Astrometry of the Quadruple Star System WDS 16579+4722 in the Constellation Hercules

Shannon Pangalos-Scott[1,5] quadrivium.steam@gmail.com, Danielle Holden[1], Melody Fyre[1], Kelsey Bishop[1], Rachel Freed[4], Rebecca Chamberlain[1], and Russ Genet[2,3]

1. The Evergreen State College, Olympia, Washington
2. Cuesta College, San Luis Obispo, California
3. California Polytechnic State University, San Luis Obispo, California
4. Sonoma State University, Cotati, California
5. QUADRIVIUM: STEAM & Astronomical Society, Olympia, Washington

Abstract: Quadruple star system WDS 16579+4722, located within the constellation group of Hercules is a multiple-star, wide hierarchical system with three physical binaries. The fourth star located within the star group is classified as a visual binary. Historical data from the Washington Double Star Catalog, as well as projected paths from Stelle Doppie, were compared to current images obtained from a Las Cumbres Observatory site in Tenerife, Spain. Separation and position angle for all pairs were measured using AstroImageJ.

Introduction

WDS 16579+4722 (also designated V1090 Herc) is located within the constellation group of Hercules, at a right ascension of 16 hours, 57 minutes, 53.18 seconds, a declination of +47 22 00.0 degrees, and at a distance of 59.69 light-years from Earth. In 1823, the first pair to have their position angle and separation recorded, was the primary (A) and the tertiary (C) stars. This was due in part to the apparent magnitude of the A and C stars. They are the brightest in the system, with a 0.12 delta magnitude (ΔM) between the pair. It wasn't until 1908 that the secondary (B) and quaternary (D) stars were discovered and their positions relative to the primary star (AB and AD) were recorded (Table 1).

The three physically bound stars (A, B, and C) in this system are classified as a wide, hierarchical, simplex, triple system and follow all of Kepler's Laws of Planetary Motion of celestial bodies orbiting around a center of mass. The AB pairing in this system has an approximate 430-year orbital period. This cycle is stable, with nested, elliptical orbits; the center of mass between these two stars would be classified as a two-bodied system. The tertiary star (C) in this system, traverses a wide elliptical orbit around the AB pair, with an estimated 64,000-year orbit. This pairing of (AB)C, would also be treated as a two-body system, where the AB component would be treated as a single star and has negligible interaction between the C stars motions. These stars are all rotating variable stars. The quaternary star (D) in this system is a visual double and only appears close to the A, B, and C stars from an Earth perspective. Records from the Washington Double Star Catalog (WDS) were compared to current images of this system obtained from the Las Cumbres Observatory (LCO) and their global network of

Star	Mag	Spectral Class	Chromacity	Avg. Temp.	ΔM	ρ	θ
Primary (A)	7.93	KOV	Yellow-orange	5,240 K	From A	From A	From A
Secondary (B)	10.85	M3V	Red	3,500 K	2.93	5.02"	63.8
Tertiary (C)	8.05	K7V	Yellow-orange	4,000 K	0.12	112.4"	261
Quaternary (D)	15	M8	Red	2700 K	7.07	25.9"	246°

Table 1: The magnitude, spectral class, chromaticity, and average temperature for each star. Data from Stelle Doppie, records the last measured delta magnitude (ΔM), separation angle (ρ), and the position angle (θ) from the primary.

Received October 30, 2020

Astrometry of the Quadruple Star System WDS 16579+4722 in the Constellation Hercules

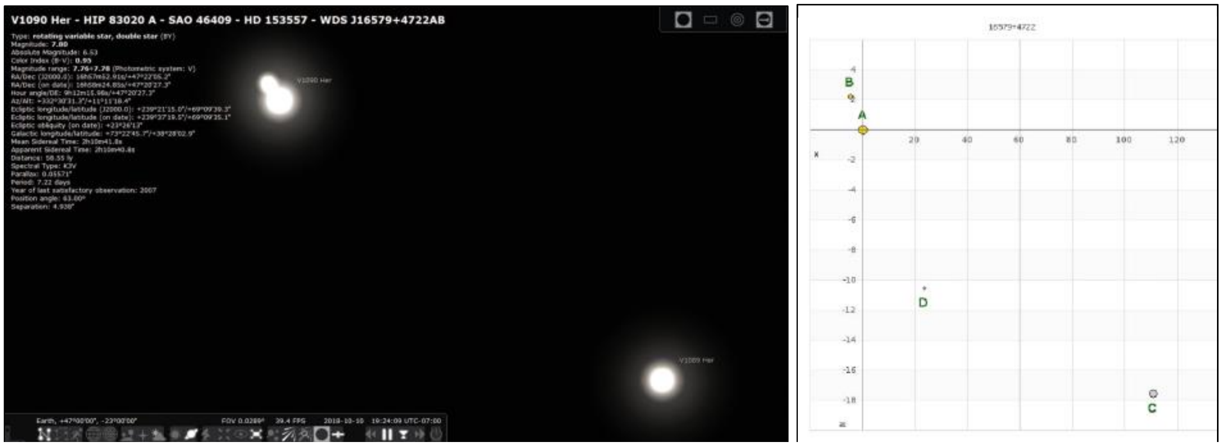

Figure 1: (left) November 2018, night sky simulation showing the location of WDS 16579+4722, including A, B, and C, generated using Stellarium version 0.18.1. Star D in this system is not represented.
(right) November 2018, from the Stelle Doopie Double Star Database, the position of the four stars in this system WDS 16579+4722.

telescopes. To offer a visual representation of the relationship between the A, B, and C physical binary pairs in this system, a simulation from Stellarium (Figure 1, left), a computer-generated planetarium, and a virtual eyepiece in Stelle Doppie (Figure 1, right) have been added.

Equipment and Procedures

An initial set of images was requested from LCO on October 12, 2018, ten each with a 0.5-sec and 1.0-sec exposure time using a red filter.

A total of 36 images were received on October 13, 2018, with an exposure range of 0.73 to 1.24 seconds, using a red filter. These images were taken from the LCO observation port at the Teide

Observatory on the island of Tenerife, part of the Canary Islands in Spain, using the 0M4-SCICAM-SBIG camera with CCD digital imaging on one of the sites modified, equatorially mounted, 0.4 meter Meade telescopes (Figure 2). All of these images were plate solvable and were used to measure the separation and position angle for the AB, AC, and BC components.

In order to take measurements of the AD component, it was determined that an additional set of images with longer exposure times and a clear-neutral filter should be requested. An observation request was sent through the LCO Observation Portal on November 1, 2018. A new set of images, also from the Teide Observatory, with an exposure range of 5.34 to 5.36 seconds was received on November 2, 2018 (Figure 3). This second set of images could not be plate solved because of said longer exposure time; regardless, measurements were taken with consistent results.

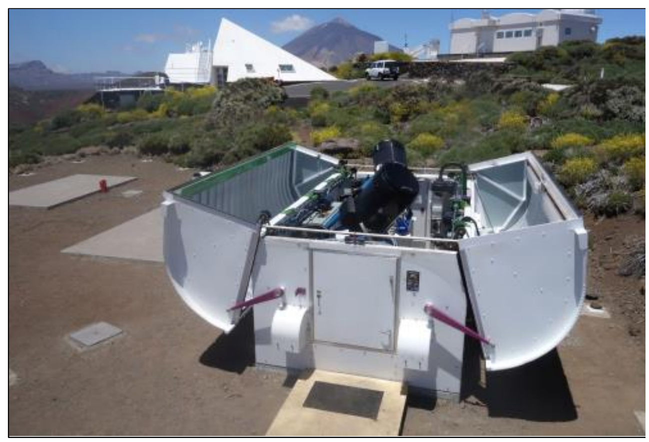

Figure 2: Two 0.4-meter telescopes operated by the LCO network at Teide Observatory in Tenerife, Spain.
Image made available by LCO under an Attribution-Noncommercial-Share
Alike 3.0 license. https://lco.global/images/observatory/

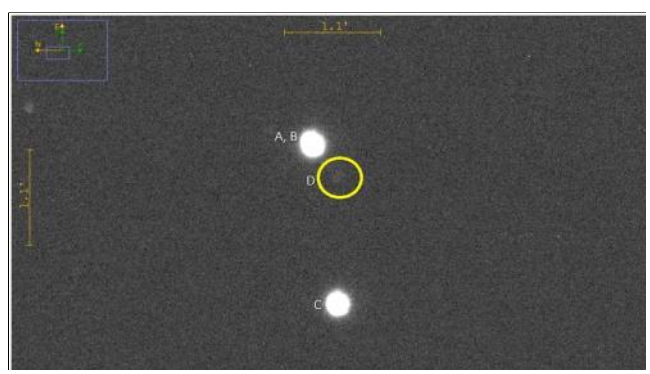

Figure 3: Image from LCO and opened in AstroImageJ. Positions labeled, the B star up and to the left of A, D star is outlined with a yellow ring.

Astrometry of the Quadruple Star System WDS 16579+4722 in the Constellation Hercules

Position angle (degrees) and separation (arcseconds) between the four separate pairs was measured using AstroImageJ (Figure 4). The total average value, standard deviation, and standard error of the mean for each data set were taken in Google Sheets (Table 2). These results were then compared to the trajectory paths that were projected in the WDS and Stelle Doppie.

From the original images received on October 13th, 360 measurements were taken for the AB component, another 360 for the AC component, then another 80 for the BC component. 100 measurements were taken for the AD component from the images that were received on November 2nd. In total, 900 astrometric measurements were taken for the entire multi-star system using a total of 46 images that were received from Teide Observatory.

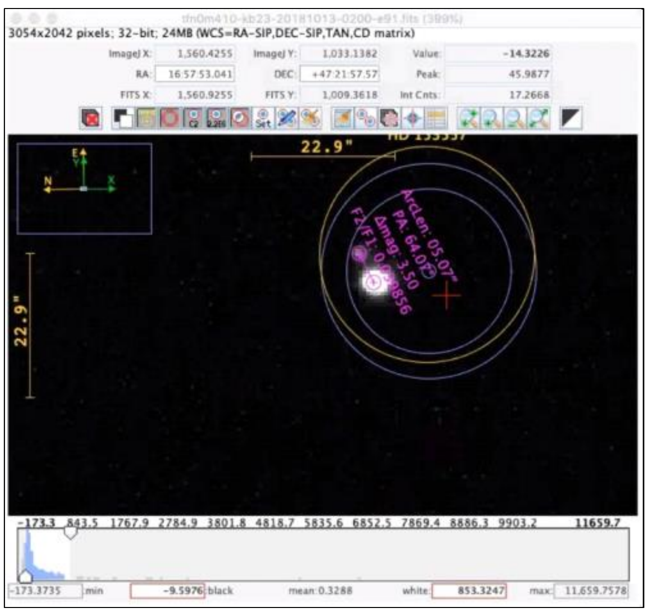

Figure 4: Screenshot of AstroImageJ interface, showing position from the primary (A) to secondary (B).

Results

Current measurements, representing the separation and position angle between the primary star (A) and the three subsequent stars (B, C, D) as well as measurements between the secondary (B) and tertiary (C) stars were taken (Table 2). Measurements of eight images from both request sets are shown, additional raw data is linked in the description for Table 2 and can be made available upon request. The visual binary pair AD (Figure 3) proved difficult to measure due to the large delta magnitude, thus causing a larger overall standard deviation in the pair's measurements of 1.08 and 1.48.

Each measurements' distribution fell within expected ranges and no statistical anomalies were present, this is represented by the standard error of the mean within the statistical population having less than a 1% deviation. The following scatter plots (Figures 5-8) illustrate past historical data from the WDS for the components that were measured. The change in separation and position angle is plotted along the y-axis, against time along the x-axis. The new data position of the secondary (B) star appears to closely follow the orbit projected by Stella Doppie when position angle and separation are plotted in polar coordinates.

(Figure 9).

	Image Request 1						*Image Request 2*	
Image Number	***Sep. (AB)***	***PA (AB)***	***Sep. (AC)***	***PA (AC)***	***Sep. (BC)***	***PA (BC)***	***Sep. (AD)***	***PA (AD)***
1	5.08	63.85	114.63	260.88	118.75	260.14	27.43	234.94
2	5.13	63.76	110.14	261.21	118.23	260.33	26.36	236.77
3	4.93	65.55	112.85	261.60	119.12	260.08	26.52	233.16
4	4.95	62.69	109.12	261.06	118.55	260.06	24.42	234.58
5	4.96	59.88	109.11	261.49	119.25	260.02	24.68	234.5
6	5.21	62.17	108.40	260.49	118.41	260.36	26.59	234.41
7	4.78	62.75	111.24	260.77	119.22	260.04	24.7	233.48
8	4.79	62.4	111.08	260.81	118.75	260.22	24.65	233.47
Mean	4.92	62.47	110.86	261.26	118.79	260.15	25.59	234.84
Standard Deviation	0.332	1.96	1.77	0.424	0.38	0.13	1.08	1.48
Standard Error of Mean	0.055	0.33	0.3	0.071	0.13	0.05	0.34	0.47

Table 2: Summary of final data with standard mean, standard deviation, and the standard error of the mean. The separation is calculated in arcseconds and the position angle is calculated in degrees. All data was reduced to two digits after the decimal point once final calculations were determined.

Discussion

As with the initial data that was collected on this system in 1823, the first set of stars that were measured were those with the highest magnitudes, the primary (A), and the tertiary (C) stars. When these measurements were compared to historical data that was obtained from the WDS of this system's primary AB component, the orientation error became apparent. This oversight presented itself as an opportunity to not only calculate the current positions of the AB component but of the AC, AD, and BC as well. These new measurements were then compared against the historical records for the AB and AC pair, which indicated that the change in position and separation angle over time are typical characteristics of physical doubles that are gravitationally bound. While historical records indicate that the BC component is also a physical binary, records available only date back to 1995, this data represents a glimpse of a larger orbital path that requires additional records to quantify. There were a total of three historical records for the AD pair, 1908, 1998, and 2000, then the current 2018 measurements outlined in this document. While historical records indicate that this pair is a visual binary, with such a small sample size and since plate solving the current images wasn't possible using

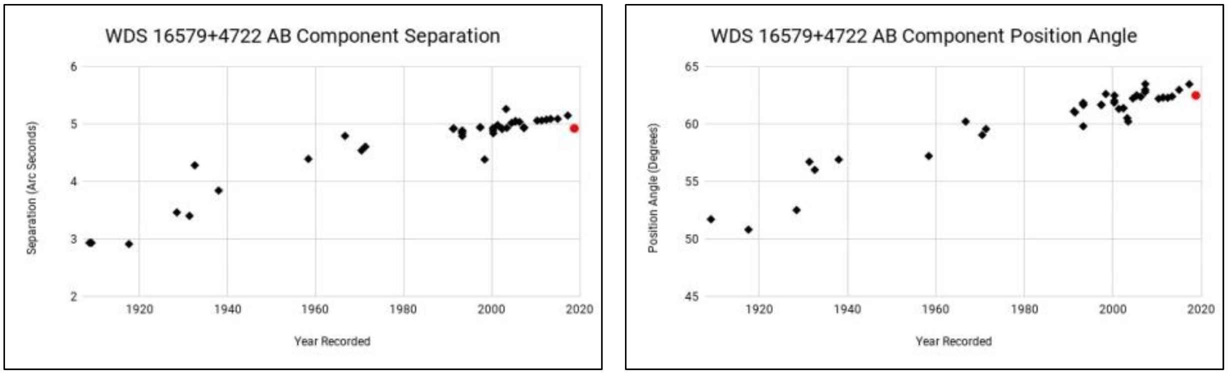

Figure 5: Historical data collected from the Washington Double Star Catalog of WDS 16579+4722 AB, (left) the separation of the primary star relative to the secondary over time, (right) the position angle of the secondary star in relation to the primary over time. The new position is shown with a red dot.

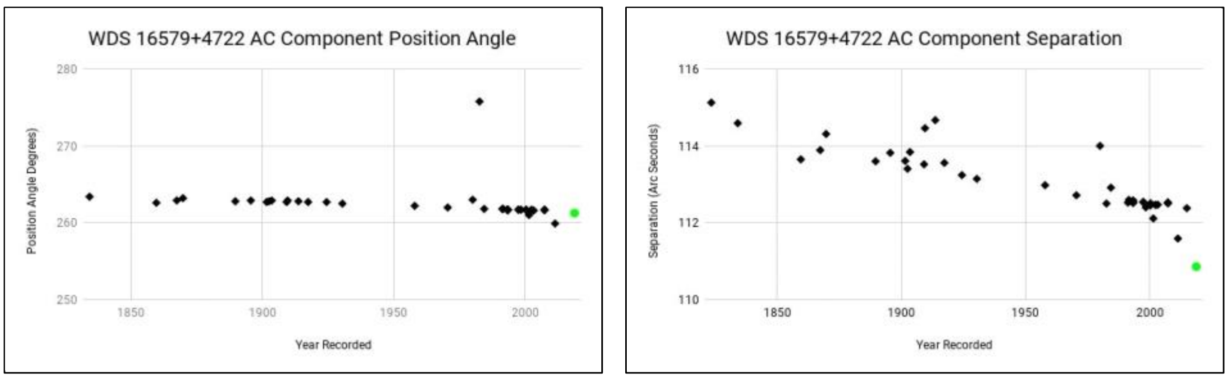

Figure 6: Historical data collected from the Washington Double Star Catalog of WDS 16579+4722 AC, (left) the separation of the primary star relative to the secondary over time, (right) the position angle of the secondary star in relation to the primary over time. The new position is shown with a green dot.

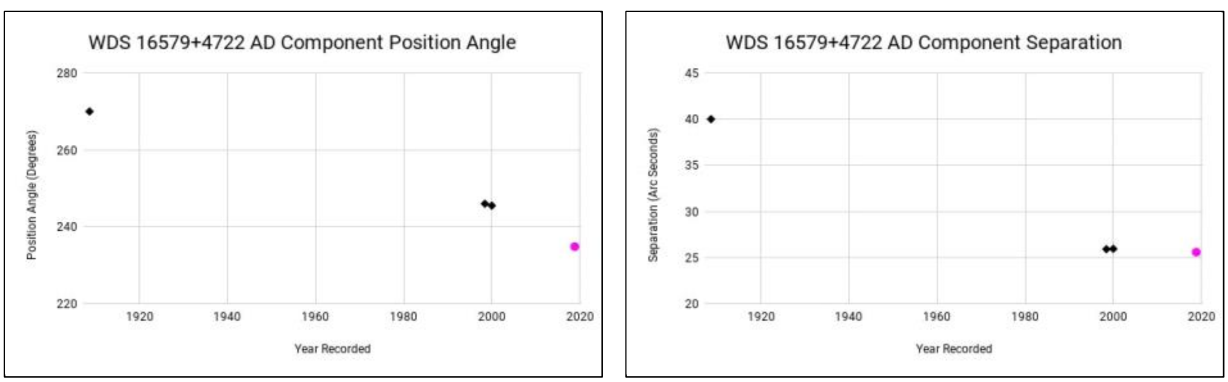

Figure 7: Historical data collected from the Washington Double Star Catalog of WDS 16579+4722 AD, (left) the separation of the primary star relative to the secondary over time, (right) the position angle of the secondary star in relation to the primary over time. The new position is shown with a pink dot.

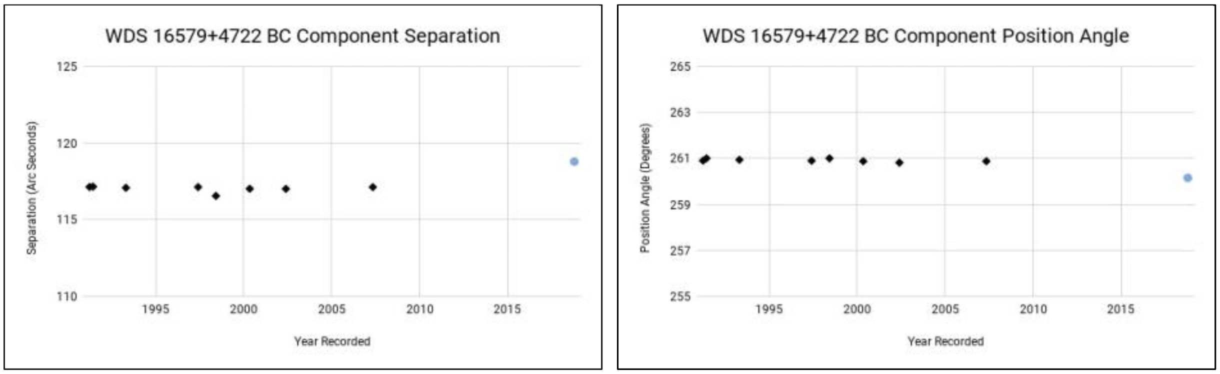

Figure 8: Historical data collected from the Washington Double Star Catalog of WDS 16579+4722 BC, (left) the separation of the primary star relative to the secondary over time, (right) the position angle of the secondary star in relation to the primary over time. The new position is shown with a blue dot.

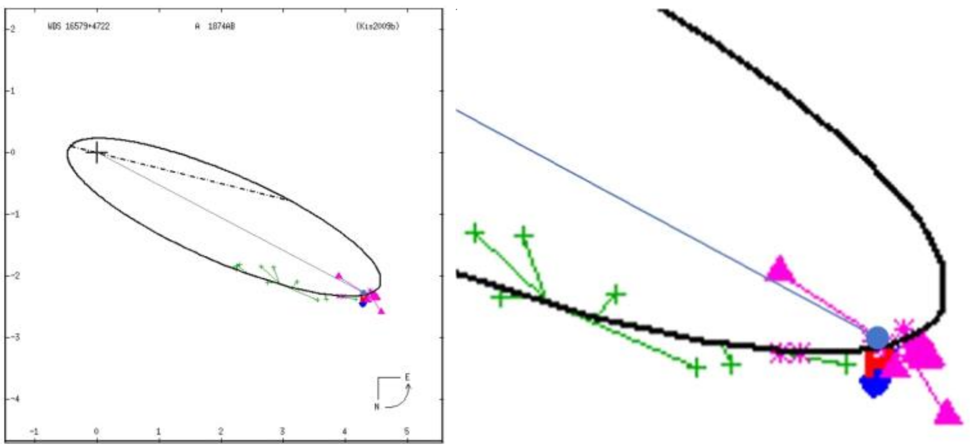

Figure 9: (left) Orbital path of the double star WDS 16579+4722 with the newly measured position of the secondary B star, marked with a light blue dot. (right) Orbital path image enlarged.

the equipment available, further observations and measurements are required to fully understand the orbital characteristics of this pair.

Conclusion

By analyzing and comparing images from October 13 and November 2, 2018, of the multiple star system, WDS 16579+4722 in Hercules, the data was able to offer supplemental evidence that supports historical records for this system. There is a substantial amount of documentation exploring the hierarchical relationships within this system. By investigating systems with these motions, it presents opportunities to explore various aspects of stellar evolution as well as help scientists further their understandings of gravitational perturbations within the complex motions of multiple two-body systems.

To support the importance of STEAM education and research through communities of practice, the findings from this paper as well as additional papers titled, "Astrometric Measurements of Physical Double WDS 03121-2859 in the Constellation Fornax" and "Astrometric Measurements of WDS 13169+1701 Binary Star System in Coma Berenices" were presented at the American Physical Society: Conference for Undergraduate Women in Physics, January 2019 in Seattle Washington.

Acknowledgements

From InStAR, Paul Harderson facilitated administration. Brian Mason, of the U.S. Naval Observatory, provided past observational data. Information and data were gathered from Las Cumbres Observatory, GAIA Data Release 2, Washington Double Star Catalogue, and Stelle Doppie. Dr. Cheryl Genet collaborated on developing educational materials, articles, publications, and the Canvas website and design. From The Evergreen State College, George Freeman and Lee Lyttle, Academic Deans and office staff that encouraged this work. Undergraduate students from The Evergreen

State College, Zach Medici, and Francisco Velez, that attended team meetings and/or supported astronomical research.

References and Sources

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

Genet, R., Buchheim, R.., Johnson, J., Harshaw, R., & Freed, R. (2018). Small Telescope and Astronomi cal Research (STAR) Handbook(1st ed.). Tucson, AZ: Institute for Student Astronomical Research.

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

Las Cumbres Observatory | Many Eyes - One Vision 2018. https://lco.global/

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

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

Washington Double Star Catalog. (n.d.). http://ad.usno.navy.mil/wds/