Calculations with GAIA DR2 Data Indicate That 12003+1136 HJ 197 and 13274-6152 B 2752 are not Physical Pairs

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Abstract: We measured the position angle (theta) and the separation (rho) of the double star systems WDS 12003+1136 (HJ 197) and WDS 13274-6152 (B 2752) utilizing several images from a 0.4-meter telescope from the Las Cumbres Observatory (LCO). We found that HJ 197 had a position angle of 270.97° and a separation of 14.68 arcseconds. B 2752 had a position angle of 298.16° and a separation of 10.16 arcseconds. However, utilizing parallax and proper motion data obtained from GAIA DR2 for both star systems, they were found to have very wide separations of 783 and 1040.20 light years respectively. From these data, we concluded that these star systems may not be physical.

Introduction

This paper presents the latest astrometric data measurements for two double star systems, WDS 12003+1136 (HJ 197) and WDS 13274-6152 (B 2752). This paper also uses available parallax and proper motion vectors from GAIA DR2 data to address whether these systems are gravitationally bound physical doubles or optical binaries.

With the recent availability of GAIA Data Release 2 (DR2) measurements, a large percentage of the double star systems have had their positions measured to a degree not possible before. In many cases, not only are the stars' positions in the sky more refined, but also the parallax measurements indicating the stars' distance from the earth is better understood. With these additional pieces of data available, we were able to obtain greater confidence in the actual distance between the stars of a proposed double star system.

Additionally, proper motion vectors allow another element in determination of the likelihood that the stars may be gravitationally bound to each other by computing their relative proper motion and applying statistical probabilities as proposed by Harshaw (2014) and Harshaw (2018). The "Harshaw Statistical Value" compares the relative proper motion vectors of each star in a system and calculates a probability statistic on a scale of 0.0-1.0. According to Harshaw (2014), "two stars that are in orbit around one another should have identical, or very nearly identical, proper motions." Thus, the closer the value of the Harshaw statistic is to 0.0, the more likely the stars are gravitationally bound. Generally, anything greater than 0.1 is most likely not a physical double star because the disparity of the proper motion is too great to be gravitationally bound.

Star system HJ 197 was first discovered by John F.W. Herschel in 1825. Historically, this system has been measured 10 times with the most recent measurement in 2015. The stars in this system exhibit apparent brightnesses which are very similar. The primary star has a magnitude of 12.7 and the secondary has a magnitude of 13.1. Over the last 195 years, the stars of HJ 197 have shifted position angle (theta) from 285° to 271° and the separation (rho) has changed from 12.7 to 14.8 arcseconds. Listed in the Stelle Doppie database, the relative proper motion (rPM) of these stars is given as 0.462 and is listed as uncertain whether this system is a physical double. Historical data for HJ 197 was furnished by the United States Naval Observatory. A chart of the historical position measurements along with the current measurement presented in this paper, Figure 1.

Star system B 2752 was discovered by Willem Hendrik van den Bos in 1931. B 2752 has only been measured 4 times since its discovery with the most recent measurement occurring in 2015. The primary star of this system has a magnitude of 9.62 and the secondary star has a magnitude of 13.6. Over the last 89 years, B 2752 has been measured to have a change of position angle from 297° to 298° and a change of separation angle from 8.0 to 10.2 arcseconds. Historical data for B 2752 was furnished by the United States Naval Observatory. A chart of the historical position measurements along with the current measurement

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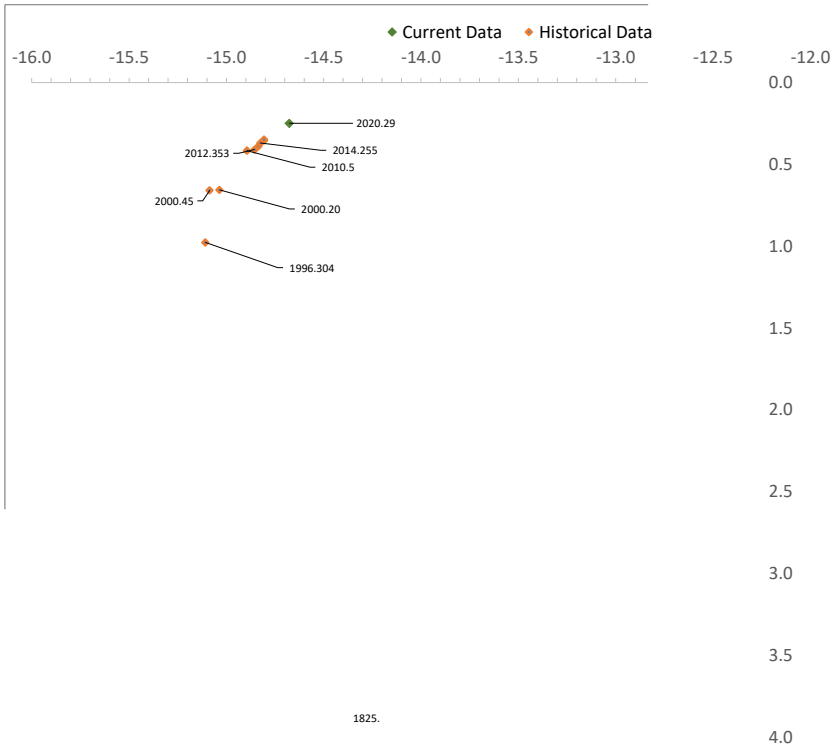

Figure 1: Historical Measurements for HJ 197.

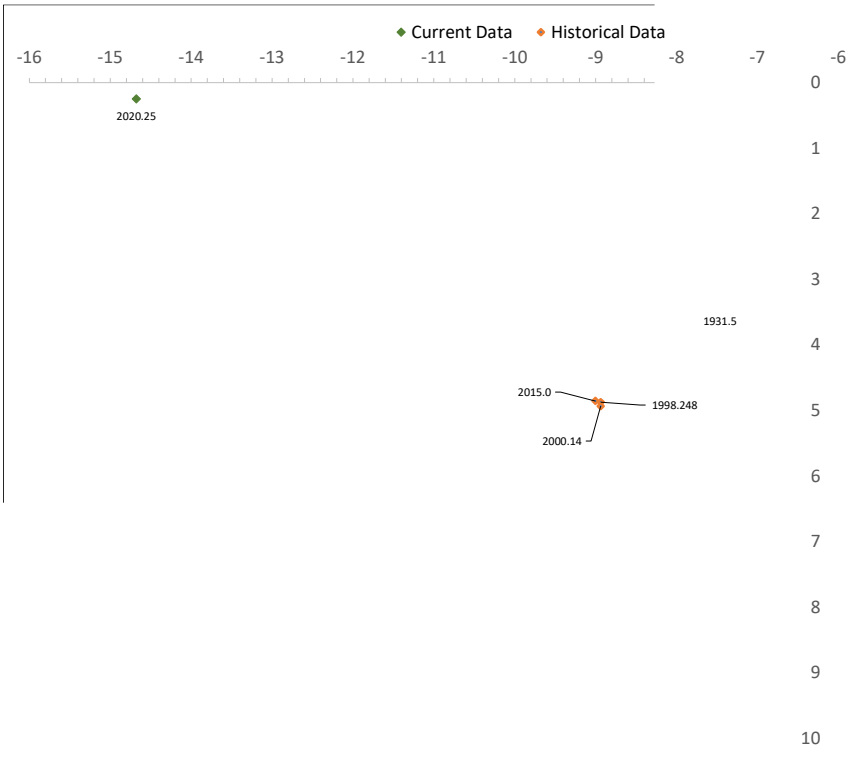

Figure 2 Historical Measurements for B 2752.

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along with the current measurement presented in this paper, Figure 2.

Methods

We used the Las Cumbres Observatory's (LCO) network of 0.4m telescopes to obtain the images used for our measurements. These telescopes each have an SBIG STX6303, 6-megapixel CCD camera mounted at Cassegrain focus providing a resolution of 0.57 arcseconds per pixel square giving a total field of view of 19 x 29 arcminutes. Ten images of HJ 197 were acquired on April 1, 2020 using telescope KB28 located at Siding Spring Observatory in New South Wales, Australia. A sample image of HJ 197 is shown in Figure 3. Ten images of B 2752 were acquired on April 16, 2020 using telescope KB56 also located at Siding Spring Observatory. A sample image of B 2752 is shown in Figure 4. These images were calibrated to WCS coordinates by the OSS-Pipeline in preparation for measurements.

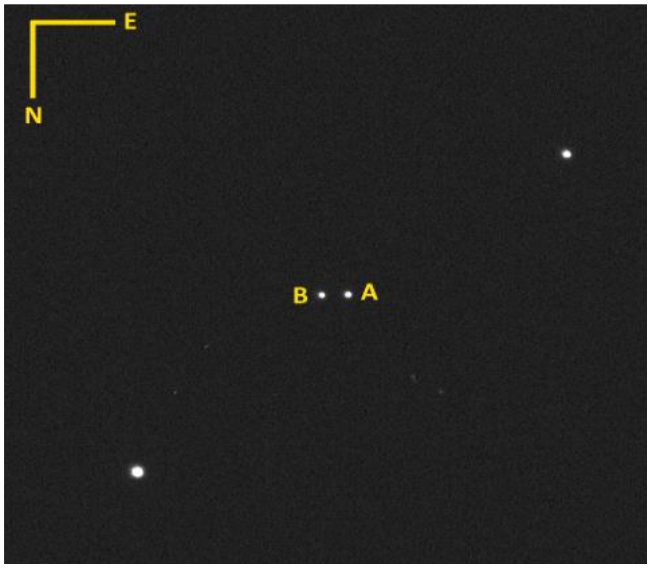

Figure 3: Sample Image of HJ 197.

AstroImageJ, an astronomical image analysis software, was used to measure the position angle and separation from the centroid of the primary star to the centroid of the secondary star of each system. This process is illustrated in Figure 5. We repeated this process for each image for HJ 197 and B 2752. Measurements were repeated by three independent members of the team and results were compared to validate that no systematic errors were introduced. The data was then exported to a spreadsheet for statistical analysis to calculate the mean, standard deviation, and standard error of the mean (SEM) for the position angle and separation values for each star system.

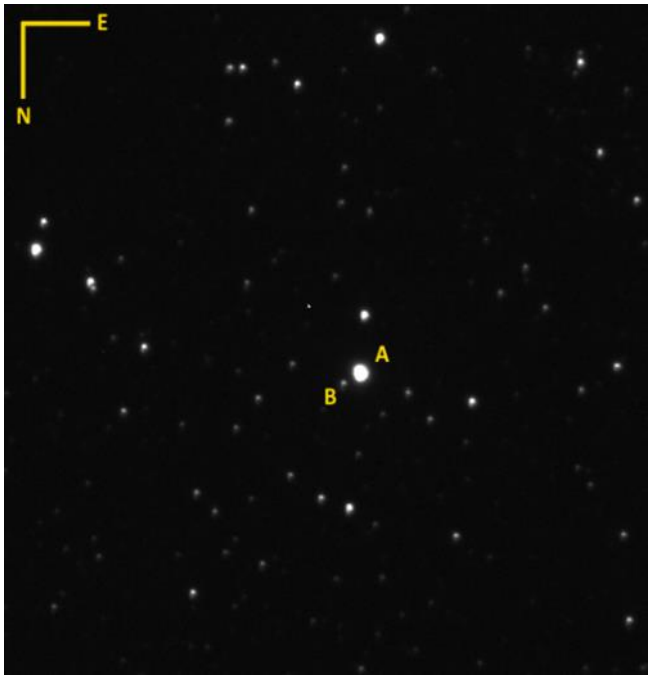

Figure 4 Sample Image of B 2752.

Aladin v10.0 software was used to access the GAIA DR2 database to obtain measurement data on the stars' proper motion vectors parallax measurements. We used a parallax calculator spreadsheet created by Richard Harshaw to calculate the distance in light years to each of the component stars and compute the distance between the stars. The Harshaw statistical value was calculated using another spreadsheet by Harshaw.

Results

The results for the measurements of star system HJ 197 are shown in Table 1. We measured a mean position angle of 270.97° and a separation angle of 14.68 arcseconds for HJ 197.

Parallax measurements from the GAIA DR2 data were used to calculate the distance between the stars in each system and the Harshaw statistical values for each system. The parallax distances for the components of HJ 197 were calculated to be 2127 light-years for the primary star and 1343 light years for the secondary star yielding a separation distance of approximately 783 light years, Table 2.

As a second test of the likelihood of these stars being a physical pair, we used proper motion values from the GAIA DR2 data and the equations from Harshaw (2018) to calculate what is known as "the Harshaw statistical value" for HJ 197. GAIA DR2 proper motion values are shown in Table 3. This Harshaw statistical

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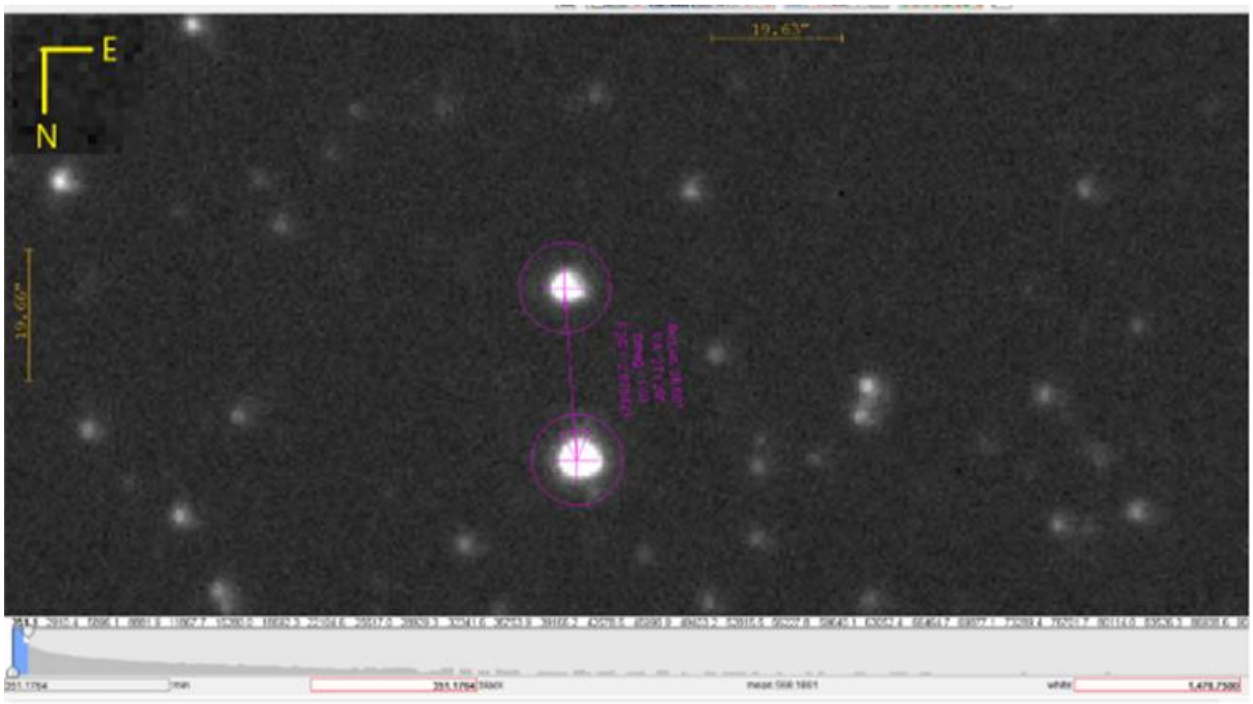

Figure 5 AstroImageJ Measurement.

HJ 197	Position Angle (deg)	Std Dev. Pos. Angle	SEM (deg)	Separation (arcsec)	Std Dev Sep.	SEM (arcsec)
LCO (2020.25)	270.97	0.0249	0.0079	14.68	0.0808	0.0256
Last Measured (2015.141)	271.35			14.81		

Table 1. Measurement Data for Star System HJ 197

HJ 197	*Parallax*	*Error*
Star A	1.5325	0.0447
Star B	2.4264	0.0433

Results	*Parsecs*			*Light Years*		
	Min Distance	Mid Point	Max Distance	Min Distance	Mid Point	Max Distance
Star A	634.03	652.53	672.13	2066.95	2127.24	2191.15
Star B	404.91	412.13	419.62	1320.00	1343.55	1367.97

Table 2. Parallax Distance Data for HJ 197.

This Harshaw statistical value was found to be 0.46.

The results for the measurements of star system B 2752 are shown in Table 4. The mean position angle was measured to be 298.16° and the separation angle was measured to be 10.16 arcseconds. The parallax distances were calculated to be 5211 light years for the primary star and 6251 light years for the secondary star yielding a separation distance of 1040 light years. In addition, we calculated the Harshaw statistical value for B 2752 which was found to be 0.20732. The data for these calculations are shown in Tables 5 and 6.

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HJ 197	*RA Proper Motion*	*DEC Proper Motion*
Star A	5.705	-15.351
Star B	24.84	-35.083

Table 3. Proper Motion Vectors for HJ 197 .

B2752	Position Angle (deg)	Std Dev. Pos. Angle	SEM (deg)	Separation (arcsec)	Std Dev Sep.	SEM (arcsec)
LCO (2020.29)	298.16	0.2744	0.1940	10.16	0.0567	0.0401
Last Measured (2015.0)	298.339			10.23		

Table 4. Measurement Data for Star System B 2752

B 2752	Parallax	Error
Star A	0.63	0.04
Star B	0.52	0.02

Results	Parsecs			Light Years		
	Min Distance	Mid Point	Max Distance	Min Distance	Mid Point	Max Distance
Star A	1491.42	1598.47	1722.06	4862.04	5211.00	5613.91
Star B	1833.52	1917.55	2009.65	5977.26	6251.20	6551.45

Table 5. Parallax Distance Data for B 2752

B 2752	*RA Proper Motion*	*DEC Proper Motion*
Star A	-5.494	-1.103
Star B	-8.29	-1.974

Table 6. Proper Motion Vectors for B 2752

Discussion

The astrometry data we measured is statistically accurate with little deviation from the mean. The data for HJ 197 is presented in Table 1 while the data for B 2752 is presented in Table 4. However, the distance calculations based on the parallax data from GAIA DR2 indicates that, in both cases, the star systems are widely separated.

Both star systems have relatively large parallax values from which we derived separation distances of 783 and 1040 light years respectively, indicating that the distance between the stars of these systems is too large and it is very unlikely that the stars in each system are gravitationally bound. Richard Harshaw noted that in his observation of 2500+ star systems in the WDS catalog, very few physical double stars have exceeded a separation of 2 parsecs or 6.5 light years. Thus, we concluded that the star systems HJ 197 and B2752 are most probably not gravitationally bound and are therefore optical doubles.

Finally, as additional evidence that these pairs are not physical doubles, we consulted the Harshaw Statistical value. The statistical value for HJ 197 suggests that the stars have sufficiently different proper motion vectors to, again, confirm that HJ 197 is an optical double. While the Harshaw statistical value for B 2752 is considerably smaller, it is still much too large to indicate a high probability of these stars being a physical double.

Conclusion

Through the measurements and calculations of HJ 197 and B 2752, they do not appear to be physical double star systems but rather are optical doubles due to differences of several hundred lightyears and high Harshaw values.

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References

European Space Agency (ESA). (April 27, 2018), GAIA Data Release 2 (GAIA DR2)

Harshaw, R., 2018, "Gaia DR2 and the Washington Double Star Catalog: A Tale of Two Databases", Journal of Double Star Observations. 14 (4), 734-740. http://www.jdso.org/volume14/number4/Harshaw_734_740.pdf.

Harshaw, Richard. "Another Statistical Tool for Evaluating Binary Stars", JDSO, January 1, 2014.

"Stelle Doppie," Washington Double Stars Catalog, last modified September 05, 2019, https://www.stelledoppie.it/index2.php?section=2.

"Washington Double Stars Catalog," United States Naval Observatory, last modified April 27, 2020, http://www.astro.gsu.edu/wds/.

"Simbad," Centre de Données astronomiques de Strasbourg, last modified May, 01, 2020, http://simbad.u-strasbg.fr/simbad/.

Fitzgerald, M.T. (2018, accepted), "The Our Solar Siblings Pipeline: Tackling the data issues of the scaling problem for robotic telescope-based astronomy education projects.", Robotic Telescopes, Student Research and Education Proceedings

Las Cumbres Observatory (LCO), 2018, 0.4 Meter, JPEG, Las Cumbres Observatory, Global Headquarters California, accessed 22 March 2018, https://lco.global/observatory/telescopes.

Washington Double Star Catalog (WDS) (n.d.). Naval Oceanography Portal (Retrieved in October 2019), https://www.usno.navy.mil/USNO/ astrometry/ optical-IR-prod/wds/WDS

European Space Agency (ESA). (April 27, 2018). GAIA Data Release 2 (GAIA DR2). Retrieved from https://www.cosmos.esa.int/web/gaia/dr2.