Astrometric Measurement of WDS 01335-0331

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Abstract: The double star WDS 01335-0331 was measured using a 0.4 meter telescope. A set of 10 10 second exposures was taken on Feb 21, 2020 and we calculated an average separation of 5.28 arcseconds and an average positional angle of 111.8 degrees.

Introduction

Research was conducted on the double star WDS 01335- 0331 in the constellation of Cetus. The star was chosen from the Washington Double Star Catalogue of neglected double stars. The system was observed to determine if an orbital path exists as well as the spectral types. This binary was initially observed in 1827 by John Herschel (discovery number HJ 640) and last observed in 2017. In 193 years, there have been 30 recorded observations of this system.

Assuming that the stars are main sequence, the masses of the stars can be calculated using the mass-luminosity relationship. If the luminosity and effective temperature are known or calculated, then the spectral type can be estimated by looking at a Hertzsprung–Russell diagram.

Methods and Materials

The reason WDS 01335-0331 was picked was because its properties matched our seven parameters suited to making astrometric measurements with a small telescope. The parameters included magnitudes between 7 and 11, a separation between 5 and 8 arcseconds, and delta magnitude of less than 1 to ensure that the double star could be resolved into two stars. Furthermore, a right ascension (RA) between 1 and 13 was chosen to ensure the star could be seen during the observing time frame. A parallax of 5 milliarcseconds (mas) or higher was also chosen because parallax measurements below this number were not reliable [1]. Only doubles that had 50 observations or less, and double star systems with observations that were spread throughout time were considered. The search was further refined by looking for a system with an unknown spectral type and the nature of the double was unknown. These additional parameters were chosen due to our hope of estimating the spectral type and determine if it is an optical double or a physical binary.

To find the star, the Gaia Double Star Catalog Selection Tool (GDS Catalog Selection Tool) created by Dave Rowe, was downloaded and used [2]. The entirety of the Washington Double Star and Gaia catalog is included in the program.

Once downloaded, the first four parameters were put into the GDS Star Catalog, resulting in 186 double stars. After excluding stars without the required parallax and those with catalogued spectral types, four choices remained. Of the four, WDS 01335-0331 was selected based on the quantity and timing of the previous observations. Using the WDS name, the website Stelle Doppie [3] was used to find that the formal classification of the system was unknown.

Telescopes of the Las Cumbres Observatory (LCO) were used for our measurements [4]. Ten images were taken for exposure times of 2, 3, and 4 seconds. This was done through a SBIG STL-6303 camera with a clear filter on the Haleakala 0.4 meter telescope in Hawaii [5]. Unfortunately, it was realized that the images that were received needed longer exposure times. Exposure times of 10 seconds for 10 pictures (see Figure 1) were used on the second attempt.

Once the images were received and converted into a format the program AstroImageJ (AIJ) [6] could use, measurements were taken and put into a spreadsheet. The measurements important to our research are seen in Table I. Historical data was used in conjunction with Harshaw's Plotting Tool to produce Figure 2.

Received September 14, 2020

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Figure 1: The double star WDS 01335-0331 HJ 640 taken with an exposure time of 10 seconds. This image was taken on the Haleakala Observatory in Hawaii on the island of Maui on February 21, 2020.

Results

The data we collected from our observations (see Table I) gave us an average separation (SEP) of 5.27" and an average position angle (PA) of 111.8°. The average of our observational data (see Table I) was used to calculate an additional data point represented by the triangle on Figure 2. The other data-points were provided courtesy of Dr. Brian Mason at the United States Naval Observatory (USNO).

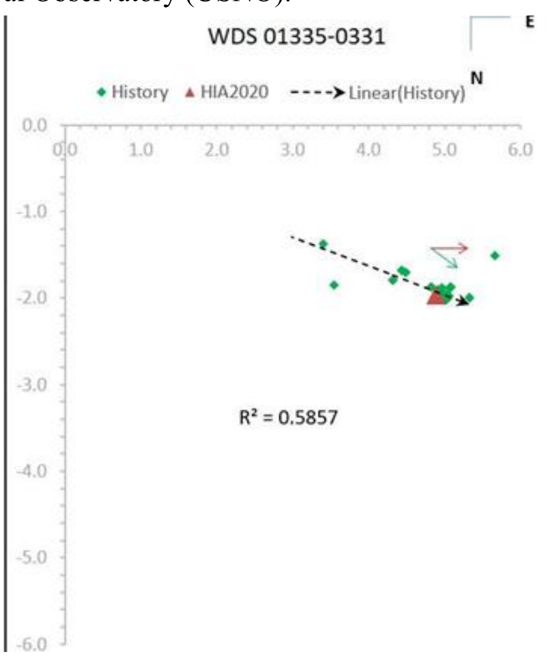

Figure 2: Cartesian plot of the double stars positions with added observation represented by the triangular point. The horizontal vector represents how much the stars should have moved over the time that they have been observed. The angled vector represents how much the stars have moved. The magnitudes have been multiplied by 2 for ease of viewing.

Data Points	SEP(arcsec)	PA(Deg)
1	5.31″	111.9°
2	5.27″	111.7°
3	5.23″	112.0°
4	5.28″	111.4°
5	5.25″	112.7°
6	5.28″	111.5°
7	5.27″	111.3°
8	5.26″	112.1°
9	5.24″	111.5°
Average	5.27″	111.8°
Standard Deviation	±0.02	±0.4
Mean Error	±0.007	±0.1

Table 1: Astrometric measurements.

Discussion

Our data supports previous measurements of the separation being around 5.32". Our average PA of 111.8° with an error range of 111.4° to 112.2° also supports previous observations of the position angle being around 112.01° [3].

When comparing the two parallaxes from Table 2, the primary has 10.37 milliarcseconds (mas) with an error of 10.33 mas to 10.41 mas while the secondary has 10.44 mas with an error of 10.34 mas to 10.54 mas. When taken into account, the two parallaxes overlap. Furthermore, using Harshaw's Plotting Tool [7] in conjunction with WDS Gaia Data Release 2 Version 3B [8], it is found that the two stars have a possible weighted separation of 511 AU. This separation could mean that the system is gravitationally bound, but the exact alignment of the two stars to the Earth's line of sight is unknown. The actual separation could be different and therefore the system could be two separate stars. The orbital velocities would also need to be known but the necessary data for calculating this is yet to be documented by a future mission [9].

Referring to Table II, the RA Proper Motion (PM) of the primary was 39.7 mas/year(yr) with an error of 39.6 mas/yr to 39.8 mas/yr. The secondary star has a RA PM of 39.6 mas/yr with an error of 39.4 mas/yr to 39.7 mas/yr. The ranges of the PM overlap, meaning that the stars could be moving together. According to Harshaw, "Two stars that are in orbit around one another should have identical, or very nearly identical, proper motions. Large differences in proper motion would suggest the stars are not gravitationally related" [10]. Therefore, because the PM overlap, it is once again likely that system is gravitationally bound. Additionally, the two vectors in Figure 2 are almost the exact same magnitude but have a difference in direction of 37 degrees. According to Harshaw's Instructions in his

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plotting tool [7], there is likely no problem with Gaia's PM data for this pair, which means the data can be trusted for PM.

The Declination (DEC) PM of the primary is -79.9 mas/yr with an error of -79.6 mas/yr to -79.7 mas/yr for the primary star. The secondary star has a DEC PM of -78.9 mas/yr with an error of -79.0 mas/yr to -78.8 mas/yr. The DEC PM do not overlap but they are close.

Based on both stars luminosity's, they appear to be main sequence stars. Using the masses and separation, the approximate orbital period can be calculated using the Distance PA Calculator [8] (approximate because it is unknown if the star is at its periastron or apastron position within its assumed orbit). The orbital period is greater than or equal to 8,900 years for the reasons discussed in the previous sentence (see Table II).

The stars were plotted on the Hertzsprung-Russel Diagram (HR Diagram) using the solar luminosity and effective temperature. Upon viewing the plot (see Figure 4), one can see that both stars fall within the spectral classification of K0V, which means both are orange dwarf main sequence stars.

The data presented by Figure 2 further indicate that the orbital period is extensive as there is no drastic change in the position of the stars, excluding outliers, with subsequent observations. It is assumed that a trend would be visible if the data was gathered over a significantly longer time period (a couple of centuries), for more accurate data analysis as well as providing time for the stars to change orientation to a more significant degree. Based on the approximate orbital period of 8,900 years, more data is needed to clearly establish WDS 01335-0331 as a physical binary.

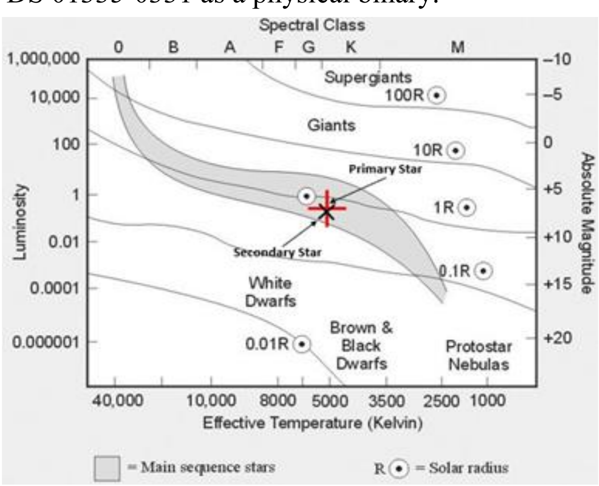

Figure 3:. Using the HR Diagram [11] to approximate the spectral type of both stars. The addition symbol (+) is the primary star while the small multiplication symbol (x), is the secondary star. The stars are similar in temperature and luminosity

Pulling the above information together, the star system WDS 01335-0331 is likely a physical binary. The parallax's overlap, the separation between the stars is likely small enough for them to be gravitationally bound (orbital velocities still need to be calculated) and their PM's are nearly identical. Additionally, in the WDS Gaia Data Release 2 Version 2 is a probability function done by Richard Harshaw to give the probability that a double star is a physical binary. It relies on four weight factors of parallax, PM, R2, and radial velocity with parallax being assigned the highest relative weight [10]. The double star WDS 01335-0331 probability of being a physical binary is 89 percent.

	Primary Star	**Secondary Star**
Parallax (arcsec)	0.01037″	0.01044″
Parallax Error (arcsec)	4.05×10^{-6}	1.022×10^{-4}
Proper Motion RA (arcsec/yr)	0.0397	0.0396
PM Error (arcsec/yr)	6.8×10^{-5}	1.59×10^{-5}
Proper Motion Dec (arcsec/yr)	-0.0797	-0.0789
PM Error (arcsec/yr)	5.7×10^{-5}	1.2×10^{-4}
Radial Velocity (km/s)	25.6	NA
RV Error (km/s)	0.52	NA
Temperature (K)	5280	5240
Luminosity (*LO*)	0.53	0.44
Calculated Values from Gaia Data		
Solar Mass (*MO*)	0.86	0.82
SEP (arcsec)	5.32	
PA (Deg)	112.01	
Orbital Period (yrs)	8900	

Table 2: Gaia data.

Conclusion

The double star WDS 01335-0331 was chosen from a set of parameters determined by the team in hopes to classify the type of double. Images were taken and retaken with the LCO 0.4 meter telescope in Hawaii. After analyzing the data from these images and calculating error, our team was able to match this data with the Gaia data. Certain tools were used to plot the cartesian positions of the double star, reliability of PM data, separation of stars, solar masses, approximate orbital period, SEP, PA, and probability of double star being a physical binary. The PM, the parallax, and the separation point to WDS 01335-0331 possibly being a physical binary and with a probability of 89 percent. Ultimately, it can not be concluded that the star system is a physical binary but it is probably one.

Acknowledgements

We thank Rachel Freed for her help in providing the links and information that was needed to complete this research. Thanks goes to Dr. Stephen McNeil for his guidance and instruction that led this team to the Double Star that was observed and studied. A special thanks to Dr. Brian Mason for providing historical data. We thank the Las Cumbres Observatory for allowing our team time on one of their 0.4 meter telescopes and for providing the images used.

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