Astrometric Measurements of WDS 07043-2412 JAW3, WDS 10039-6009 JAW10, WDS 12016-6000 WFC121 (JAW30), WDS 12030-6055 JAW31, WDS 13449-6235 JAW37 and WDS 06406-4006 JAW46 BC with Analysis using GAIA DR3 data

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Abstract

WDS 07043-2412 JAW3, WDS 10039-6009 JAW10, WDS 12016-6000 WFC121 (JAW30), WDS 12030-6055 JAW31, WDS 13449-6235 JAW37 and WDS 06406-4006 JAW46 BC were imaged using the Las Cumbres Observatory Global Telescope Network. Calibrated images were obtained and these were analysed using the software AstroImageJ to determine position angle, separation and delta magnitude. The mean, minimum and maximum physical distance separation were calculated. In addition, the angle (ν) between each of the components space velocity vectors in 3-dimensional space and Buchheim distance probability estimation were calculated for those pairs with the necessary data.

1. Introduction

In 2005, using the Aladin Interactive Sky Atlas, the 2MASS All Sky Survey Database and the Washington Double Star (WDS) catalogue, 45 pairs of stars were identified by the author, measured and suggested as additional double stars to the WDS catalogue (Jaworski, 2005a). These pairs were subsequently included and some of these pairs are in the current version of the WDS catalogue under another WDS identifier. Thus, TDS7075 is the same as JAW13; WFC110 is the same as JAW19; WFC121 is the same as JAW30; TOB148 is the same as JAW34 and TOB115 is the same as JAW35.

In addition, whilst systematically checking the details of the double stars in the southern neglected doubles list 1 of the WDS catalogue in 2005, 10 double stars were noted, measured and also suggested as additions to the WDS catalogue (Jaworski, 2005b). These pairs are included in the current version of the WDS catalogue.

The above work was carried out prior to the GAIA mission. The author believes that a review of these pairs in light of the GAIA data would be useful. The parallaxes of all the pairs were thus examined using GAIA DR3 data. Six pairs namely 07043-2412 JAW3, 10039-6009 JAW10, 12016-6000 WFC121 (JAW30), 12030-6055 JAW31, 13449-6235 JAW37 and 06406-4006 JAW46 BC were found to have relatively similar parallax values and were imaged and are further analysed in this paper. Selected data, from GAIA DR3 and other sources on these pairs can be found in Table 1.

12436-6116 TOB115 (JAW35) and 09595-6239 JAW7 were excluded from the study due to insufficient astrophysical data in GAIA DR3.

The remaining pairs all had a physical distance separation (using the cosine rule, see Methods) of >100 pc and were regarded as optical double stars and were excluded from further analysis, *Appendix 1*.

Table 1. Selected GAIA DR3 data on 07043-2412 JAW3, 10039-6009 JAW10, 12016-6000 WFC121 (JAW30), 12030-6055 JAW31, 13449-6235 JAW37 and 06406-4006 JAW46 BC. Stellar luminosity and mass data come from GAIA DR3 FLAME. Additional information was obtained from SIMBAD https://simbad.u-strasbg.fr/ and from the WDS historical data files.

WDS Identifier	GAIA DR3 source ID	Parallax ± 1σ mAS	Total proper motion mAS/yr	pmra ± 1σ mAS/yr	pmdec ± 1σ mAS/yr	Radial velocity ± 1σ km/sec	Lum (SolLum) Stellar mass (SolMass)
07043-2412 JAW3							
A	2921424389541068928	4.7575 ± 0.0168	15.712	1.891 ± 0.012	-15.598 ± 0.015	-8.0 ± 0.3	2.4 1.1
B*	2921424389540353152	4.7799 ± 0.0131	15.487	1.464 ± 0.009	-15.417 ± 0.011	-	2.2 1.0
10039-6009 JAW10							
A	5256695483896245760	0.9958 ± 0.0211	8.320	-7.436 ± 0.030	3.731 ± 0.025	-	- -
B	5256695415176766848	0.9567 ± 0.0234	9.089	-8.039 ± 0.033	4.240 ± 0.027	-13.0 ± 8.0	82.0 2.8
12016-6000 WFC121 (JAW30)							
A	6070876937964630784	1.3577 ± 0.0162	12.081	-12.074 ± 0.016	-0.412 ± 0.018	-14.1 ± 2.4	- -
B	6070876727469430144	1.3161 ± 0.0169	12.154	-12.147 ± 0.016	-0.411 ± 0.018	-14.4 ± 6.5	17.9 2.0
12030-6055 JAW31							
A	6058758533122208000	1.0012 ± 0.0197	7.005	-6.770 ± 0.019	1.799 ± 0.020	-15.6 ± 1.4	- -
B	6058758326963775232	1.0353 ± 0.0177	6.558	-6.172 ± 0.017	2.216 ± 0.018	-21.5 ± 10.7	- -
13449-6235 JAW37							
A	5865438790935618944	0.6290 ± 0.0132	8.372	-8.320 ± 0.009	0.931 ± 0.011	-22.1 ± 0.2	- -
B	5865438859655105792	0.6689 ± 0.0144	14.015	-11.365 ± 0.010	-8.202 ± 0.012	-30.0 ± 0.4	- -
06406-4006 JAW46 BC							
B***	5575839140529949312	4.5933 ± 0.0112	27.921	-4.372 ± 0.012	27.577 ± 0.014	-	1.4 0.9
C	5575839144827553536	4.5862 ± 0.0148	26.910	-6.734 ± 0.016	26.054 ± 0.018	19.5 ± 0.6	0.9 1.0

* Spectroscopic binary. WDS Notes.
** Høg, E., Kuzmin, A., Bastian, U., Fabricius, C., Kuimov, K., Lindegren, L., Makarov, V. V., & Röser, S. (1998). The Tycho Reference Catalogue. Astronomy and Astrophysics, 335, L65-L68.
***Eclipsing binary. WDS notes.

2. Methods

Using the Las Cumbres Observatory Global Telescope Network 07043-2412 JAW3, 10039-6009 JAW10, 12030-6055 JAW31, 13449-6235 JAW37, 12016-6000 WFC121 (JAW30) and 06406-4006 JAW46 BC were imaged at Cerro Tololo Inter-American Observatory. Images were taken with a PlaneWave DeltaRho 350 telescope and QHY600 CMOS camera systems. The camera format was 9576 x 6388 pixels, 3.76 micron pixels size, FOV 1.9 x 1.2 degrees readout mode full frame, 30'x30'

in readout mode central 30x30, pixel size ~0.74″/pixel, default binning 1 x 1, read noise ~ 3 to 3.5 e- and gain 0.7 e-/ADU.

Fifteen images of each pair, except 12016-6000 WFC121 (JAW30), were taken on January 5 and January 6, 2026. The images were recorded through a Bessel-V Filter and the exposure times varied from 3.8 to 30 seconds. The air mass for all images was <1.6. The image sets of each object from both nights were combined. Fifteen images of 12016-6000 WFC121 (JAW30) were taken on February 1, 2026 (exposure time 25 sec, air mass 1.6). All the calibrated images were visually inspected for quality and all were chosen for analysis. The images were analysed using AstroImageJ, Figure 1. The mean, standard deviation and standard error of the mean for position angle, separation and delta magnitude were determined, Table 2.

To calculate *D*, the mean physical separation distance of the components in pc, the cosine rule was used (Letchford et al, 2022).

$$D = \sqrt{[D_A^2 + D_B^2 - 2D_A D_B \cos(\rho/3{,}600)]} \quad (1)$$

Where *D* is the mean separation distance of the two stars in pc; D_A is the mean distance from the Sun to the primary in pc, obtained from parallax measures; D_B is the mean distance from the Sun to the secondary in pc, and ρ is apparent separation in arcseconds (″) reported in this paper, Table 3.

The minimum separation distance (separation distance if the components are equidistant from the Sun) and maximum distance separation, Figure 2 and Figure 3, was calculated using the data in Table 1, measure of apparent separation reported in this paper and Equation (1), Table 3.

The angle (ν) between each of the components space velocity vectors in 3D was calculated using the method of Nugent (Nugent, 2025), Table 3. Nugent defined the component's angular space motion differences (θ) as follows:
(ν) values < 15° are designated as Common Space Motion (CSM) pairs,
(ν) values > 15° and < 30° are designated as Similar Space Motion (SSM) pairs,
(ν) values > 30° are designated as Different Space Motion (DSM) pairs.

Buchheim's distance probability calculation for double stars involves using parallax and parallax error data to determine the probability that two stars are within one light year of each other in the radial direction (Sethi et al, 2024). Using Buchheim's distance probability calculation method, the probability that the components of 07043-2412 JAW3, 10039-6009 JAW10, 12030-6055 JAW31, 13449-6235 JAW37, 06406-4006 JAW46 AC and 06406-4006 JAW46 BC are within one light year of each other in the radial direction was calculated, Table 3.

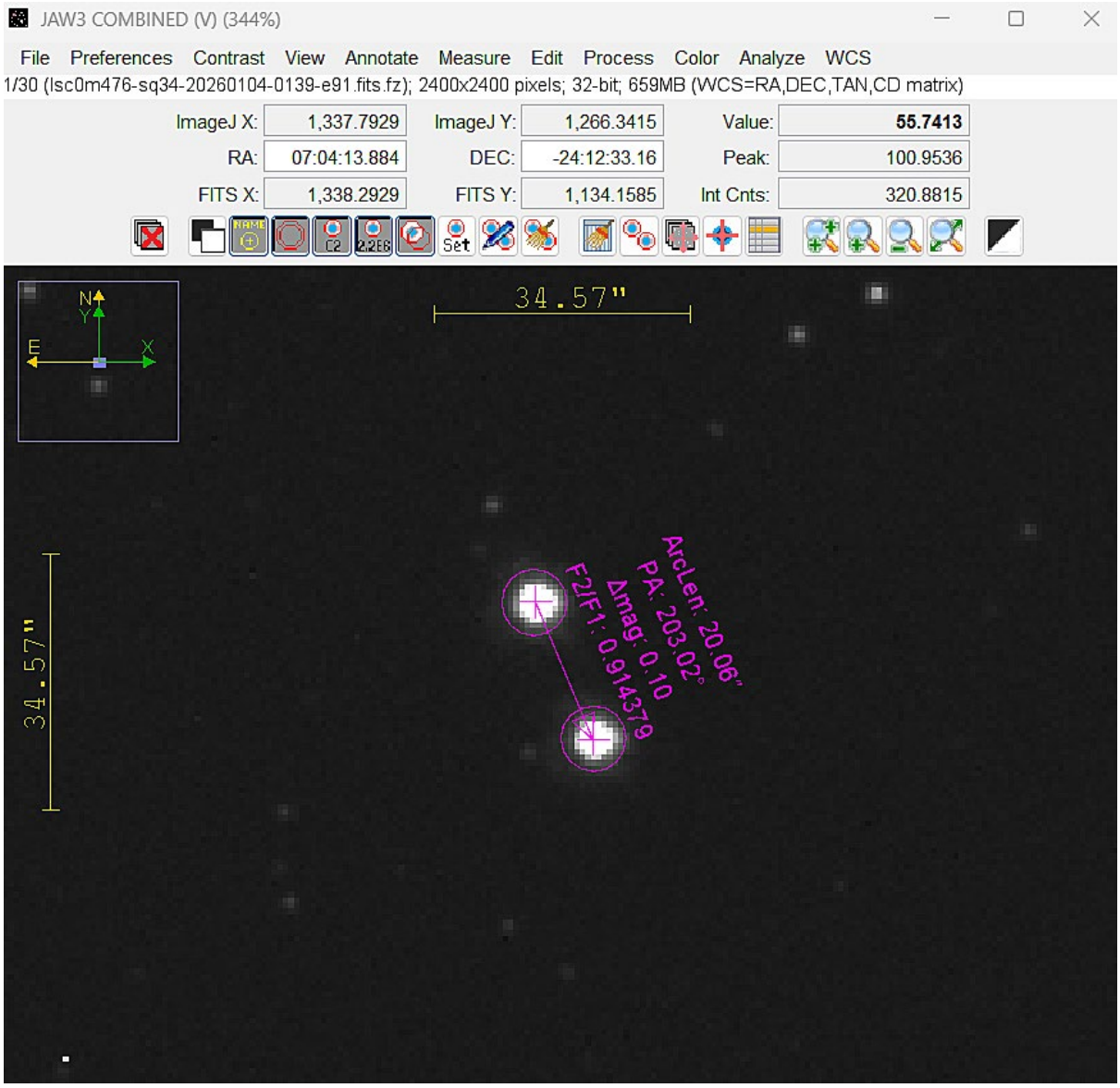

Figure 1: A sample image of 07043-2412 JAW3 analysed using AstroImageJ showing separation, position angle and delta magnitude.

The distances, with 1σ uncertainty, from the Sun to the components of WDS 07043-2412 JAW3, 10039-6009 JAW10, 12030-6055 JAW31, 13449-6235 JAW37 and 06406-4006 JAW46 BC based on GAIA DR3 parallax data were calculated. Examples are shown in Figure 2 and Figure 3.

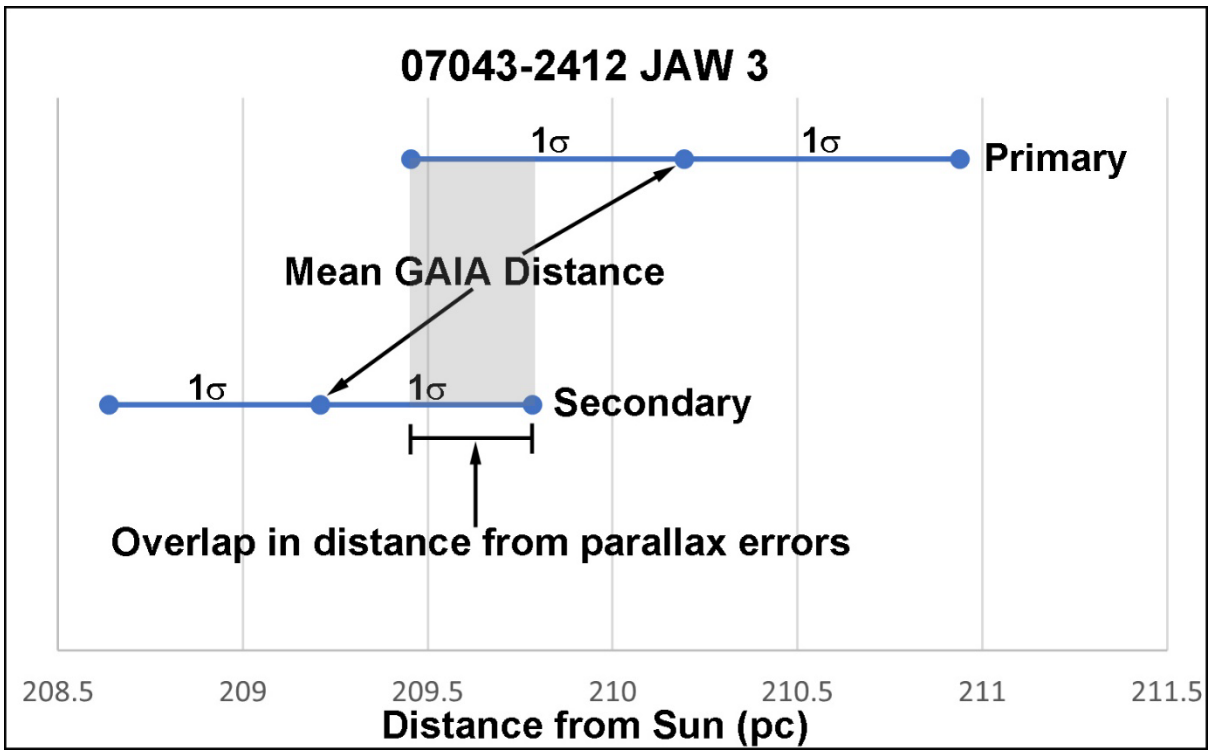

Figure 2: Gaia distances of 07043-2412 JAW3 components from the Sun including 1σ parallax errors.

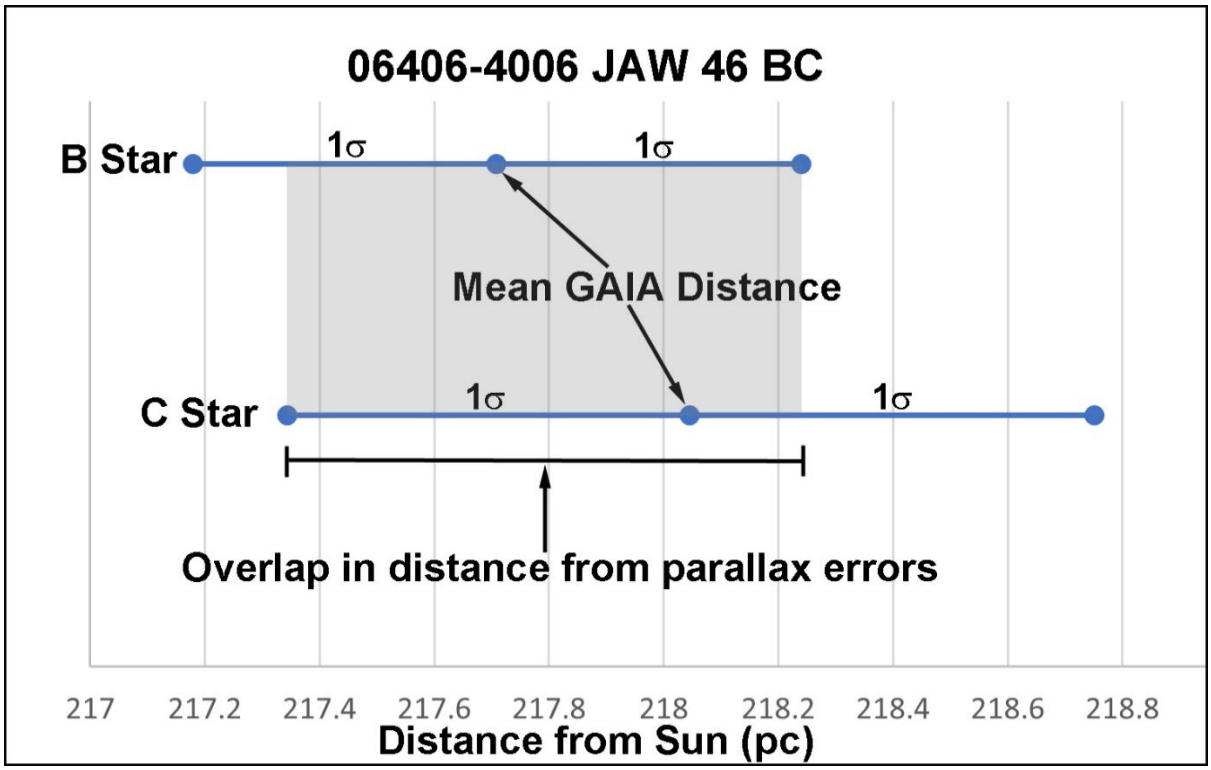

Figure 3: Gaia distances of 06406-4006 JAW46 BC components from the Sun including 1σ parallax errors.

3. Data

The results of the analysis of the images of 07043-2412 JAW3, 10039-6009 JAW10, 12016-6000 WFC121 (JAW30), 12030-6055 JAW31, 13449-6235 JAW37 and 06406-4006 JAW46 BC by AstroImageJ are given in Table 2.

Table 2. Position angle, separation and delta magnitude values for 07043-2412 JAW3, 10039-6009 JAW10, 12016-6000 WFC121 (JAW30), 12030-6055 JAW31, 13449-6235 JAW37 and 06406-4006 JAW46 BC.

WDS Identifier **Epoch** **Mean Decimal date (DD)** **Mean Julian date (JD UTC)** **Last measurement**	**Measurement**	**Position Angle (Theta)** **degrees**	**Separation (Rho)** **arcseconds**	**Delta Magnitude (Bessel-V filter)**
07043-2412 JAW3 DD: 2026.0137 JD: 2461046.108	Mean SD SEM	203.1 0.03 0.01	20.07 0.015 0.003	0.09 0.01 0.001
Last Measurement (2016.0)		203.1	20.07	0.05
10039-6009 JAW10 DD: 2026.0137 JD: 2461046.148	Mean SD SEM	166.6 0.06 0.01	22.99 0.017 0.003	1.54 0.01 0.002
Last Measurement (2015.0)		166.5	22.98	1.46
12016-6000 WFC121 (JAW30) DD: 2026.0863 JD: 2461072.659	Mean SD SEM	150.1 0.11 0.03	9.09 0.024 0.006	0.50 0.01 0.002
Last Measurement (2016.0)		150.1	9.08	0.62
12030-6055 JAW31 DD: 2026.0137 JD: 2461046.231	Mean SD SEM	128.1 0.06 0.01	20.63 0.041 0.008	1.59 0.02 0.003
Last Measurement (2015.220)		127.7	20.73	1.45
13449-6235 JAW37 DD: 2026.0137 JD: 2461046.304	Mean SD SEM	343.1 0.05 0.01	17.52 0.029 0.005	0.29 0.01 0.001
Last Measurement (2015.0)		343.2	17.60	0.39
06406-4006 JAW46 BC DD: 2026.0137 JD: 2461046.12	Mean SD SEM	240.1 0.15 0.03	12.82 0.023 0.004	0.26 0.03 0.01
Last Measurement (2015.0)		240.0	12.79	0.2

Table 3. Mean physical distance separation (*D*), minimum distance separation, maximum distance separation, angle (v) between each of the components space velocity vectors in 3-dimensional space and Buchheim distance probability for 07043-2412 JAW3, 10039-6009 JAW10, 12016-6000 WFC121 (JAW30), 12030-6055 JAW31, 13449-6235 JAW37 and 06406-4006 JAW46 BC.

WDS IDENTIFIER	Mean physical distance separation (*D*) AU	Minimum distance separation AU	Maximum distance separation AU	Overlap in distance with 1σ error AU	Angle (v) between each of the components space velocity vectors in 3-dimensional space Degrees	Buchheim distance probability calculation %
07043-2412 JAW3	203,221	4,219	474,782	68,067	-	15.1
10039-6009 JAW10	8,465,568	23,087	18,169,052	1,165,396	-	0.3
12016-6000 WFC121 (JAW30)	4,802,049	980,469	8,632,066	No overlap	0.3	0.4
12030-6055 JAW31	6,785,702	20,605	14,269,637	655,207	11.2	0.4
13449-6235 JAW37	19,560,818	6,036,075	33,088,566	No overlap	40.1	0.1
06406-4006 JAW46 BC	69,576	2,791	324,368	184,914	-	25.4

4. Discussion

Updated astrometric measurements for 07043-2412 JAW3, 10039-6009 JAW10, 12016-6000 WFC 121 (JAW30), 12030-6055 JAW31, 13449-6235 JAW37, 06406-4006 JAW46 BC are provided.

The approximate upper bound for physical 3D separation of a binary system has been estimated to be ~2,500 AU (Nugent, 2026). However, another view is that wide gravitationally bound binaries may have separation distances of up to ~20,000 AU (Tokovinin A, personal communication).Based on mean physical distance separation 07043-2412 JAW3, 10039-6009 JAW10, 12016-6000 WFC 121 (JAW30), 12030-6055 JAW31, 13449-6235 JAW37, 06406-4006 JAW46 BC appear to be optical double stars.

5. Conclusion

Updated astrometric measurements for 07043-2412 JAW3, 10039-6009 JAW10, 12016-6000 WFC121(JAW30), 12030-6055 JAW31, 13449-6235 JAW37 and 06406-4006 JAW46 BC are provided. All six pairs appear to be optical double stars.

Acknowledgements

I would like to thank Dr. Rachel Matson USNO, for providing the historical data required for the analyses of 07043-2412 JAW3, 10039-6009 JAW10, 12016-6000 WFC121 (JAW30), 12030-6055 JAW31, 13449-6235 JAW37, and 06406-4006 JAW46 BC . I would also like to acknowledge the Boyce Research Initiatives and Education Foundation (https://boyce-astro.org/). I would like to thank Pat Boyce for providing the educational material and technical support required to complete this paper. I would also like to thank Professor A. Tokovinin for his assistance.

This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory http://www.astro.gsu.edu/wds/. Observations were made using the Las Cumbres Observatory Global Telescope Network https://lco.global/.

This work has also made use of data from the European Space Agency (ESA) mission Gaia (https://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the DPAC has been

provided by national institutions, particularly the institutions participating in the Gaia Multilateral Agreement.

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Appendix 1:

Parallax (from GAIA DR3 unless otherwise specified), apparent separation, date of last measurement and physical distance separation of JAW1 to JAW50.

WDS IDENTIFIER	Parallax ± 1σ mas	Apparent* separation arcsec	Date of last measurement*	Mean physical distance separation pc
06135-2158 JAW1 A B	 0.9698 ± 0.0118 2.4510 ± 0.0156	23.887	2015	623.14
07026-2240 JAW2 A B	 1.0887 ± 0.0243 3.6494 ± 0.0215	18.595	2015	644.51
07043-2412 JAW3	See Table 1	See Table 2	See Table 2	See Table 3
07107-2315 JAW4 A B	 1.2875 ± 0.0201 2.4811	18.693	2015	373.65

	± 0.0162			
08098-2449 JAW5 AB A B	 2.4234 ± 0.0151 1.7317 ± 0.0137	26.89	2018	164.82
09442-6224 JAW6 A B	 1.6781 ± 0.0100 3.9316 ± 0.2971	17.03	2015	341.56
09595-6239 JAW7 A B	 2.4186 ± 0.0134 -	15.048	2015	N/A
10000-6151 JAW8 A B	 0.2848 ± 0.0103 0.9610 ± 0.0133	19.602	2015	2470.65
10036-6057 JAW9 A B	 4.2212 ± 0.0128 1.0445 ± 0.0113	16.127	2015	720.50
10039-6009 JAW10	See Table 1	See Table 2	See Table 2	See Table 3
10044-6039 JAW11 A B	 0.4353 ± 0.0137 3.4367 ± 0.0112	13.6	2015	2006.29
10093-6113 JAW12 A B	 0.9454 ± 0.0202 1.1080 ± 0.0182	21.193	2015	155.23
10098-6001 TDS7075 (JAW13) A B	 0.6026 ± 0.0200 0.9882 ± 0.0115	10.073	2015	647.53
10112-6238 JAW14 A B	 1.8813 ± 0.0113 0.8896 ± 0.0161	18.154	2015	592.55
10127-6119 JAW15 A B	 1.4556 ± 0.0170 0.9894 ± 0.0107	20.931	2015	323.71
10134-6230 JAW16				

A B	1.4587 ± 0.0214 1.0557 ± 0.0112	15.051	2015	261.70
10377-6007 JAW17 A B	 5.4854 ± 0.0729 0.3788 ± 0.0128	18.2	2010	2457.61
10378-6005 JAW18 A B	 0.2308 ± 0.0152 0.5601 ± 0.0166	15.439	2015	2547.36
10533-6207 WFC110 (JAW19) A B	 0.6681 ± 0.0164 1.3298 ± 0.0141	8.89	2015	744.79
11102-6047 JAW20 A B	 1.9428 ± 0.0121 0.3788 ± 0.0165	20.93	2015	2125.19
11155-6130 JAW21 A B	 1.8019 ± 0.0113 0.7117 ± 0.0139	20.13	2015	850.12
11159-6225 JAW22 A B	 2.9064 ± 0.0123 0.4635 ± 0.0134	22.257	2015	1813.43
11173-6144 JAW23 A B	 1.7996 ± 0.0122 0.4418 ± 0.0191	15.916	2015	1707.79
11179-6027 JAW24 A B	 0.4455 ± 0.0202 1.3730 ± 0.0136	17.681	2015	1516.34
11185-6049 JAW25 A B	 3.1725 ± 0.0138 2.1541 ± 0.0149	21.688	2015	149.02
11222-6048 JAW26 A B	 1.2912 ± 0.0119 0.9174	16.037	2015	315.56

	± 0.0115			
11293-6026 JAW27 A B	 1.7323 ± 0.0171 1.2355 ± 0.0278	23.258	2015	232.12
11428-6130 JAW28 A B	 0.3129 ± 0.0306 0.7761 ± 0.0124	26.779	2015	1907.42
11523-6202 JAW29 A B	 2.1337 ± 0.0156 7.7846 ± 0.0125	14.956	2015	340.21
12016-6000 WFC121 (JAW30)	See Table 1	See Table 2	See Table 2	See Table 3
12030-6055 JAW31	See Table 1	See Table 2	See Table 2	See Table 3
12067-6114 JAW32 (R187) A B	 0.5329 ± 0.0192 0.4933 ± 0.0178	14.028	2015	150.64
12172-6047 JAW33 A B	 0.6259 ± 0.0159 0.7778 ± 0.0143	20.512	2015	312.02
12201-6132 TOB148 (JAW34) A B	 1.0885 ± 0.0127 2.2854 ± 0.0141	18.969	2015	481.14
12436-6116 TOB115 (JAW35) A B	 0.6075** ± 0.2896 -	19.277	2015	N/A
12564-5956 JAW36 A B	 1.6140 ± 0.0165 1.1787 ± 0.0146	21.463	2015	228.81
13449-6235 JAW37	See Table 1	See Table 2	See Table 2	See Table 3
13554-6224 JAW38 A B	 1.2911 ± 0.0123 0.5061 ± 0.0151	16.95	2015	1201.36
14108-6226 JAW39				

A B	1.9445 ± 0.0375 0.8238 ± 0.0219	16.107	2015	699.62
15522-6002 JAW40 A B	0.7984 ± 0.0218 1.6793 ± 0.0139	10.878	2015	657.02
16115-6113 JAW41 A B	3.4411 ± 0.0156 0.6121 ± 0.0141	22.688	2015	1343.12
17186-6231 JAW42 A B	1.2315 ± 0.0234 3.6796 ± 0.0270	24.845	2015	540.25
17278-6238 JAW43 A B	1.6647 ± 0.0165 1.1134 ±0.0156	21.293	2015	297.44
17514-6226 JAW44 A B	3.3730 ± 0.0207 1.1540 ± 0.0202	30.786	2015	570.08
18029-5959 JAW45 A B	2.0749 ± 0.0167 3.8277 ± 0.7550 (GAIA DR2)	14.967	2015	220.70
06406-4006 JAW46 AC A C	2.8142 ± 0.0129 4.5862 ± 0.0148	18.07	2015	137.30
06406-4006 JAW46 BC	See Table 1	See Table 2	See Table 2	See Table 3
07463-4302 JAW47 AC A C	2.6157 ± 0.0146 0.8574 ± 0.0192	26.14	2015	784.01
07463-4302 JAW47 BC B C	2.6555 ± 0.0126 ± 0.8574 ± 0.0192	31.06	2015	789.74
08141-4044 JAW48 AC A	2.9932	17.18	2015	359.20

C	± 0.0104 1.4424 ± 0.0116			
08141-4044 JAW48 BC B C	 2.9622 ± 0.0122 1.4424 ± 0.0116	16.04	2015	355.70
14496-4836 JAW49 AC A C	 1.3731 ± 0.0207 2.4242 ± 0.0199	21.986	2015	315.77
14496-4836 JAW49 BC B C	 1.4259 ± 0.0212 2.4242 ± 0.0199	26.659	2015	288.80
15262-8013 JAW50 AC A C	 3.7456 ± 0.0185 0.9694 ± 0.0118	33.031	2015	764.59
15262-8013 JAW50 BC B C	 0.8322 ± 0.0118 0.9694 ± 0.0118	26.334	2015	170.07

*Stelle Doppie Stelle Doppie - Double Star Database
**GAIA DR2