars with a DSLR camera and 35.5-cm reflector from 2008.781 to 2008.844 (Ernő Berkó)
A sequence of algorithms for the determination of binary star orbital elements and construction of the orbit relative to the apparent ellipse (Bill Oliver)
Measurement of ten bright double stars using a Celestron Microguide eyepiece (Ian Coster)
Analysis of six neglected pairs in the (Ian Coster)
A provisional orbit for STF 333 (WDS 02592+2120) (Ian Coster)
Measures of 36 anonymous and neglected southern visual double stars (Tófol Tobal & Xavier Miret)
OAG common proper motion wide pairs survey (Xavier Miret & Tófol Tobal)
Pp. 75, 2009

DSSC18: Micrometric measures of double stars in 2009 (Bob Argyle)
Micrometer measures of double stars in 2009 (Jean-François Courtot)
Measures of double stars with a DSLR camera and 35.5-cm reflector from 2008.852 to 2008.997 (Ernő Berkó)
Measures of double stars with a DSLR camera and 35.5-cm reflector from 2009.200 to 2009.835 (Ernő Berkó)
Measurement of some neglected southern multiple stars in Dorado and Pictor (Tim Napier-Munn & Graham Jenkinson)

DSSC18: (ctd)
Investigation of two anomalies in the (Tim Napier-Munn & Graham Jenkinson)
Five new visual double stars (Abdul Ahad)
Measures of 58 neglected southern visual double stars (Tòfol Tobal)
OAG Common proper motion wide pairs survey - Part II (OAG Supplement No. 24) (Xavier Miret & Tòfol Tobal)
Pp. 67, 2010

DSSC19:
Micrometric measures of northern double stars in 2010 (Bob Argyle)
Micrometer measures of wide southern double stars (Bob Argyle)
The triple visual-eclipsing system CHR 175 (Thom Gandet)
High proper motion pairs from the SPM4 Catalogue (John Greaves)
Common-motion pairs and other doubles found in spectral surveys - 1. Stephenson dwarfs and PG stars (Brian Skiff)
Measurements of visually discovered double stars between 1985-2007 (György Vaskúti)
Measures of double stars with a DSLR camera and 35.5-cm reflector from 2008.852 to 2008.997 (Ernő Berkó)
Lost Chevalier pairs? (Ernő Berkó)
Three new visual double stars (Abdul Ahad)
A new double star in Cygnus? (Peter Clark)
Second European Pro-Am meeting on double stars (Bob Argyle)
OAG common proper motion wide pairs survey - Part III (X. Miret, T. Tobal, A. Bernal, M. Bernal, I. Novalbos, J. A. Santos, & N. Miret)
Pp. 73, 2011

DSSC20
Micrometric measures of double stars in 2011 (Bob Argyle)
Micrometric measures of double stars in 2011 (Jean-François Courtot)
Astrometric measurements from 2010.7898 to 2011.6113 and six probable new pairs (Guiseppe Micello)
Measures of double stars near M39 (Mike Swan)
A new common proper motion pair in Serpens (Abdul Ahad)
A companion to the pulsating variable V1162 Tauri (Abdul Ahad)
Lost Chevalier pairs - a followup (Bill Hartkopf)
Observations of Visually Discovered Double Stars 1997 - 2011 (György Vaskúti)
Measures of double stars with a DSLR camera and 35.5-cm reflector on 2010.041 (Ernő Berkó)
Common-motion pairs and other doubles found in spectral surveys - 2. HD and miscellaneous stars (Brian Skiff)
Common-motion pairs and other doubles found in spectral surveys - 3. Lowell, Kuiper, Vyssotsky and other low-mass pairs (Brian Skiff)
An uncatalogued double star discovered by Ward (Bob Argyle and Ernő Berkó)
The wide triple system 14 Ari (Bob Argyle, Brian Skiff and Robert Kerr)
Measures of 74 equatorial neglected visual double stars RA: 00h00m to 05h59m - OAG Common proper motion survey - Supplement 26 (Tòfol Tobal)
Pp. 89, 2012

DSSC21
Micrometric measures of double stars in 2012 (Bob Argyle)
Micrometric measures of double stars in 2012 (Jean-François Courtot)
Orbit and astrophysical study of 12392-4022 = B1215 (Fernando Rica Romero)
Measures for 24 pairs in Capricornus (Abdul Ahad)
Three new cpm pairs in Capricornus (Abdul Ahad)
Measures of wide double stars using a webcam (Axel Tute)
Common-motion pairs and other doubles found in spectral surveys - 4. Faint M-dwarf doubles from the Sloan Digital Sky Survey (Brian Skiff)

DSSC21: (ctd) Common-motion pairs and other doubles found in spectral surveys - 5. Miscellaneous pairs (Brian Skiff)
Common-motion pairs and other doubles found in spectral surveys - 6. Measures for known pairs (Brian Skiff)
Twenty one wide double stars in Aquila (Giuseppe Micello)
Pp. 107, 2013

DSSC22 Micrometric measures of double stars in 2013 (Bob Argyle)
Micrometric measures of wide southern double stars in 2013 (Bob Argyle)
The system J 868 (00152+2722) - a new optical double star with orbital parameters (F. M. Rica)
A new visual binary system in Cetus (Abdul Ahad)
A new visual double star in Orion (Abdul Ahad)
Measurement of 24 southern multiple stars (Graeme Jenkinson and Tim Napier-Munn)
Common-motion pairs and other doubles found in spectral surveys: - 7. Miscellaneous new and known pairs (Brian Skiff)
Pp. 54, 2014

DSSC23 Micrometric measures of double stars in 2014 (Bob Argyle)
Micrometric measures of double stars in 2014 (Jean-François Courtot)
Orbital solution and astrophysical parameters for 09005+3225 (= HU 718) and WDS 11137+2008 AB (= STF 1517 AB) (Francisco Rica)
A new double star near Gamma Hydrae (Abdul Ahad)
Two new common proper motion doubles in Virgo (Abdul Ahad)
Measurement of nine neglected southern multiple stars (Graeme Jenkinson)
Common-motion pairs and other doubles found in spectral surveys - 8. One hundred forty new pairs found in the Orion complex (Brian Skiff)
Common-motion pairs and other doubles found in spectral surveys - 9. Survey work for 2014 (Brian Skiff)
New astrometric catalogue available from USNO (Brian Skiff)
Pp. 100, 2015

DSSC24 Micrometric measures of double stars in 2015 (Bob Argyle)
Micrometric measures of double stars in 2015 (Jean-François Courtot)
Measures of double stars at the Winer Observatory and discovery of new pairs (Andrè Debackére)
Discoveries of new pairs with the LCOGT network telescopes (T2M Faulkes Telescope North, Hawaii and T1M McDonald, Texas) (Andrè Debackére)
Five new common proper motion double stars (Abdul Ahad)
Measures of 17 southern multiple stars) (Graeme Jenkinson)
Measurement of neglected southern multiple stars - two listed pairs and a possible new pair (Graeme Jenkinson)
Measures of multiple stars in Norma (Graeme Jennkinson)
A new visual double star in Aquila (Ian Coster)
Common-motion pairs and other doubles found in spectral surveys: - 10. Survey work for 2015 (Brian Skiff)
Pp. 92, 2016

DSSC25 Micrometric measures of double stars in 2016 (Bob Argyle)
Micrometric measures of southern double stars in 2016 (Bob Argyle)
Micrometric measures of double stars in 2016 (Jean-François Courtot)
Some 2016 measurements of wide and faint double stars (Wilfried Knapp)

DSSC25: (ctd)

Double stars measurements with an astrometric eyepiece in 2016 (Neil Webster)
Two new visual common proper motion pairs (Kasper Wierzchos)
Measures of wide double stars with a webcam - II (Axel Tute)
Common-motion pairs and other doubles found in spectral surveys: - 11.
Survey work for 2016 prior to Gaia (Brian Skiff)
Measures of double stars with robotic telescopes (A. Debackére)
Study of the double star DBR 89 (A. Debackére)
Pp. 102, 2017

DSSC26

Micrometric measures of double stars in 2017 (Bob Argyle)
Micrometric measures of visual double stars (VI list) (Marco Scardia)
Micrometric measures of double stars in 2017 (Jean-François Courtot)
An improved technique for measuring the separation of close binary stars with a filar micrometer (Grant Morris)
Astronomical Association of Queensland 2016 programme. Measurements of nine neglected southern double stars (Graeme Jenkinson)
Measurements of double stars with robotic telescopes in 2017 (André Debackére)
Double star measurements with a Meade 12mm astrometric eyepiece in 2017 (Neil Webster)
Astrometric and photometric measurements of the double star J 703 (07106+1543) (André Debackére)
2017 measurements of some wide and faint double stars (Wilfried Knapp)
Pp. 63, 2018

DSSC27

Micrometric measures of double stars in 2018 (Bob Argyle)
Measurements of double stars in 2018 Jean-François Courtot
Double star measures (2016-18) made with Reticle and Maksutov at f/30 (Rob Moseley and Martin Grahn)
Double star measurements made with a Meade 12-mm astrometric eyepiece in 2018 (Neil Webster)
Measurements of double stars with robotic telescopes in 2017-2018 (André Debackère)
Recovery of Skiff objects in Gaia DR2 (Wilfried Knapp)
Physical pairs found in Gaia DR2 (Wilfried Knapp)
Recovery of KPP objects in Gaia DR2 (Wilfried Knapp)
Photographic measurements of wide double stars (Michael Hayes)
Update on the double star J 703 (07106+1543) (André Debackère)
A serendipitous double star discovery (Stephen Westmoreland)
Blue Star Observatory measurement of twenty neglected southern multiple stars (Peter N. Culshaw, Diane Hughes, John Hughes, Des Janke & Graeme Jenkinson)
Pp. 102, 2019

DSSC28

Micrometric measures of double stars in 2019 (Bob Argyle)
Measurements of double stars in 2019 (Jean-François Courtot)
Micrometric measurements of double stars in 2019 (Andreas Alzner)
Nearby stars with evidence of orbital motion (John Greaves)
Double star measurements performed with a 12-mm astrometric eyepiece during 2019 (Neil Webster)
On the Lowell Proper Motion Survey double stars listed in Simbad but unnoted in WDS (John Greaves)
A miscellany of double stars not in WDS (John Greaves)
A new common proper motion binary in Leo (Abdul Ahad)
Catalogue access and new lists of neglected doubles (Brian Mason)
Astronomical Association of Queensland 2018 programmes: Blue Star Observatory measurement of 16 neglected southern multiple stars (Peter Culshaw, Diane Hughes, John Hughes, Des Janke & Graeme Jenkinson
Observation of neglected double stars (Andre Debackére)
Pp. 64, 2020

DSSC29 Micrometric measurements of double stars in 2020 (Jean-François Courtot)
Micrometric measures of double stars 2020.10 to 2020.90 (Andreas Alzner)
Description of a CCD astrometric double star survey system (Ken Sturrock)
Astronomical Association of Queensland 2020 programme: Blue Star Observatory measurement of nine neglected southern multiple stars (Peter N. Culshaw, Diane Hughes, John Hughes, Des Janke and Graeme Jenkinson)
Astronomical Association of Queensland 2020 programme: Blue Star Observatory measurement of ten neglected southern multiple stars (Peter N. Culshaw, Diane Hughes, John Hughes, Des Janke and Graeme Jenkinson)
CMOS astrometry of double stars in 2020 (Grant Morris)
Double star measurements 2020 (Wilfried Knapp)
Observation of neglected double stars - 2 (André Debackére)
Observation of double stars with robotic telescopes in 2019/20 (André Debackére)
Pp. 79, 2021

DSSC30 Micrometric measurements of double stars in 2021 (Jean-François Courtot)
Two faint, common proper motion pairs in Hercules (Bob Argyle)
Astronomical Association of Queensland 2021 programme: Blue Star Observatory measurement of nine neglected southern multiple stars (Graeme Jenkinson and Des Janke)
Double star measurements 2021 (Wilfried Knapp)
Measurement of double stars with robotic telescopes in 2021 (André Debackére)
A tight common radial velocity pair in Canis Minor (John Greaves)
Pp. 38, 2022