Astrometry of the Triple System WDS 19315-2053 AC Pair in Sagittarius

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Abstract: Astrometric measurements were made of the AC pair in the triple system WDS 19315-2053, also known as HJ2875 AC, in the constellation Sagittarius. Images of the AC pair were taken by the Las Cumbres Observatory (LCO) 0.4-meter telescope at the Haleakalā Observatory on 1 August 2020. Separation (10.34'' +/- 0.0199'') and position angle (332.45° +/- 0.0151°) for the pair were determined using AstroImageJ and compared to historical observations obtained from the United States Naval Observatory. While historical data indicated that the nature of the pair was physical, research presented here suggests that the stars in this system are not gravitationally bound. This conclusion is based on separation angle and position angle changing in a non-systematic fashion during almost 200 years of observations, and parallax measurements from Gaia indicating separation on the scale of dozens of parsecs.

Introduction

First recorded by John Herschel in 1828, WDS 19315-2053 is a triple system located in the constellation Sagittarius (Herschel & Dryer, 1912). This system has a relatively limited observational history, spanning only 17 observations with varying astrometric techniques. The AC (primary and tertiary) pair was originally designated AB (primary and secondary) before the discovery of the true secondary in 1951 (Rossiter, 1953). The coordinates of the AC pair in this star system are at a right ascension of $19^H31^M32.07^S$, with a declination of -20° 52′ 56.9″.

WDS 19315-2053 AC is recorded as being a physical double with a first recorded separation (ρ) of 5″ and a position angle (θ) of 332° in 1828. The most recent astrometric measurements were taken in 2015, which recorded a ρ of 10.04″ and a θ of 332°. To date, there has only been one recorded observation of the AB pair in this system recorded in 1951. The secondary star in this system has a ρ of .7″ and a θ of 284°, with a 2.52 delta magnitude (**Δ**M) between the pair.

The primary star is a main-sequence star with a spectral classification of F8/G0, a magnitude ranging between 9.48 -10.63, and a solar mass ($M_\odot$) between 1.1-1.15. Stars of this spectral class have a surface temperature between 6050K - 6300K which gives them a chromaticity of yellow-orange and a luminosity class of V. There were no recorded values for spectral classification for the secondary and tertiary stars in this system.

WDS 19315-2053 (cross-listed as SAO 188239) happens to lie near the ecliptic plane. Lunar occultations of SAO 188239 have been observed three times: 11 November 1972 from South Africa, Radcliffe Observatory, 19 September 1991 from Dunedin, New Zealand and 17 October 1999 from Japan. Unfortunately, these records show no evidence of the system being a double star (Brian Loader, personal communication). The B component star is too dim to observe at lunar occultation, and there are several factors which probably account for this null result of the C component: its magnitude is close to the observable limit, requiring the Moon to be close to 1st or 3rd quarter; and the geometry would have to have been such that the primary star was blocked first (Brian Loader, personal communication). The next opportunities for lunar occultations are not well-placed for observation (i.e. remote areas of Earth). Nevertheless, the location of WDS 19315-2053 may mean that occultations with other Solar system bodies are possible.

Maintained by the United States Naval Observatory, the Washington Double Star Catalog (WDS) is the compendium of astrometric double and multiple star information (Mason et al., 2001). The WDS Catalog includes information such as positions (J2000), discoverer designations, epochs, position angles, separations, magnitudes, spectral types, and proper motions**.** Data in the Washington Double Star Catalog have been collected, collated, and maintained for over fifty years when the original Index Catalog of Double Stars (IDS) (Jeffers & Van Den Bos, 1963) was transferred from Lick Observatory to the U.S. Naval Observatory.

The European Space Agency provides information from the Gaia satellite, which extends the success of the Hipparcos and Tycho programs (Perryman et al., 1997). The Gaia satellite provides highly accurate five-parameter astrometry for 1.3 billion sources, which also includes parallax measurements better than 0.1 milliarcsecond to determine distance (Mignard et al., 2018).

Methods

From the Washington Double Star Catalog (Mason et al, 2001) double star systems meeting the following criteria were identified: the right ascension (RA) was between 13 and 23 hours, the stars had a separation of at least 5 arcseconds, and magnitudes were between 7 and 12. Using the Boyce DoubleSTARS query Web interface (Boyce, 2017) the following criteria for candidate systems that were located within the Washington Double Star Catalog (WDS) were followed: observable in the summer night sky by the Las Cumbres Observatory (LCO) 0.4 meter telescopes (Pickles et al., 2010), systems that had relatively few historic observations, and systems that had not been observed within the past five years. The 1,365 candidates were then sorted by spectral class; the only star with the Sun's spectral class (G2V), WDS 19315-2053 AC, was chosen. This paper reports the results of new observations of the double star HJ 2875 AC as well as an inference about the related system RST5548 AB (these systems have the same primary star, and thus constitute a suspected triple star system).

Historical Data for the system was requested from Brian Mason from the U.S. Naval Observatory. Some observations were omitted before further interpreting the data using Richard Harshaw's Historical Data Analysis Plot Tool for Excel (Buchheim et al., 2017; Harshaw, 2020), resulting in 14 usable historical observations. The observations that were removed from the analysis included the first two data points from John Herschel, data points that were marked for deletion within the Historical Data, and data points that did not include separation or position angle. The earliest observation from John Herschel in 1828 appears to be an outlier in terms of separation, measured at 5 arcseconds in contrast to the next 170 years of data measuring it at approximately 10 arcseconds. The 1830 observation may also be an outlier as there is an independent reason to doubt these two measurements because of the method John Herschel used with a ring micrometer, which was prone to inaccuracies (Richard Harshaw, personal communication). Multiple images were requested via The Las Cumbres Observatory (LCO) Observatory site at the Haleakalā Observatory, Maui, HI. An image of WDS 19135-2053 is shown in Figure 1.

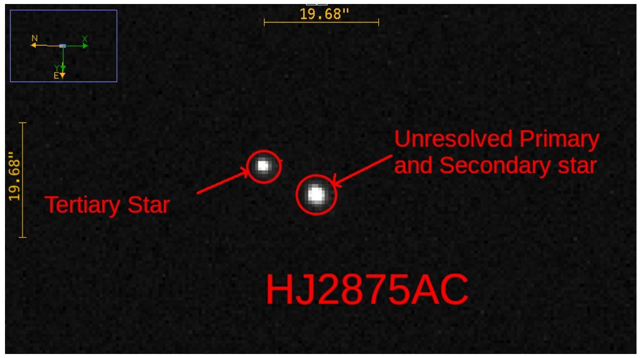

Figure 1: Image of the AC component of WDS 19135-2053, taken from LCO, with labels showing the primary Star (A) and the tertiary star (C). The secondary component is obscured by the primary star and therefore located within the primary star's region, and is not visible within this image.

Historical data for the triple star system is provided in Table 1. The initial measurements made by John Herschel in 1828 and 1830 were excluded as the separations in these measurements, (5 and 9 arcseconds respectively), were deemed outliers upon further analysis.

Table 1: Historical Data for the AC component of WDS 19135-2053, HJ 2875 AC

Epoch	Position Angle (degrees)	Separation (arcseconds)
1897.72	331.8	10.91
1900.67	333	10.63
1919.12	334	9.871
1922.39	333.2	10.389
1926.78	334.2	10.317
1930.9	332.4	10.34
1969.7	330.6	11.33
1991.73	332.3	10.281
1998.41	332.8	10.33
1999.596	332.4	10.34
2008.639	332.5	10.31
2015	332.298	10.402

A first set of images were taken on 12 July 2020, from the LCO observation portal at the Teide Observatory, on Tenerife, Spain. These images had a 1 second exposure time, which proved to be too dim to take accurate measurements. A second set of images were captured on 20 July 2020, from the LCO observation portal at the Haleakala Observatory, on Maui, Hawaii using the site's 0.4-meter telescope. The SBIG STL 6303 CCD Camera was used to capture images of WDS 19315-2053 AC. Bessel V (visible), and B (blue) filters, along with Sloan Digital Sky Survey (SDSS) Rp (Red) filters were used. Using the three different filters (visible, blue, red), and two different exposure times of 1.5 seconds and 2.0 seconds, 10 images for each filter and exposure time combination were taken. The images were received via Google

Drive from the LCO Observing Portal, and subsequently decompressed. The FITs files were reduced through the Our Solar Siblings Pipeline (Fitzgerald, 2018) and analyzed in AstroImageJ (AIJ). A flow chart of the process is shown in Figure 2.

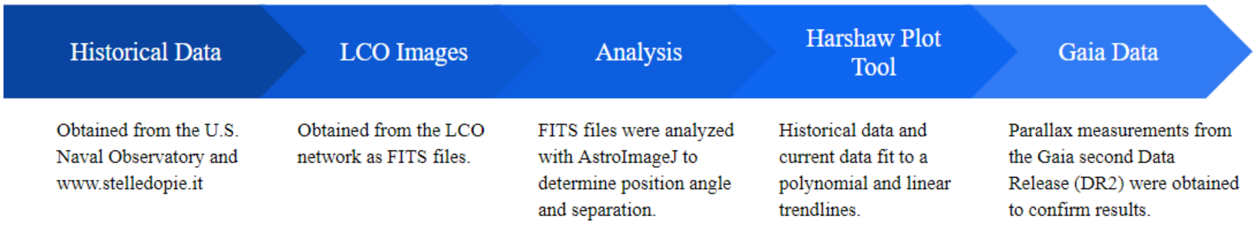

Figure 2: Flow chart of Data Processing

Data and Results

Position angle and separation data was collected in three filters with the results shown in Table 2.

Table 2: Summary of separation and position angle data for WDS 19315-2053 AC, measured in AstroimageJ. The SDSS Rp and Bessel B, and V data are shown, respectively.

Position Angle and Separation Measurements in 3 filters; Exposure time 1.5 seconds each						
	SDSS Rp		**Bessel V**		**Bessel B**	
Image #	**Position Angle (degrees)**	**Separation (arcseconds)**	**Position Angle (degrees)**	**Separation (arcseconds)**	**Position Angle (degrees)**	**Separation (arcseconds)**
1	332.35	10.40	332.20	10.27	332.33	10.28
2	332.20	10.41	332.35	10.35	332.62	10.32
3	333.32	10.37	332.63	10.34	332.42	10.22
4	332.51	10.36	332.68	10.37	332.15	10.35
5	332.65	10.40	332.40	10.38	332.58	10.37
6	332.49	10.34	332.63	10.34	332.10	10.23
7	332.47	10.41	N/A	N/A	332.61	10.34
8	332.28	10.42	N/A	N/A	332.64	10.34
9	332.40	10.37	N/A	N/A	332.72	10.32
10	332.53	10.37	N/A	N/A	332.37	10.23
Average	**332.42**	**10.38**	**332.48**	**10.34**	**332.45**	**10.30**
Standard Deviation	**0.127**	**0.025**	**0.175**	**0.034**	**0.202**	**0.053**
SEM	**0.040**	**0.008**	**0.071**	**0.014**	**0.064**	**0.017**

The position angle and separation were averaged across all the filters and found to be 332.45 ± 0.015 degrees and 10.34 ± 0.020 arcseconds, respectively, as shown in Table 3.

Table 3: Position angles and separations averages were calculated across all three filters,and are shown here, along with their standard deviations and standard error means.

Filter (1.5 second exposures)	Position Angle (degrees)	Separation (arcseconds)
SDSS Rp	332.42	10.38
Bessel B	332.45	10.30
Bessel V	332.48	10.34

Average	**332.45**	**10.34**
Standard Deviation	**0.026**	**0.034**
S.E.M.	**0.015**	**0.020**

Discussion

Figure 3 displays the plot of the position angle vs. time and the plot of separation vs time. The earliest observation (from 1828) appears to be an outlier in terms of separation angle and magnitude. The current measurements appear to fit well with recent historic data in this visualization.

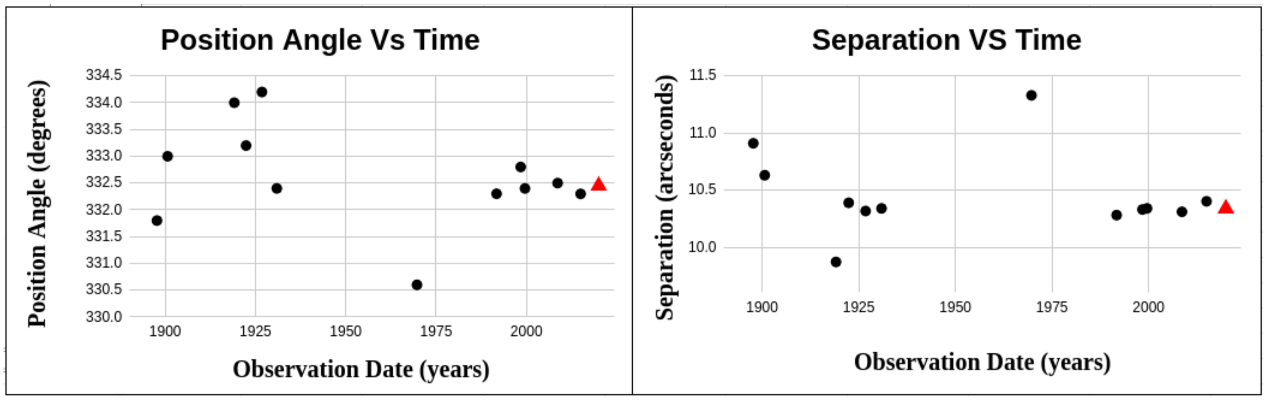

Figure 3. Plotting (left) Position Angle vs Time; (right) Separation vs Time. The Triangle represents the new datapoint.

Figure 4 shows current measurement together with the historic data using the Harshaw Plotting tool (Harshaw, 2020). Including the 1828 and 1830 observations, the extrapolated polynomial fit does not encircle the origin (Figure 4). A linear fit can imply a random, non-orbital relationship (due to different proper motions). Alternatively, an orbiting pair viewed edge-on (i.e. Earth is in the same plane as the orbiting pair) would also generate a linear fit in these plots. In that case, the extrapolated line would go through the origin, while these data do not have that feature.

Without the 1830 observation, the quadratic best fit actually has the wrong curvature for an orbit, while the linear fit is the furthest yet from passing through the origin. While the 1830 entry obtained from the WDS does not include a recorded magnitude for the primary star, the secondary star does have a recorded magnitude that is several orders of magnitude brighter than what is expected (Knapp et al., 2019). This may be simply a records error, but it does raise questions about the accuracy of that measurement.

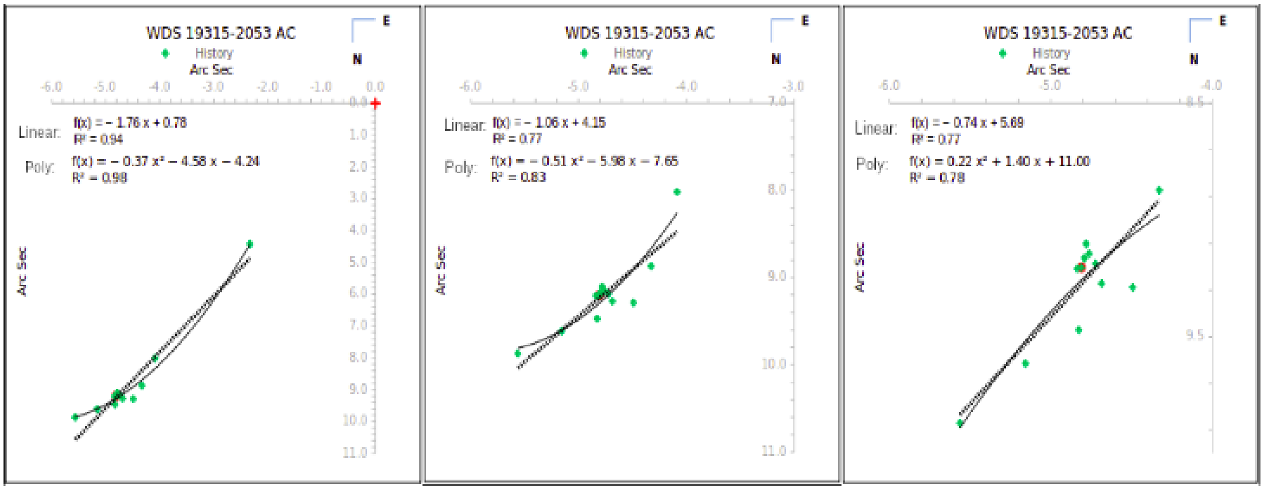

Figure 4: Historical Data and Current Data fit to a Polynomial Trendline and a Linear Trendline: with all available data minus 1907 observation due to no position angle, (center) with all available data minus 1907 and 1828, an outlier, (right) with all available data minus 1907, 1828, and 1830 (a possible outlier).

The primary star is listed as having a spectral class either of F8 or G0. Given the canonical absolute magnitudes of these classes (4.4 and 4.7 respectively) and the apparent magnitude of 9.48, this gives a distance range of between about 338 and 295 light years. Then, given the observed angular separation (about 10.4 arc seconds for the A and C components), the resulting separation would be between about 940 and 1070 AU. That would imply an orbital period of several thousand years. Thus an orbiting component star would obviously change position in the same sense, or with possibly one direction reversal if the star had reached its greatest elongation during the historic period in which it was observed. However, the historic data do not change monotonically: the transition from nearest to farthest separation angle is not in a chronological sequence.

Parallax measurements from the Gaia second Data Release (DR2) were obtained. The A component star has a reported distance ranging from 201 to 248 parsecs, while the C component has a reported distance ranging from 186 to 188 parsecs.

The evidence points to the AC components being a visual binary pair only rather than an orbiting pair.

Conclusion

Given all of these considerations, it seems extremely unlikely that the A and C components are gravitationally bound, thus, the AC components are likely a visual binary pair rather than an orbiting pair. This conclusion is also supported by the lack of synchronicity in the separation and position angle of the AC system over its observational history. In addition to separation angle and position angle change in a non-systematic fashion during almost 200 years of observations, parallax measurements from Gaia indicate separation on the scale of dozens of parsecs, indicative that the pair isn't close enough to orbit each other. However, future observation of this system is required to enhance this hypothesis, as longitudinal data analysis is the only way to confirm the hypothesis that the A and C components are a visual binary.

Acknowledgments
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References

AstroImageJ at https://www.astro.louisville.edu/software/astroimagej/

Boyce, P. and Boyce, G., "A Community-Centered Astronomy Research Program" (2017). Proceedings of the Society for Astronomical Science. Boyce, G. and Boyce, P. Boyce, Research Initiatives and Education Foundation (BRIEF), http://www.boyce-astro.org/home.html.

Buchheim, R., Johnson, J., Harshaw, R., & Gennet, R. (2015). Small Telescope Astronomical Research Handbook. Collins Foundation Press.

Buchheim, R. K., 2017, Displaying New Measurements on WDS Orbital Plots. Journal of Double Star Observations. Vol. 13 No. 2, pp 233-236.

Fitzgerald, M. T. (2018). The Our Solar Siblings Pipeline: Tackling the data issues of the scaling problem for robotic telescope based astronomy education projects. *RTSRE Proceedings*, *1*(1), Article 1. https://rtsre.org/index.php/rtsre/article/view/12

Harshaw, R. 2020, Using Plot Tool 3.19 to Generate Graphical Representations of the Historical Measurement Data. *Journal of Double Star Observations*, 16, 386-400.

Harshaw, R.W., 2018, "Gaia DR2 and the Washington Double Star Catalog: A Tale of Two Data-bases ", Journal of Double Star Observations, 14, 734-740.

Herschel, W., Dreyer, J.L, 1912, The Scientific Papers of William Herschel, The Royal Society, London.

Jeffers, H.M., van den Bos, W.H. & Greeby, F.M. 1963, *Index Catalogue of Visual Double Stars, 1961.0*, Pub. of the Lick Observatory, 21

Knapp, W.R.A. and Nanson, J. 2019. "A Catalog of High Proper Motion Stars in the Northern Sky (HPMSNS Catalog)," Journal of Double Star Observations, 15, 42-58, Jan 2019.
Las Cumbres Observatory | Many Eyes - One Vision 2018. https://lco.global/

Mason, B.D., Wycoff, G.L., Hartkopf, W.I., Douglass, G.G. and Worley, C.E., 2001, US Naval Observatory Double Star CD-ROM. I. The Washington Double Star Catalog Astronomical Journal, Volume 122, Issue 6, pp. 3466-3471.

Mignard, F., et al. (2018). Gaia Data Release 2 - The celestial reference frame (Gaia-CRF2) referenced as Gaia Collaboration, A&A 616 A14. DOI: 10.1051/0004-6361/201832916

Perryman, M. A. C., Lindegren L., Kovalesky, J., Hog, E., Bastian, U., Bernacca, P.L., Creze, M., Donati, F., Grenon, M., Grewing, M., van Leeuwen, F., van der Marel, H., Mignard, F., Murray, C.A., Le Poole, R.S., Schrijver, H, Turon, C., Arenou, F., Froeschle, M., and Petersen, C.S. (1997) The Hipparcos Catalog. Astron Astrophys. 323, L49-L52.

Pickles, A.; et al., 2010, Stepp, Larry M; Gilmozzi, Roberto; Hall, Helen J (eds.). "LCO Telescope Network Capabilities". *Proc. SPIE*. Ground-based and Airborne Telescopes III. **7733**: 77332X. Bibcode:2010SPIE.7733E..2XP. doi:10.1117/12.857923.

Rossiter, R.A. (1953) Seventh list of new Southern double stars found at the Lamont-Hussey Observatory of the University of Michigan at Bloemfontein, South Africa. Astronomical Journal, Vol. 58, p. 29-30. https://ui.adsabs.harvard.edu/abs/1953AJ.....58...29R/abstract

Stellarium Astronomy Software. Version 0.18.1 (n.d.). http://stellarium.org/

Stelle Doppie - Double Star Database, Gianluca Sordiglioni. http://www.stelledoppie.it/index2.php