Astrometric Measurements and Analysis of WDS 00425+1044 HJ 5

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Abstract: Astrometric measurements of the double star system WDS 00425+1044 were conducted to provide further insight on the classification of the system as either optical or physical. Although data proves to be continuous and consistent from historical trends, consideration of the distance between the primary and secondary, as well as differences in proper motion suggest that the system is optical. The results of this measurement were theta 295.72° and rho 23.9".

Introduction

This research project was part of an Astronomy Research Seminar offered by San Diego Mesa College and supported by Boyce Research Initiatives and Education Foundation (BRIEF). BRIEF enables students to learn the tenets of scientific research as well as the fundamental aspects of binary star systems.

A double star system is one in which two or more stars appear to be companions due to a chance alignment from the perspective of an observer on Earth. Physical double star systems, commonly known as binary stars, are gravitationally bound. Binary systems have scientific value in that, by determining the mutual gravitational orbit of the stars in the system, one can apply one of the few ways to derive stellar masses. Mass, being the most important stellar property, determines the life and death of the star. By performing these astrometric measurements and classifying systems as binary, we can further our collective knowledge of stellar science.

With the use of the Stelle Doppie website and the Washington Double Star Catalog (WDS), candidate star systems were found based on the following criteria: (a) visible between 00 and 08 hours of right ascension for optimal observing during Fall, (b) an angular separation greater than five arc seconds, (c) maximum magnitude difference of three, with the primary star being between seven and 12, and the secondary between seven and 13. In addition to specific astrometric criteria, a star system with multiple observations was chosen in order to obtain an adequate amount of previous data to reference.

WDS 00425+1044 HJ 5 fulfilled these criteria. See Figure 1. Observations of HJ 5 were first recorded by John Herschel in 1825; initial reports indicated separation of 25" and position angle of 290°. Stelle Doppie labels HJ 5 as an uncertain double, with Richard Harshaw, a leader in the field of double star astronomy who maintains a database of nearly all observed double stars, labeling it as having a 0.6264 binary probability, or a 62% chance of being physically bound.

Materials and Methods

Research on HJ 5 began with a data request from the Washing Double Star catalog. Historical data was gathered from a data request on WDS 00425+1044 HJ 5 from the Washington Double Star Catalog. HJ 5 was initially viewed through AladinLite and Aladin 10 before requesting our own images for measurements.

CCD images were taken using a 0.4-meter SBIG STL-6303 camera using a telescope of the Las Cumbres Observatory Network. The 0.4-meter telescope yields a resolution of 2048 x 3072 pixels, each 0.57" square, for a total field of view (FoV) of 19 x 29 arcminutes and a default of 1 x 1 binning mode. After various test images, 2 filter types were determined to yield the best images. The filters used for HJ 5 were rp (red) with 7 second increments of exposure for 15 images, and gp (green) filter with 6 second increments of exposure for 15 images. Thirty images were collected on 2018.835.

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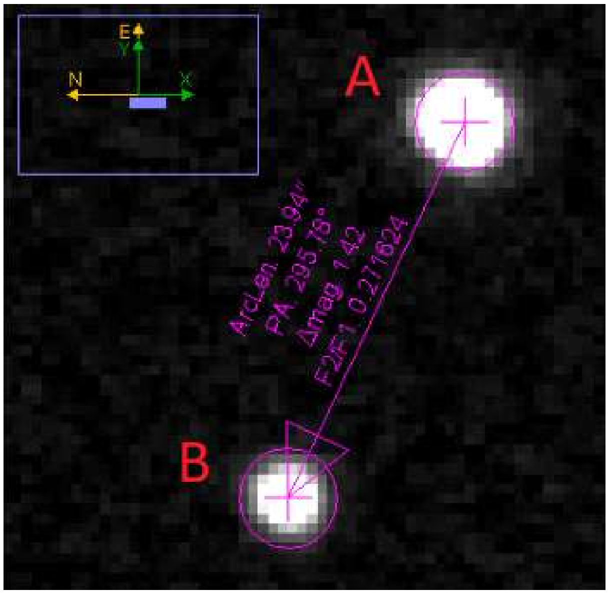

Figure 1. Image taken with a 0.4m SBIG STL-6303 telescope with gp filter; measured using AstroImageJ.

Table 1 displays the theta and rho of each recorded observation, from the initial discovery in 1825 to the measurement in this paper. Present data was averaged after performing repeated measurements on our science images using the AstroImageJ image processing software. The software located the centroids of the A and B stars to accurately measure Theta (position angle) and Rho (angular separation) between the stars. Measurements were recorded in a Microsoft Excel spreadsheet allowing statistical analysis of the data to determine the mean, standard deviation, and standard error of the mean.

Results

A visual representation of the data listed in Table 1 is plotted in Figure 2 by converting theta and rho into x and y coordinates. The primary star is located at the origin. Table 2 lists the parallax measurements (PX) and distances in parsecs (PC) to the primary and secondary stars from our position on Earth.

Table 2. Comparison of the parallax (px) and distance in parsecs (pc) of Star A and Star B. Information gathered from Richard Harshaw's extensive collection of WDS and Gaia data on double stars.

	PX	PC
Star A	2.10 ± 0.0417	466.92 - 485.84
Star B	1.71 ± 0.0478	568.89- 601.61

Epoch	θ	ρ
1825	290°	25"
1898.65	292.3°	25.5"
1912.98	291.4°	25.118"
1920.99	292.2°	25.387"
1921.59	291.8°	25.1"
1990.784	294°	24.4"
2000.68	295°	24.205"
2010.5	295.4°	24.07"
2015	295.607°	24.008"
2018.835	*295.72°*	*23.94"*

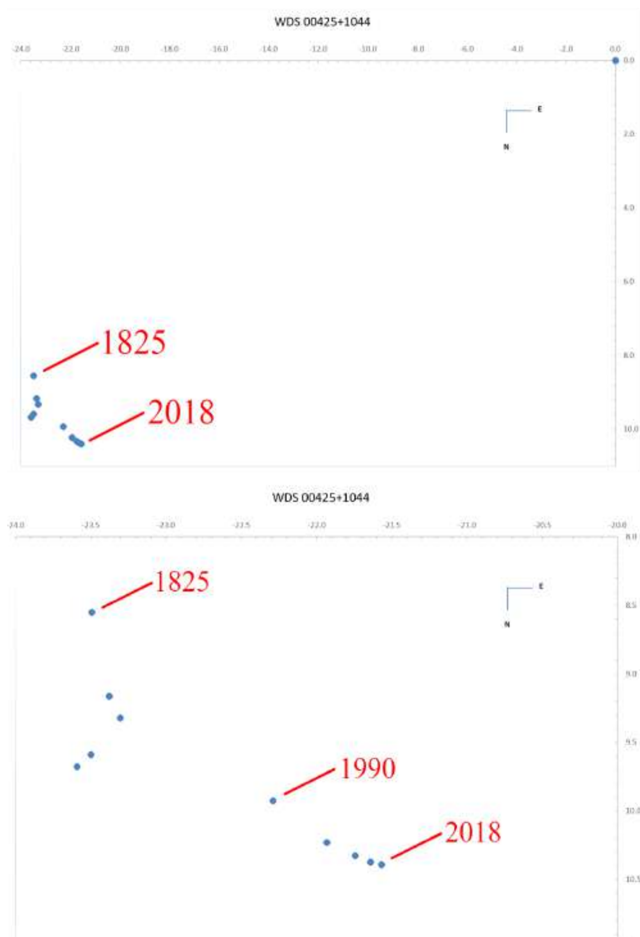

Figure 2. Plot of current and historical data ranging from 1825 to 2018. Historical data gathered from the Washington Double Star Catalog.

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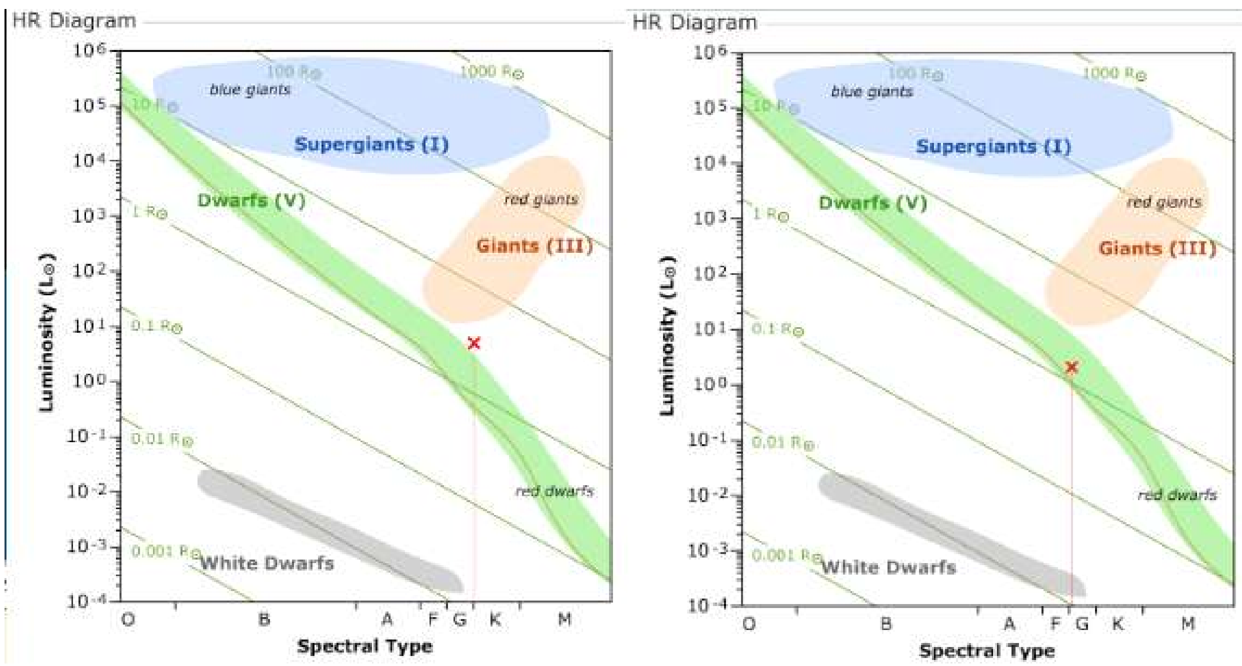

Figure 3. Placement of the primary (left) and secondary (right) stars on the Hertzsprung-Russell diagram based on information about their temperature and luminosity.

Discussion

Over the span of 193 years, with a total of 10 observations, position angle (theta) has changed by +5.723° degrees and angular separation (rho) has decreased by 1.057" arcseconds. Data trends prove to be consistent, with the exception of observations between 1912 and 1921, where theta briefly decreased, and rho increased. These slight deviations are not significant and are most probably caused by small measurement errors given the methods used during that time.

In addition to the previously mentioned data, we were able to narrow down the spectral classes for both the primary and secondary stars using information on the star's temperatures and luminosity from Gaia data. Figure 3 depicts the predicted spectral class of both the primary and secondary star based on Gaia data using reported temperature and luminosity. The primary star has of luminosity of 4.97 L_{sun} and a temperature of 5,070 Kelvin (K). The secondary star has a luminosity of 2.08 L_{sun} and a temperature 5,856 K. The Hertzsprung-Russell Diagram Explorer by the University of Nebraska-Lincoln was used to place the stars accordingly. The primary of HJ 5 (G9-K0) is most likely a star entering the Red Giant stage of its life, whereas the secondary star (G1-G2) remains on the main sequence. The spectral classes determined are inferences derived from Gaia's extrapolation of data, and are inferences, rather than precise measurements of photometry. Our reasons for wanting to find the spectral class of this star system was to get a better understanding the sizes and potential masses, as well as to further contribute to the historical data of HJ 5.

The nearest wide binary to Earth is Alpha Centauri, which, like the secondary star of HJ 5, is very similar to the Sun. Alpha Centauri is a close binary with a small distant companion, Proxima Centauri about a quarter of a light-year away, or 0.077 parsecs (Wide Binary Stars, 2018). In comparison to Alpha Centauri, it is more than highly unlikely for HJ 5 to be classified as physically bound, due to the vast distance between the stars. Given that the maximum distance of Star A is 485.84 parsecs and the minimum distance for star B is 568.89 parsecs it is clear that the max distance for star A is far less than the minimum distance for star B. Therefore the probability of the two stars being physically bound is unlikely. Parallax of star A is 2.10 ± 0.0417", whereas parallax of star B is 1.71 ± 0.0478".

One other consideration for HJ 5 is as a common proper motion pair, or, a visual binary in which the stars have a similar proper motion. Star A has a proper motion of [-21 -20]. Star B has a proper motion of [-1 -9], as illustrated in Figure 4. Using the methods provided in Harshaw's paper on tools for evaluating binary stars, we found the difference between the proper mo-

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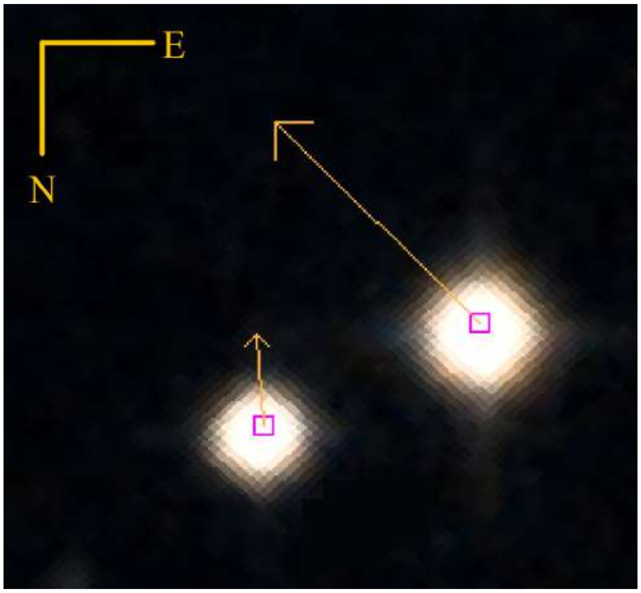

Figure 4: GAIA DR2 proper motion data on HJ 5 taken from ALADIN

tion vectors to be about [-21 -20] + [+1 +9] = [-20, -11]. This method produces a statistic by dividing the vector difference by the vector sum, resulting in 0.599. This final result (0.6) is called the "rating" and its value will range from 0.00 for orbital pairs up to 0.99 for optical ones (Harshaw, 2014). Using GAIA's proper motion data in Harshaw's method shows that this system does not satisfy the criteria for a common proper motion pair.

Conclusion

Initial records of WDS 00425+1044 HJ 5 piqued our interest for further research into determining if the double star candidate was optical or physical. The level of uncertainty surrounding HJ 5 is what made this system a worthy contender.

Astrometric data shows the separation between the component stars is decreasing by 1.057" over the span of about 200 years. The vast physical distance between the stars of HJ 5 should be conclusive evidence as to why this system is most probably not gravitationally bound. In addition, GAIA data disproves the idea of a common proper motion pair.

Due to these two factors of physical distance and proper motion, the data suggests that HJ 5 is simply an optical double. Further observations are required in order to determine if an orbital pattern exists.

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