Astrometric Measurements of WDS 13169+1701 Binary Star System in Coma Berenices

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Abstract: During the summer of 2018, as part of the Binary Star Research Seminar coordinated by the Institute for Student Astronomical Research (InStar), researchers took astrometric measurements of binary star system WDS 13169+1701.

Introduction

The binary system WDS 13169+1701 is located at a right ascension of 13 hrs 16 min 51.05 sec, and a declination of +17º 01' 01.9" at a distance of 36.63 light years from Earth, between the constellations Coma Berenices and Bootes (see Figure 1). This system's primary star has a magnitude of 6.66, while the secondary star has a magnitude of 9.5, with a delta magnitude (ΔM) of 2.82. The stellar classification of the primary star is K1V, with an average temperature of 3,700 - 5,200 Kelvin, and a chromaticity of pale yellow-orange. The secondary star's stellar classification is M1V, with an average temperature of 2,400 - 3,700 Kelvin, and a chromaticity of light orange-red. From a geocentric perspective, prior observations of the secondary star in this system show that it could either be traveling in a highly elongated orbital path around the primary, or it could be traveling in an observationally linear path adjacent to the primary star.

According to the Washington Double Star Catalog, the recorded observations for this system date back to 1782. Since then, there have been 214 recorded observations tracking the orbital path of the secondary star around the primary, the most recent of which was recorded in 2014. The first astrometric measurement of this system, from 1782, was made by William Herschel who wrote, "Double. About 1-3/4 degree from the 42d Comae towards Upsilon Bootis; the most south of a telescopic equilateral triangle. Excessively unequal. Larger primary star, pale color; smaller secondary star, dusky color. A third star preceding, above 1" (Herschel, 1912). The original discoverer of this star system is noted in Herschel's work as having recorded the binary pair in 800 CE with the initials BU; however, no additional evidence was recovered to reveal the full name of the discoverer or the measurements taken.

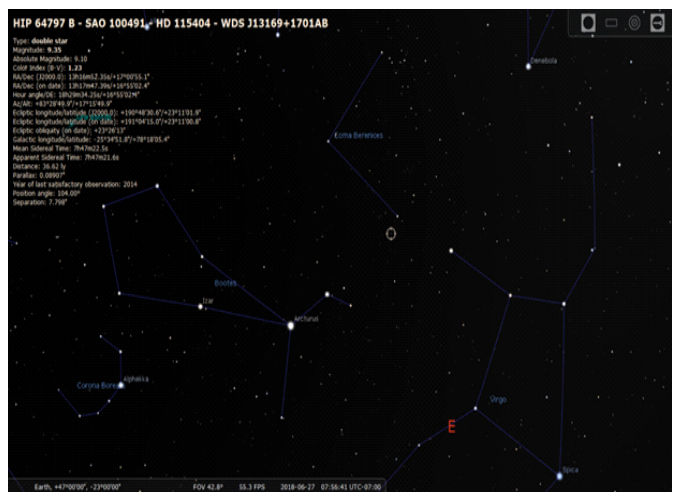

Figure 1. Night sky simulation showing the location of WDS 13169+1701 generated using Stellarium version 0.18.1.

Equipment and Procedures:

The research team compared past observational data of the stars trajectory paths from the WDS, a database maintained by the United States Naval Observatory, and current images that were requested from the Las Cumbres Observatory (LCO) portal and their global network of telescopes and observational equipment. Using LCO's network, images were taken from Haleakalā Observatory, situated 10,000 ft. above sea level on Mt. Haleakalā, a shield volcano in Hawaii. Images were

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Figure 2. Main telescope structure with a 2-meter and 0.4-meter telescope, Las Cumbres Observatory, Haleakalā Hawaii.

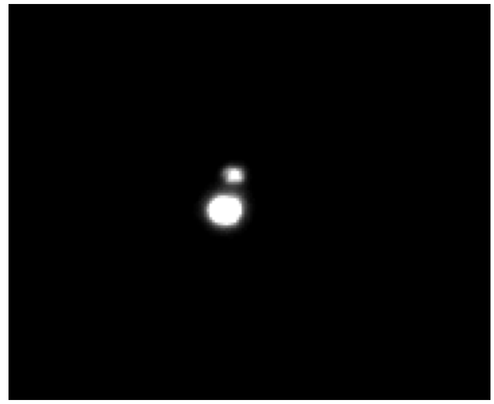

Figure 3. One-second image of WDS 13169+1701 taken from a 0.4 meter telescope at Haleakala, Hawaii and used to measure the position angle and separation.

acquired on June 26, 2018 using CCD imaging with an SBIG STL-6303 camera, with 1-sec., 5-sec., and 10-sec. exposure times using a clear, neutral filter, from the 0.4-meter Faulkes Telescope North (Figure 2).

The 5-sec and 10-sec exposure images that were requested on June 26, 2018 were discarded as they were overexposed and accurate centroiding could not be done. Using the histogram tool available in AstroImageJ to examine the overlap between the primary and secondary star, it was found that the data from the set of images with the 1-sec exposures were inconsistent and many of the images were flipped around the X axis.

A second set of ten images was requested from LCO using their 0.4-meter telescope, and they were received on August 2, 2018 with a 0.5-sec exposure time. Eight of those images had enough stars to be plate solved, and none showed the previous issue of flipping about their axis. Researchers used AstroImageJ to measure the position angle and separation between the primary and secondary stars in the system. The two smaller stars in this quadruple system were not visible in any of the requested images and were not necessary for data collection or analysis. See Figure 3.

The LCO FITS files were uploaded to astrometry.net to be plate solved; this software determines the right ascension and declination of each star. The plate solved images were then analyzed in AstroImageJ, where the brightness and contrast were adjusted to allow researchers to more accurately place the apertures on the two stars. The cursor was then dragged, using the central mouse wheel, from the primary star to the secondary star, giving the position angle, separation, and difference in magnitude of the two stars (See Figure 5).

The team used AstroImageJ to take five readings for each of the eight usable images with the 0.5-sec exposure time. All data was manually exported into a Google Sheets spreadsheet for further analysis. Researchers initially intended to calculate the averages of these five readings for each image given the variety of readings obtained from the first data set, but found that for individual image data sets, the position angle and separation measurements were identical between readings out to six significant figures. Some of this raw data can be seen in Figure 4, in both AstroImageJ and Google Sheets interfaces. The total average value, standard deviation, and standard error of the mean were calculated and are shown in Table 1.

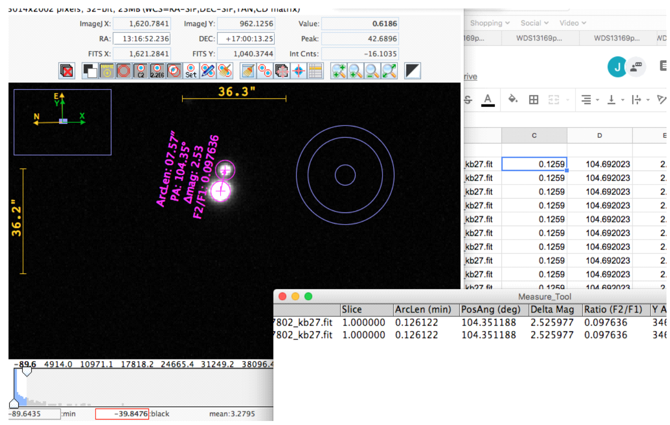

Figure 4. Screenshot of AstroImageJ interface

Results

Table 1 shows the new data, depicting the separation between the primary and secondary stars and the position angle of the secondary star in relation to the primary. Figures 5 and 6 depict past data collected and stored in the WDS, showing the change in separation

Table 1: Summary of final data with standard mean, standard deviation and the standard error of the mean.

Fits images	Separation (Arc Seconds)	Position Angle (Degrees)
1	7.55	104.69
2	7.57	104.35
3	7.55	104.08
4	7.54	104.31
5	7.64	104.28
6	7.57	104.28
7	7.60	103.31
8	7.67	103.79
Mean	**7.59**	**104.14**
Standard Deviation	**0.045**	**0.419**
Standard Error of Mean	**0.016**	**0.148**

and position angle over time, with the new data point added. The new measurements were added to the orbital diagram (Figure 7) as described by Buchheim (2017).

Discussion

Throughout the research process, the team ran into a plethora of problems regarding data collection and software use. Researchers utilized AstroImageJ, an open-source software, for analysis of plate solved images, but ran into an issue with the software flipping images about their axes. There were additional issues with the software running on the personal computers of the researchers due to the requirement of a legacy Java and incompatibility with some operating systems. The original batch of images received from LCO were over exposed and difficult to plate solve. These obstacles caused delays in the collection of usable data. The research team came together and worked to improve communication and overcome these issues before the deadline by requesting a second batch of data, troubleshooting the software, and calling additional team meetings.

As shown in Table 1, only eight photographs of the ten taken from the second batch of images were able to be plate solved using nova.astrometry.net and used to take astrometrical measurements via AstroImageJ. This smaller sample size did not negatively affect results and the team did not expect it to, as the originally requested ten images was more than adequate to ensure usable and consistent data. Table 1 shows that the separation angle between the primary and secondary star was determined to be 7.59 arc seconds and the position angle to be 104.14 degrees. These readings coincide with the position angle and separation values projected by Stelle Doppie with a separation of 7.775 in arc seconds and a position angle of 104.8 (Stelle Doppie, 2016). The low value of the standard deviation calculated reflects readings that are consistent and without statistical outliers. The goal of the research team was to achieve a standard deviation within one percent of our average values. The standard deviation of the separation readings is 0.045, 0.5% of the final point, and the standard deviation of the position angle is 0.419, 0.4% of the final point. Having a small error of the mean shows the same data was taken multiple times and that the standard deviation for each separate data collection was consistently small.

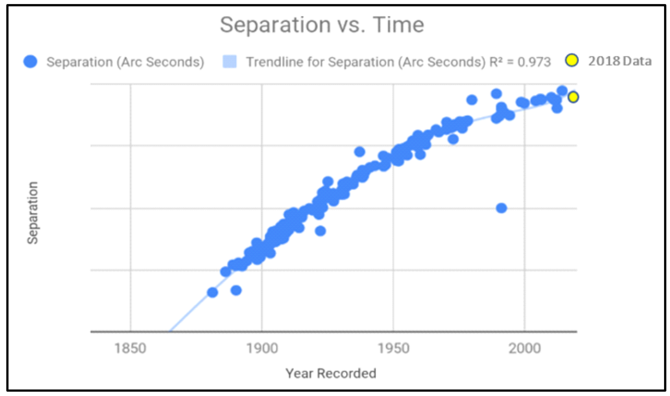

Figure 5. Historical data from the Washington Double Star Catalog of binary system 13169+1701, showing the separation of the primary relative to the secondary over time, new position shown with yellow dot.

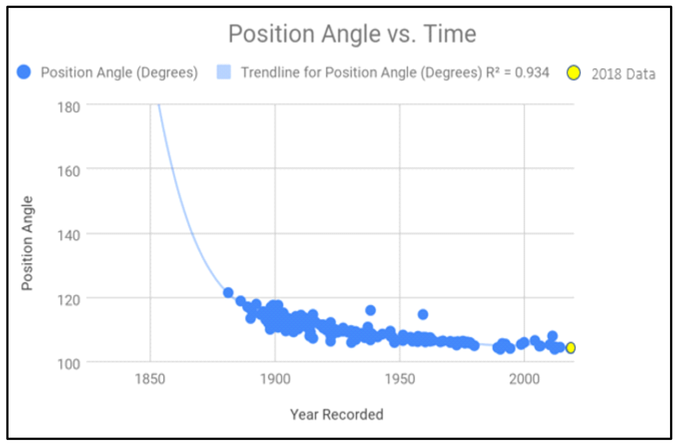

Figure 6. Historical data from the Washington Double Star Catalog of binary system 13169+1701, showing the position angle of the secondary star in relation to the primary over time. The new position is shown with a yellow dot.

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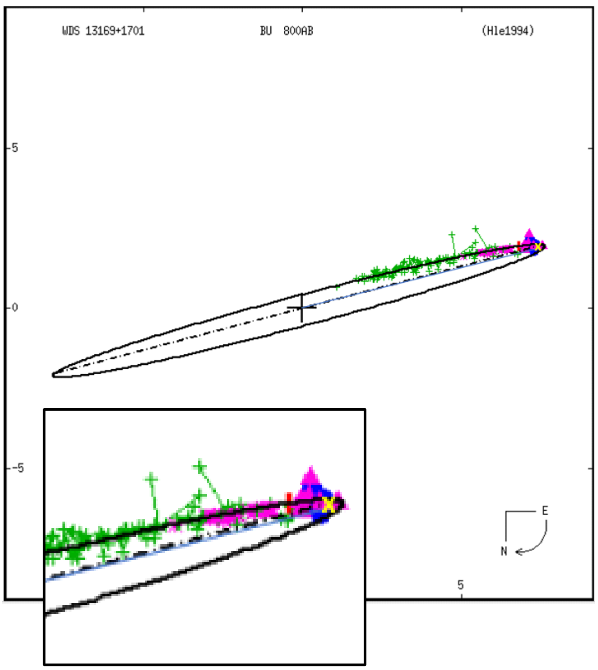

Figure 7. Orbital path of the double star WDS 13169+1701 with the newly measured position marked with a yellow "X". Inset shows the image enlarged for clarity.

Figure 8. Eric Holcomb at University of Oregon's Pine Mountain Observatory in the Deschutes National Forest, August 6, 2018 observing 13169+1701 on the observatory's 24" Cassegrain reflector telescope. Photo by team member, Shannon Pangalos-Scott.

Figure 9. Binary system 13169+1701, taken with a 12-megapixel mobile phone camera mounted to the lens of a 24" Cassegrain reflector telescope at Pine Mountain Observatory on August 6, 2018. Photo by team member, Micaiah Dougherty.

As part of the Summer 2018 Astronomy and Cosmology program at The Evergreen State College, research team members visited the University of Oregon's Pine Mountain Observatory on August 6, 2018. Additional field observations were made at the site, using a 24-inch Cassegrain reflector telescope, although these observations were not use in the data analysis because the image quality was not optimal. (Figures 8 and 9)

Conclusion

By analyzing the new measurements from August 2, 2018, researchers were able to determine that this data is indicative of a true binary system, where the smaller secondary star is gravitationally bound to the larger primary star traveling along an estimated 770-year orbital period. The 2018 observations are values that would be expected from the current literature on this binary system, and are comparable to the position angle and separation values projected based on past orbital data and the hypothesis that the two primary stars of WDS 13169+1701 are gravitationally bound.

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