Astrometric Observations on the Star System WDS 15213-5132

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Abstract: Historical astrometric data reports the star system WDS 15213-5132 as a physical double. Data was acquired for this system using a Las Cumbres Observatory (LCO) 0.4 m diameter remote telescope, and analyzed with AstroImageJ. The data was then compared to the historical data. A position angle of 307.5 degrees and a separation of 6.06 arcseconds were both measured. The data supports the historical classification as a physical double.

1) Introduction

The majority of stars observed from Earth in the local stellar neighborhood are binary star systems (Ryden, et al. 2011). Due to the massive amount of binary star systems, many binary systems go unobserved once discovered. The masses, lifespans, and overall nature of both stars in a binary system can be determined by measuring the orbital behavior of the binary star system. These properties are important to help determine the evolution of stars and the overall nature of star systems that are of similar size. Focusing on double star systems that are less observed can expand what is known about the nature of stars.

2) Methods

For this research, a number of factors were considered for choosing a binary system, so that it could be observed well enough to obtain data. The main parameters used in selecting this system were separation, number of observations, and time between observations. The importance and specifications of these parameters are as follows.

First, a separation greater than 7 milli-arcseconds is large enough to resolve the two stars using the LCO telescopes. Second, the number of observations of the system needed to be less than 20 in order to be considered less observed. Lastly, the time between observations being five years or greater avoids saturation of information. The WDS 15213-5132 star system became the top candidate for study, as it was discovered in 1892, and is recorded as a physical double. Only seventeen observations had been made previously, and only nine of those contained information concerning position angle and angular separation data, which are needed to calculate orbital movement. Lastly the period of time between observations ranged from five to ten years.

This system was found by first using the night sky simulator program, Stellarium(Wolf et al. 2020). An artificial observation point was placed in South America to view areas of the sky that were visible from the southern hemisphere during the months of January through March. After this, an area of sky having a right ascension ranging from 14.00.00 to 16.00.00 hours and declination between -60.00.00 and -40.00.00 degrees was used in the David Rowe Gaia Double Star (GDS) selection tool (Rowe, 2020). This program searches through the Gaia satellite database with the given parameters returning a selection of binary systems. Among the candidates, WDS 15213-5132 was selected following the aforementioned criteria.

The Gaia data was obtained from the VizieR online database(SADC, 2020) using information from Gaia Data Release 2. Once that data was obtained, values such as mass, spectral type, minimum orbital period, and more were then calculated. By looking at an HR diagram, as in Figure 3, spectral type can be determined as well as the mass. By the placement of the stars on the HR diagram, the mass of both stars can be approximated by the equation

$$M = L^{\frac{1}{4}} \qquad (1)$$

where M is the mass in solar masses and L is the luminosity in solar luminosities, as reported in the GAIA Data Release 2. The separation and position angle can be calculated from the equations

$$r = \sqrt{\left((\alpha_A - \alpha_B)\cdot\cos\left(\delta_B \cdot \frac{\pi}{180}\right)\right)^2 + (\delta_A - \delta_B)^2} \qquad (2)$$

and

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$$PA = \frac{\tan^{-1}((\alpha_B - \alpha_A)\cdot \frac{\pi}{180} \cdot \cos(\delta_B \frac{\pi}{180}))}{(\delta_B - \delta_A)\cdot \frac{\pi}{180}} \cdot \frac{180}{\pi} + 360 \quad (3)$$

where r is the separation in arcseconds, α is the right ascension in degrees, δ is the declination in degrees, and the A and B subscripts correspond to the primary and secondary stars, respectively.To find the gravitational force of attraction between the two stars, the equation

$$F_g = \frac{GM_A M_B M_\odot^2}{(1.496 \times 10^{11} \cdot r')^2} \quad (4)$$

was used, with G being the gravitational constant, the masses of the two stars in solar masses as calculated by Equation 1. $M_\odot$ is the mass of the Sun in kilograms, and r' is the separation in Astronomical Units.
Kepler's Third Law was used to find the minimum orbital period of the system,

$$P = \sqrt{\frac{(r')^3}{M_A + M_B}} \quad (5)$$

This equation gives the minimum orbital period in years. In both Equations 4 and 5, the separation r' is in Astronomical units, while Equation 2 yields the separation in arcseconds. Hence the separation was converted to Astronomical Units using

$$r' = \frac{r}{3600} \cdot \frac{\pi}{180} \cdot \frac{1000}{p_A} \cdot 206265 \quad (6)$$

with p_A being the parallax angle of the primary star in milli-arcseconds as reported from the GAIA data. Unlike the units conversion for the separation, several values used in Equations 2-4 were converted within the equations, as GAIA reported the values in improper units for such equations.

Next, a request for observation was made to the Las Cumbres Observatory (LCO) through the online portal, and as part of their Global Sky Partners Program (LCO,2020). The images were taken using a STL-6303 SBIG Charged Coupling Device (CCD) camera mounted on a Cassegrain 0.4 m telescope, using a clear filter. The data was taken on 17 February 2020 at 01:38:43.260 to 01:40:50.108 UTC at the South African Astronomical Observatory (-32.3806333 Latitude, 20.8098883 Longitude). A sample image is shown in Figure 1.

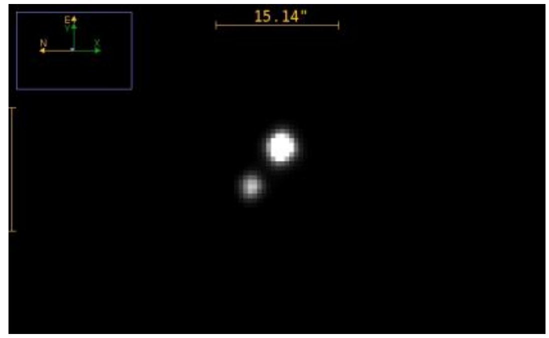

Figure 1. Image of the WDS 15213-5132 binary star system viewed from the LCO and enhanced using AstroImageJ. Ten five-second images were obtained with a fraction Besselian year of 2020.09.

The received images were analyzed using AstroImageJ (UL, 2020), which gave information on the position angle and separation of the star system. Ten images were taken with an exposure time of five seconds each. The minimum acceptable S/N used in calculations was about 100, and the S/N of the five-second exposures ranged from 316-374. Once the data was collected, a comparison was made to the historical data, giving a better idea of the orbital behavior of WDS 15213-5132.

3) Data

A. LCO Data

Exposure	PA(Deg)	Sep(arcsec)
1	307.3	6.05
2	307.2	6.06
3	307.7	6.06
4	307.1	6.04
5	307.3	6.06
6	307.2	6.05
7	307.5	6.08
8	307.3	6.07
9	307.4	6.06
10	307.5	6.05
Mean	307.4	6.06
Standard Deviation	0.2	0.02
Standard Error of Mean	.06	.006

Table I. Averaged data collected from the LCO images using ten exposures with an exposure time of five seconds each.

The standard error of the mean was calculated using the equation:

$$\sigma_m = \frac{\sigma}{\sqrt{n}} \quad (7)$$

σ_m is the standard error of the mean, n is the number of samples taken, and σ is the standard deviation of the measurements.

B. Gaia Data

Reported Values	Primary Star	Secondary Star
Parallax (mas)	8.59 ± 0.04	8.58 ± 0.05
RA (mas/yr)	-84.77 ± 0.09	-85.82 ± 0.09
Dec (mas/yr)	-29.70 ± 0.07	-29.41 ± 0.09
Temperature (K)	5987	5175
Luminosity ($L_\odot$)	1.4	0.36

Table II. Data reported from the Gaia Data Release 2 (2018) retrieved from the VizieR database. " $L_\odot$ " stands for "Solar Luminosities".

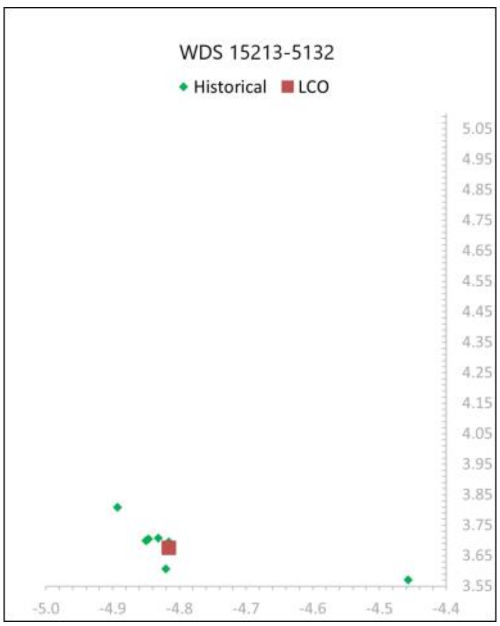

Figure 2. Historical data concerning WDS 15213-5132 displaying the proper motion of the system. The added "LCO" point is an average value based on the data collected from the LCO observation.

4) Analysis

Looking at Table III, WDS 15213-5132 appears to be composed of a F9 or G0 primary star, with a K0 secondary star. Figure 3 is a graphical representation of said finding imposed over an HR diagram. The calculated surface temperatures of the primary and secondary stars are about 5988 Kelvin, and 5175 Kelvin respectively. The luminosity of these stars is around 1.4 $L_\odot$ (Solar Luminosities) for the primary star, and about 0.3 $L_\odot$ for the secondary, as listed in Table II. It can also be determined that the reported values of luminosity and temperature place both stars as main sequence stars, with a calculated orbital period of about 13,900 years. (see equation 5)

Measurements	Value	Uncertainty
Mass Pry. ($M_\odot$)	1.1	
Mass Scdry. ($M_\odot$)	0.77	
Spectral Type Pry.	F9–G0 V	
Spectral Type Scdry.	K0 V	
Separation (arcsec)	6.10	0.04
Position Angle (deg)	307.34	0.04
Min. Orbital Pd. (yrs)	13900	100
Force of Gravity (N)	1.97×10^{22}	0.07×10^{22}

Table III. Calculated values based on Gaia data. " $M_\odot$ " stands for "Solar Masses".

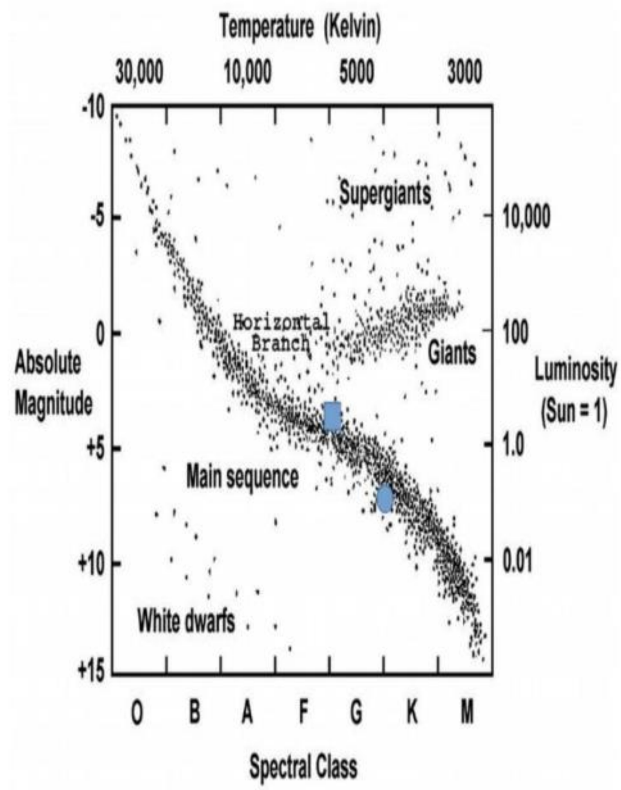

Figure 3. An HR diagram indicating the approximate calculated luminosity and temperature of WDS 15213-5132 (Harvard University, 2020). The added rectangle is the approximate placement of the primary star, and the added ellipse is the approximate placement of the secondary.

Notice in Table II that the parallax of the two stars is within one deviation, and the proper motion and declination for both stars is within three standard deviations of each value. This suggests that the two stars involved are not wandering too far from one another while orbiting, and that WDS 15213-5132 is behaving as a physical double. However it is hard to make a definite conclusion with these facts alone due to the long orbital period, as the data needed to use these figures as as decisive indicators for a physical double has not been collected. From the magnitude of the gravitational force calculated (see Table III), the stars involved seem to be gravity locked. Considering that the gravitational force between the Earth and the Sun is 3.47 x 10^{22} N, and the force between the stars of WDS 15213-5132 is 1.97x10^{22} N, which is within the same order of magnitude, further supporting the idea of a gravity locked orbit.

The position angle and separation from the measured LCO data have a very small standard deviation from the measured values as recorded in Table I. The proper motion of WDS 15213-1532 is shown in Figure 2, where the calculated position angle and separation were utilized to produce the mentioned graph. The furthest outlying points to the top left, and bottom right of the graph were the earliest observations of WDS 15213 -1532, using methods less accurate than modern methods resulting in a very wide variance from the rest of the data.

Apart from what has been said, a further suggestive indicator of WDS 15213-1532 being a physical double is that the current separation matches the historical data trend within its standard deviation, while the current position angle fits the historical data trend within two standard deviations. This is hard to confirm however, as the orbital period calculated is significantly longer than the time that has passed since discovery. Such few points are insufficient to fully determine the orbital path of the two stars with our observations and calculations only showing about .1% of the orbit.

5) Conclusion

By comparing the data gathered from the historical, LCO, and Gaia data sets, the measurements and calculations indicate that WDS 15213-5132 is a physical double. Although, due to the long orbital period and the relatively short period of time that it has been observed, WDS 15213-5132 should be observed sporadically in the coming centuries and millennia to gather more information on WDS 15213-5132 so a more viable model of the systems orbit may be built.

6) Acknowledgements

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7) Biography

The Authors of this paper are Junior and Senior level students pursuing Bachelors of Physics degrees at Brigham Young University Idaho. Their subjects of study and interest vary from applied physics and teaching to theoretical and mathematical physics.

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