Observations of Double Star WDS 09545-8025

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Abstract: CCD images were gathered from the South African Astronomical Observatory, part of the Las Cumbres Observatory (LCO) network, using a 0.4 meter telescope. The resulting images were then processed using AstroImageJ to determine the position angle and separation of the star. The data was analyzed and compared with existing Gaia and historical information. Results from historical data, Gaia data, and recent observations suggest that the system is a binary system. The data collected shows the two stars have an average seperation angle of 9.311 ± 0.007 arcseconds and position angle of 285.70 ± 0.17º strongly suggests that the Double Star WDS 09545-8025 is a gravitationally bound binary system, but could require a few thousand more years of data.

I. Introduction

The search for binary stars compares two stars in close proximity. Two types of double star classications are optical pair and gravitationally bound system. An optical pair is a set of stars that appear to be orbiting one another, but have do not orbit around a common center of mass (CM). A gravitationally bound system is a set of stars that orbit one another around a common CM. There are several means used to verify whether a system is an optical double or a physical binary. Two stars whose parallax and proper motion is similar suggests the stars to share a CM which moves relative to Earth. One can calculate the star system's mass, and predict the stars' individual masses, separation distance from one another, as well as the gravitational force the objects exert on one another. Making these predictions can help to consider the star system a optical pair or gravitationally bound system.

WDS 09545-8025 was first observed in 1836 by John Hershel [1] and most recently in 2015 making a total of 15 observations since it was first discovered. The objective of this research was to measure the position angle (θ) and separation (ρ) of WDS 09545-8025 and compare resulting measurements with previous data.

II. Methods and Materials

The selection of the star was made using Dave Rowe's Gaia Double Star Selection Tool (GDS) [2]. Criteria used for selecting this double star was that the magnitude of the primary star should be between 7 and 12 with delta magnitude less than 1, and separation to be limited between 5 and 10 arcseconds. These specific conditions fit the criteria to be imaged from a 0.4 meter telescope provided by the Las Cumbres Observatory (LCO) network [3]. Declination was restricted to be between -80 and -90 with the most recent observation being at least five years ago. Five possible systems resulted with only two being recorded as physical doubles. WDS 09545-8025 had more recorded observations compared to the other four, and so it was chosen.

An observation request was sent to LCO which used the South African Astronomical Observatory 0.4 meter telescope. The binary star system was imaged using a clear filter on a SBIG STX6303 camera [4]. Initially two sets of ten images were requested with differing exposure times of one second and two seconds. This was to help determine the Signal to Noise (S/N) ratio required to collect the highest quality images of the stars. Despite the two different exposure times, both sets of data did not provide an adequate S/N ratio. New sets of ten images with three and four second exposure times were requested, and both sets provided equally low quality images. Eventually, data was requested for ten second exposures and fifteen second exposures. The ten second exposures provided the best

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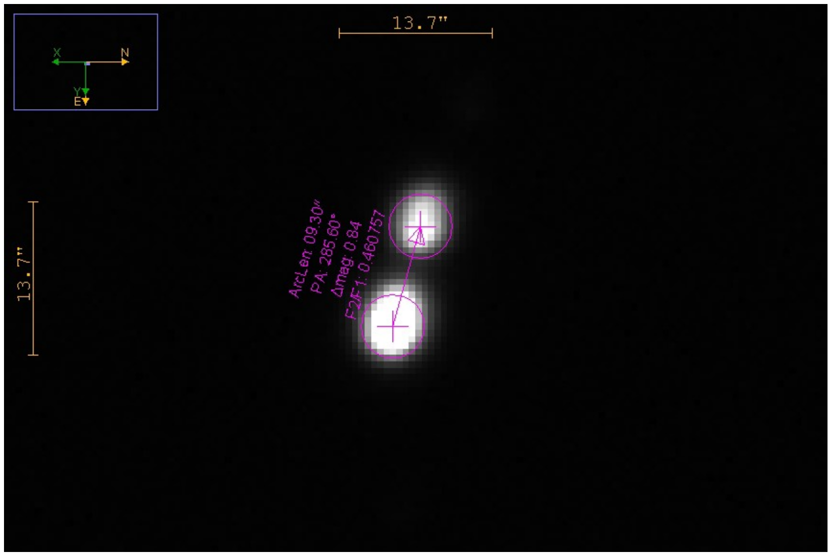

Figure 1. Image from AstroImageJ of WDS 09545-8025.
Top star: Secondary. Bottom star: Primary

S/N ratio, which were then oficially requested to the LCO telescope, resulting in seven quality images like the image provided in Figure 1.

AstroImageJ is an interactive software program that was used to determine the separation and position angle of the star. The application uses color images and pixel saturation to easily align the images of the stars. With the stars aligned, state of the art software calculates the separation and position angle instantaneously [5].The gathered data was entered into a spreadsheet and compared to historical data.

The WDS number for the double stars studied was plugged into VizieR in order to find the Gaia data. The data consisted of information such as parallax, proper motion, radial velocity, and temperature [6]. Gaia Data was compiled into Table 1 for quick reference.

Gaia Data		
Star	**Primary**	**Secondary**
Parallax (mas)	2.73 ± 0.02	2.75 ± 0.02
Proper Motion RA (mas/yr)	-17.43 ± 0.04	-17.58 ± 0.04
Proper Motion DEC (mas/yr)	15.74 ± 0.04	15.86 V 0.03
Radial Velocity (km/s)	1.72 ± 1.35	0.57 ± 1.5
Temperature (K)	6400	6500
Luminosity ($L_\odot$)	11.65	5.28

Table 1. Results from the second Gaia Data release.

III. Results

The seven observations from the LCO are arranged in Table 2, which were used to calculate the average separation distance and position angle. The average separation is 9.311 arcseconds with a standard deviation of 0.007, and the average position angle is 285.70 with a standard deviation of 0.17. These results are similar to those found in the historical data of the stars' previous observations.

Brian Mason, a US Naval Observatory Astronomer, shared the historical data on the WDS 09545-8025 stars. Microsoft Excel was used to separate the data out

10 Second Exposures		
Image	**Separation (as)**	**Position Angle (deg)**
1	9.313	285.65
2	9.312	285.92
3	9.300	285.91
4	9.308	285.72
5	9.323	285.44
6	9.323	285.73
7	9.307	285.58
Average	9.311	285.70
Std. Dev.	0.007	0.17
Std. Dev. of Mean	0.003	0.064

Table 2. Data collected from LCO and measured with AstroImageJ.

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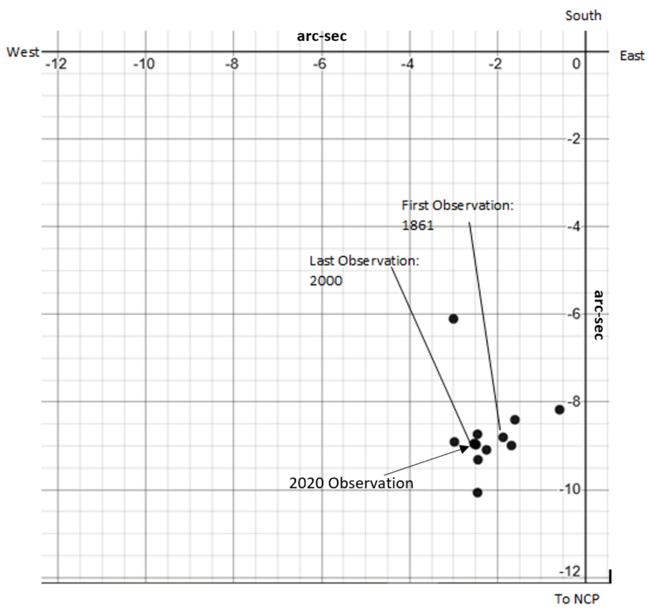

Figure 2. 1836-2000 Historical Data; includes 2020 observation

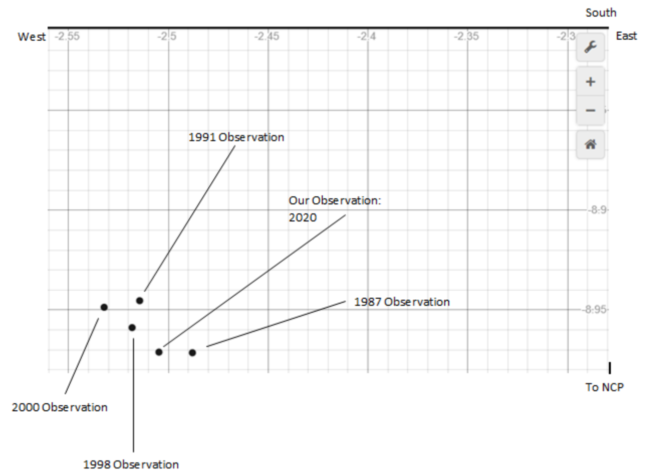

Figure 3. Five most recent observations.

into lists of observation times, position angle, and separation. Using basic trigonometry, the separation and position angle were used to create Figure 2 and Figure 3. The first and final average observations were added to the historical data and marked in the figures to show the most recent observation compared to past observations.

IV. Discussion

After comparing results of the observations with historical data and Gaia data, the likelihood of the pair being gravitationally bound becomes apparent. All historical data on the star shows that the secondary star 3 has stayed in relatively the same position to the primary star and Gaia data shows that both share very similar parallax and proper motion as seen in Table 2.

As discussed earlier, an optical double consists of two stars that appear close to one another, but are not gravitationally bound, whereas a physical binary is made of two stars that orbit a common center of mass. One way to determine if the system truly is a gravitationally bound binary is to look at the parallax and proper motion. Referring back to Table 1, the parallax of the primary star is 2.73 mas and the secondary star is 2.75 mas. The closeness in parallax values suggests the stars are gravitationally bound. The similar proper motion between the Primary and Secondary star reiterates the same ideal, the difference between proper motion being only 0.13 mas. However, parallax values under 5 mas are to be taken with some skepticism as the star system is well into the range where the Gaia instruments will have some error, especially with such small values.

Both stars studied in the Gaia data were classified in the dataset to be Main Sequence stars. Copying the model of an HR diagram, the two stars were positioned along the diagram with respect to their temperatures and luminosity in Figure 4 [7]. Main Sequence stars follow a trend, though with some amount of uncertainty due to each star's unique nature. Main Sequence stars that have a solLum between ($M > 0.7M_\odot$) fit the mass-luminosity relationship as follows:

$$\frac{L}{L_\odot} = 1.02\left(\frac{M}{M_\odot}\right)^{3.92} \qquad [8]$$

This equation helped calculate the approximate mass of the Primary star to be $1.85M_\odot$ and the Secondary star to be roughly $1.52M_\odot$. The spectral type for these stars would be massive F-type stars, falling in the temperature range with slightly more mass than the average Main Sequence F-type range.

AstroImageJ approximates the separation between the two starts is about 920 AU using the right ascension and declination of the two stars' position and their distance from Earth. Kepler's 3rd Law helped to calculate a minimum orbital period of the binary system was calculated to be at least 15000 years. Using Newton's gravitational equation, the predicted mass of both stars, and the approximated separation, we calculate the gravitational force of these stars is roughly 3.96 x 10^{22} N. With the proper motion of the stars gathered from Gaia Data, it is highly likely that these stars are gravitationally bound.

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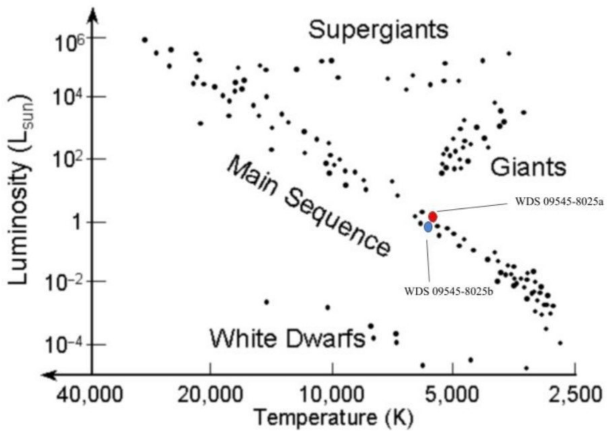

Figure 4. HR Diagram with studied stars relative placement marked. Red - Primary star. Blue - Secondary star.

V. Conclusion

Given the minimum orbital period of 15,000 years and the imperceptible motion of the Secondary Star it will take thousands of years worth of observations to prove this system to be a gravitationally bound binary. But, despite the immense time frame needed, the provided evidence strongly suggests that WDS 09545-8025 is gravitationally bound binary. The most recent observations show that the average separation of the stars is about 9.3 arcseconds with an average position angle of 285.70 degrees. The approximate mass of the Primary and Secondary stars were calculated to be 1.85 $M_{\odot}$ and 1.52 $M_{\odot}$. From this, the respective gravitational pull on both stars from each other is roughly 3.96 x 10^{22} N. This along with Gaia data showing both stars to have similar parallax and proper motion strongly suggests the possibility that the stars are gravitationally bound.

VI. Acknowledgements

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This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory.

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