Observation and Investigation of 8 Physical Doubles in the Washington Double Star Catalogue

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Abstract:

Eight physical double stars with separations between 8” and 20” were selected from the Washington Double Star Catalogue. Using the Afterglow tool, the position angles and separations were measured. The results were combined with data from GAIA DR3 to make orbital plots.

Introduction:

There were several constraints on the stars our team was able to study. During the months when this study was done, stars with a right ascension between 5 and 15 hours, and separation of 8’’ and 20’’ were observed. The target stars for this study were chosen with similar parallax and proper motion i.e., Physical Double Stars. To avoid pixel saturation, stars with a magnitude between 9 to 18 and relatively similar brightness (delta < 5) were chosen. This allowed us to get appropriate exposure time to capture both the primary and secondary stars. Using these constraints in *Stelle Doppie* for WDS Catalogue search, eight stars were selected. Those stars were: SKF2037 (WDS 05104+6020), GWP1113 (WDS 08557-1531), CRB 67 (WDS 05017+3324), HJ 3717 (WDS 05020-3935), KPP2106 (WDS 05037-7333), SKF2476 (WDS 05243-2149), UC 102 (WDS 07057+4827) and KPP992 (WDS 05005-6238).

Using ALADIN software, data from the SIMBAD data base, the VIZIER service, the GAIA DR3 data base, and other archives, the B-R and absolute Gmag, the luminosity, mass and temperature of the stars were estimated.

Instruments Used:

For our observations, six telescopes from Skynet Robotics Telescopes Network (SRTN) were used. Telescopes Prompt2 and Prompt5 in the Cerro Tololo Inter-American Observatory, Morehead telescope in Morehead, PROMPT-MO-1 in the Meckering Observatory, and finally, Prompt-USASK, USASK-14 in the Sleaford Observatory were used. All our observations were taken from Prompt2, Prompt5, PROMPT-MO-1, Prompt-USASK telescopes. The PROMPT2, PROMPT5, and Prompt-USASK telescopes had 0.4m apertures and 4,600mm focal lengths. The Morehead telescope has an aperture of 0.6m and focal length of 8600mm.The USASK-14 has an aperture of 0.4m and focal length of 3900mm. The images were taken with a 16-bit CCD with a flux range of 0 – 65353. A Hithru filter was used to allow long exposures to capture as many stars as possible. Five images with a dithering of 3X3 with 10 seconds spacing were taken for each pair of stars. Dithering helps get rid of photons of light lost on dead pixels on the lens by a controlled movement of the mount between successive exposures that very slightly modifies where photons land on the sensor on a pixel-by-pixel basis. Apart from Sleaford Observatory, all the Observatories are in barren locations and high altitudes. This allows the images to be less damaged by atmospheric *seeing* and pollution.

Measurements:

The measurements for this study were conducted using the Afterglow tool provided by SRTN. After ensuring that the images were not saturated, the images were stacked, and the separations and position angles were determined using the Afterglow tool. From which, we get a mean position angle and separation. The observed data is noted and shown in Table 2.

The resultant Proper Motion (rPM) was calculated following the method shown in Harshaw, 2016. rPM helps us understand if the stars share a common proper motion. rPM less than 0.2 is considered Common Proper Motion (CPM), between 0.2 and 0.6 is Similar Proper Motion (SPM) and above 0.6 is considered Different Proper Motion (DPM).

Table 1: Parallax and proper motion data for each system, including the proper motion ratio (rPM) calculated as the ratio of the PM difference vector magnitude to the magnitude of the longer of the component PM vectors.

System	Parallax of Primary (mas)	Parallax of Secondary (mas)	Proper Motion of Primary (mas/yr)	Proper Motion of Secondary (mas/yr)	rPM
SKF2037 (WDS 05104+6020)	11.47 ± 0.02	10.49 ± 0.01	(54.70 ± 0.01, -82.44 ± 0.01)	(54.58 ± 0.01, -80.78 ± 0.01)	0.017 (CPM)
GWP1113 (WDS 08557-1531)	4.57 ± 0.09	4.49 ± 0.17	(-74.71 ± 0.09, -4.46 ± 0.09)	(-75.35 ± 0.15, -7.98 ± 0.16)	0.047 (CPM)
CRB 67 (WDS 05017+3324)	13.28 ± 0.02	13.34 ± 0.05	(24.72 ± 0.03, -53.03 ± 0.2)	(26.60 ± 0.06, -53.56 ± 0.04)	0.033 (CPM)
HJ 3717 (WDS 05020-3935)	2.63 ± 0.01	2.63 ± 0.01	(25.10 ± 0.02, 18.62 ± 0.02)	(25.05 ± 0.01, 18.64 ± 0.01)	0.033 (CPM)
KPP2106 (WDS 05037-7333)	3.35 ± 0.01	3.38 ± 0.04	(5.22 ± 0.01, 36.25 ± 0.02)	(5.61 ± 0.05, 35.50 ± 0.06)	0.023 (CPM)
SKF2476 (WDS 05243-2149)	2.83 ± 0.03	2.21 ± 0.14	(-14.02 ± 0.02, 32.52 ± 0.03)	(-14.00 ± 0.10, 32.56 ± 0.13)	0.002 (CPM)
UC 102 (WDS 07057+4827)	11.65 ± 0.04	11.70 ± 0.03	(22.49 ± 0.03, -81.08 ± 0.03)	(22.97 ± 0.03, -79.17 ± 0.03)	0.023 (CPM)
KPP992 (WDS 05005-6238)	7.06 ± 0.02	6.99 ± 0.05	(15.01 ± 0.02, 44.78 ± 0.02)	(14.62 ± 0.06, 43.69 ± 0.07)	0.025 (DPM)

Table 2. Measurements of eight double stars made between January-February 2023.

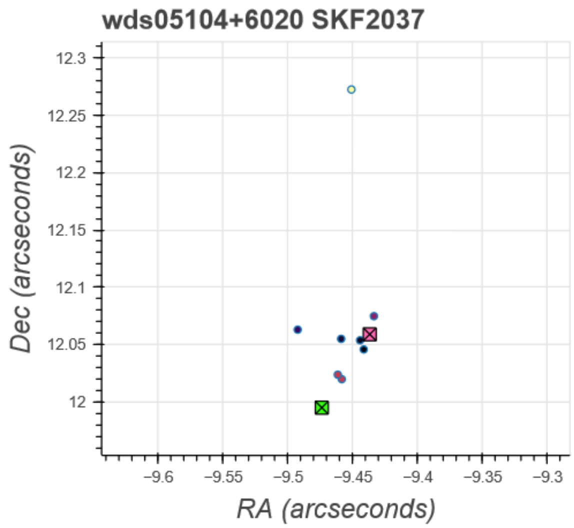
System	Date	Number of Images	Position Angle (°)	Standard error on Position Angle	Separation (")	Standard Error on Separation
SKF2037 (WDS 05104+6020)	2023.08	5	218.3	0.02	15.30	0.015
GWP1113 (WDS 08557-1531)	2023.09	5	67.5	0.06	18.97	0.007
CRB 67 (WDS 05017+3324)	2023.11	5	177.9	0.13	19.26	0.186
HJ 3717 (WDS 05020-3935)	2023.07	5	196.4	0.10	12.88	0.013
KPP2106 (WDS 05037-7333)	2023.07	5	8.9	0.02	17.00	0.016
SKF2476 (WDS 05243-2149)	2023.07	5	326.7	0.08	19.38	0.028
UC 102 (WDS 07057+4827)	2023.11	5	59.2	0.10	19.834	0.013
KPP992 (WDS 05005-6238)	2023.04	5	48.6	0.22	8.01	0.035

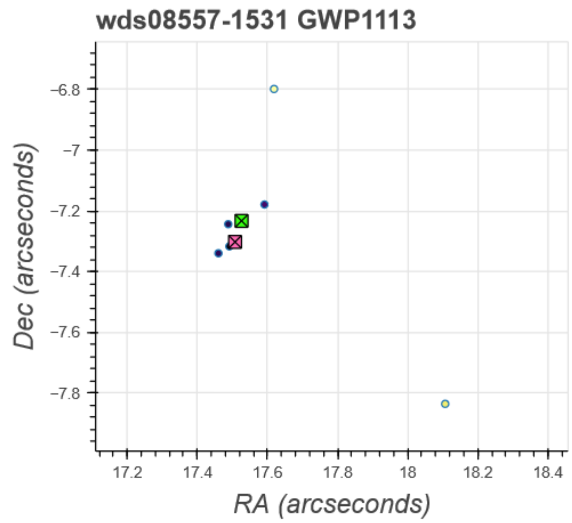
Plots:

Previous measurements for each system were requested from the US Naval Observatory. Using the historical data along with our current data, we plot a graph to witness any formation of orbit. If any forward curve is formed, that would suggest stars are orbiting and with future observations, a predicted orbit may be formed. But more importantly, it would suggest that the star system is a binary star system.

Each plot is labelled by the discover code of the system. Note that the historical data are plotted in Figure 1 chronologically using colour. The darker the colour, the more recent the data. The measurements are plotted as a circle and the measurements taken by us are the green square with an x. The other red square is the measurement we obtained from Gaia. Observing any trends from the plotted graph we can estimate if the stars are likely to be gravitationally bound.

Figure 1: Measurement of each system (labelled by their discover code) in accordance with the historical data. The darker circles are more recent measurements than the lighter circles. Our measurements are green squares with an x in the middle, while the Gaia collected data is the red square.


wds05104+6020 SKF2037
Dec (arcseconds)
RA (arcseconds)
12.3
12.25
12.2
12.15
12.1
12.05
12
−9.6
−9.55
−9.5
−9.45
−9.4
−9.35
−9.3


wds08557-1531 GWP1113
Dec (arcseconds)
RA (arcseconds)
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−7
−7.2
−7.4
−7.6
−7.8
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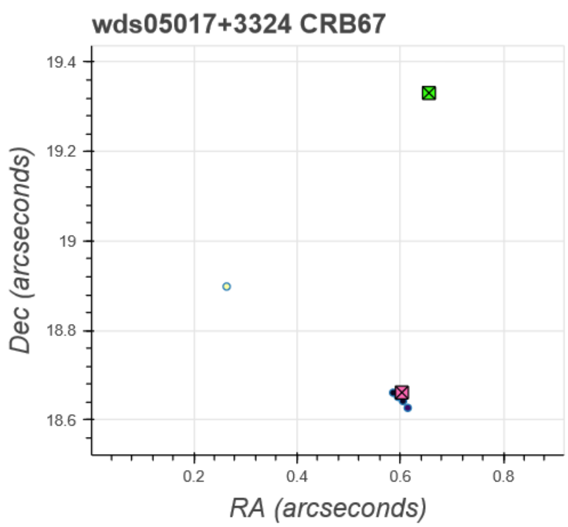
17.6
17.8
18
18.2
18.4


wds05017+3324 CRB67
Dec (arcseconds)
RA (arcseconds)
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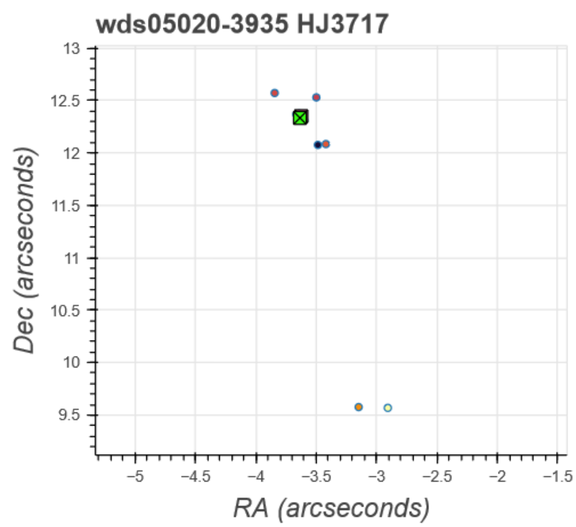
19.2
19
18.8
18.6
0.2
0.4
0.6
0.8


wds05020-3935 HJ3717
Dec (arcseconds)
RA (arcseconds)
13
12.5
12
11.5
11
10.5
10
9.5
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−4
−3.5
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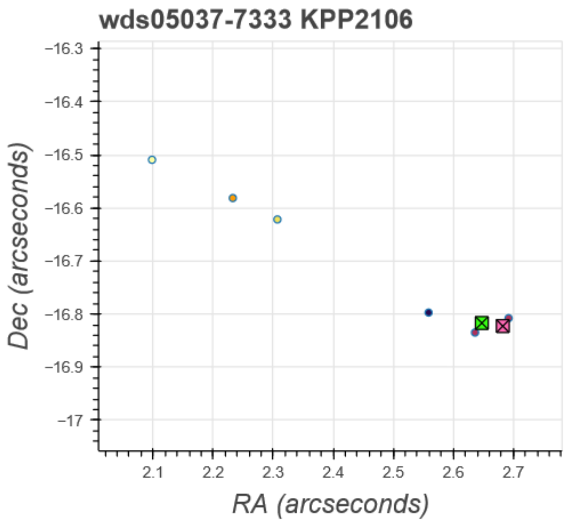
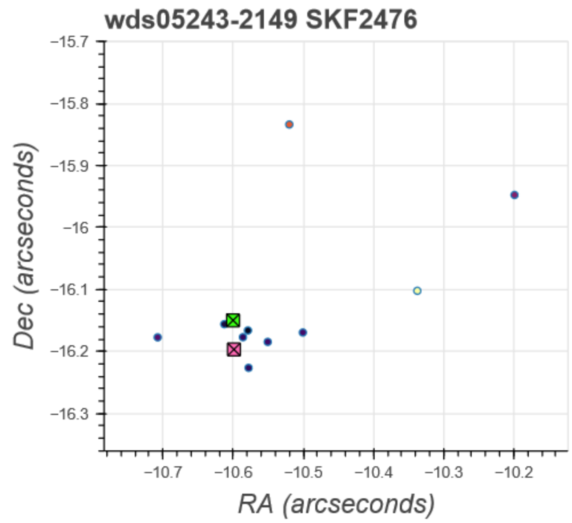
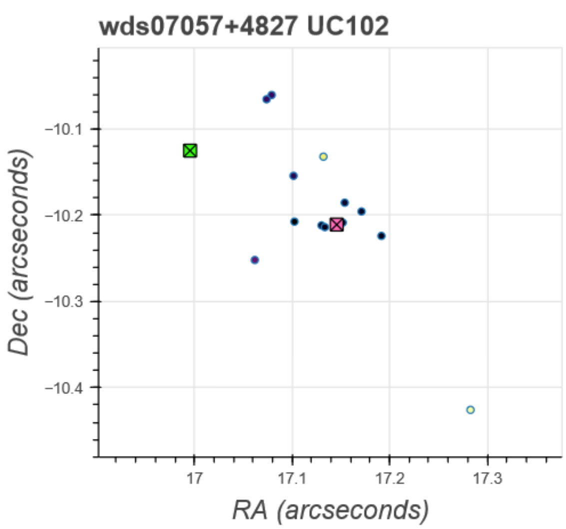
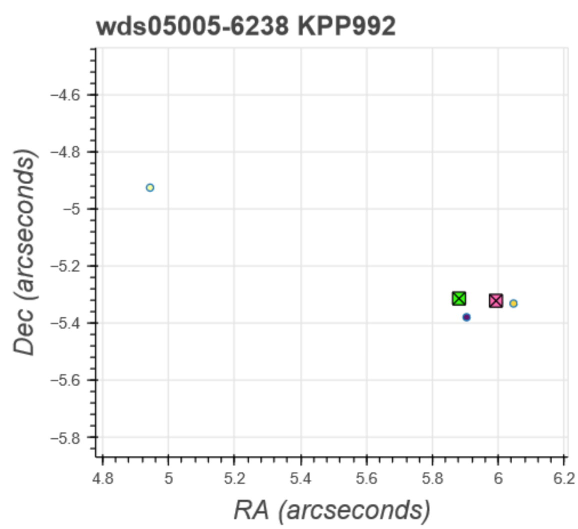
−2.5
−2
−1.5









Analysis of the Double Stars:

If two or more stars have similar parallax and proper motion, they show signs that they might be related to one another in some way. However, just parallax and proper motion are not enough data to determine these conclusions. For our star system, they do not exhibit any sign of binary system behaviour. Amongst our eight double stars, all of them seem to have Common Proper Motion i.e., the double stars are moving through space relatively together.

However, the plot reveals no notable curvature. Thus, the historical data does not show any signs of stars orbiting each other. One thing to note in Figure 1 is that we have very few historical data of our stars so far. Notably the earlier measurements show high deviations from the newer data.

When historical data is insufficient to characterise a system as binary, one theory we can use is the system escape velocity. The two stars in each system need to be moving with a velocity less than the system escape velocity. The system escape velocity and the relative space velocity of the secondary star can be calculated using the equations presented in Bonifacio et al, 2020 and Caputo et al, 2020. The calculated data can be found in Table 3.

Table 3: System Escape Velocity and Relative Space Velocity of the secondary stars in each double star system.

System	System Escape Velocity (m/s)	Relative Space Velocity (m/s)
SKF2037	265.05	754.14
GWP1113	74.79	3716.99
CRB 67	73.82	696.46
HJ 3717	177.73	1153.95
KPP2106	82.56	1475.56
SKF2476	10.03	1945.01
UC 102	207.42	886.54
KPP992	93.41	1094.43

From Table 3, we find that the secondary star in every system is moving faster than the system escape velocity of the primary star. However, we must assume that calculation could have errors because they are estimated from so many imprecisely known values. Nonetheless, this gives some rough data to be used in future for further measurements.

Conclusion:

The systems that we examined and analysed do not exhibit much data implying a physical relationship. However, further observations need to be taken to find definitive conclusions on the nature of these double stars.

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