Analysis of WDS 00115+2949 / MLB_441AB / MLB_441BC

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Abstract

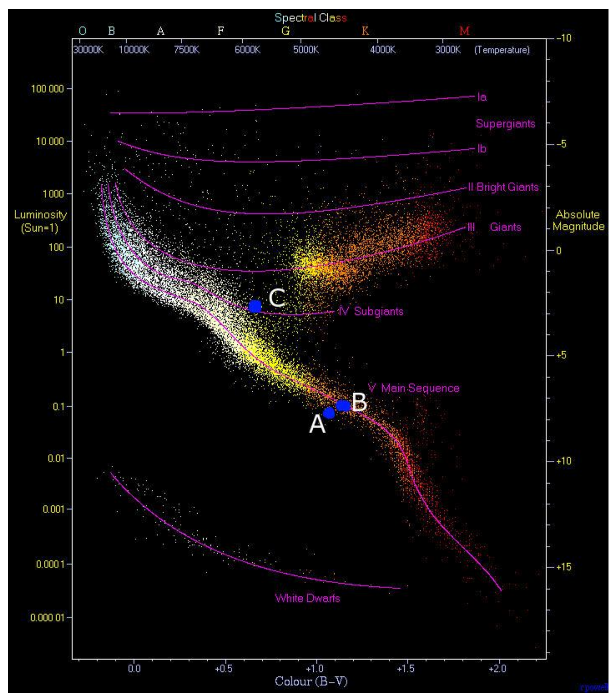
The double star WDS 00115+2949 was studied to determine if it was physical or optical, MLB_441AB and MLB_441BC. Astronomical measurements determined MLB_441AB to have a separation of 14.18 arcseconds and a position angle of 358.45 degrees. Using the astrometric data and GAIA DR2 data, MLB_441AB was determined to be an optical pair. MLB_441BC was determined to have a separation of 36.32 arcseconds and a position angle of 341.59 degrees. MLB_441BC was also determined to be an optical pair.

Introduction:

MLB_441AB and MLB_441BC were first observed by W Milburn in 1927 with the separation of MLB_441AB as 14.9 arcseconds and the position angle as 1 degree and the separation of MLB_441BC as 38.5 arcseconds and the position angle as 351 degrees (Espin & Milburn, 1927). According to Stelledoppie, for MLB_441AB the last observed separation was 14.1 arcseconds and the last observed position angle was 359 degrees as reported by Richard Harshaw (Harshaw, 2016) and for MLB_441BC the last observed separation was 36.6 arcseconds and the last observed position angle was 342 degrees as reported by Wilfried R.A. Knapp (Knapp 2018).

Component A has a luminosity of 0.615 solar, a surface temperature of 5596.50 K and was found to be a G4VI class star. Component B has a luminosity of 0.775 solar, a surface temperature of 5619.77 K and was found to be a G3VI star. Component C has a luminosity of 10.009 solar, a surface temperature of 6510.00 K and was found to be a F7IV (Noll, 2014). These components are indicated on the HR diagram below.

Figure 1: HR diagram of the luminosity and spectral class of component A, component B, and component C of WDS00115+2949



Materials and Methods

This pair was chosen by using the browser-based tool DoubleSTARS Query to search the WDS (Hewett et al., 2019). Star systems were found by meeting the

Received June 6, 2021

following criteria: a) the stars were visible between 18 to 08 hours of right ascension, b) between declination 20 degrees and 70 degrees, c) both stars had a magnitude between 9 and 12 and had a delta magnitude less than 3, d) they had less than 30 observations, and e) they had not been observed since 2015. The star system that met these requirements was WDS 00115+2949, a quadruple system in which two different pairs of components were studied.

The start of the research on MLB_441BC began with an observing request to the Las Cumbres Observatory (LCO) telescope network. We requested 20 images with a clear filter and an exposure time of 4 seconds. The SBIG STL-6303 camera on a 0.4 meter remote robotic telescope from the Teide Observatory on Tenerife, an island of the Canary Islands, was used to take the images on October 8, 2019. Twenty images were taken with a clear filter at an actual exposure time of 4.236 seconds. The images had a pixel scale of 0.58 arcsec/pixel.

The images from LCO were then imported to AstroImageJ (AIJ) and plate solved using Astrometry.net. The Astrometry tool in AIJ was then used to measure the position angle and separation of components AB and components BC.

Data

The separation and position angle of components AB in each image is shown below in Table 1. The average separation was 14.18 arcseconds and the average position angle was 358.45 degrees.

Table 1. Separation and Position angle of MLB_441AB, October 8, 2019

	Separation (arcseconds)	Position Angle (degrees)
Average	**14.18**	**358.45**
Std Dev.	0.07873	0.15221
SEM (Standard Error of the Mean)	0.01718	0.034036

MLB_441BC

The separation and position angle of components BC in each image is shown below in Table 2. The average separation was 36.32 arcseconds and the average Position Angle was 341.59 degrees

Table 2. Separation and Position angle of MLB_441BC, October 8, 2019

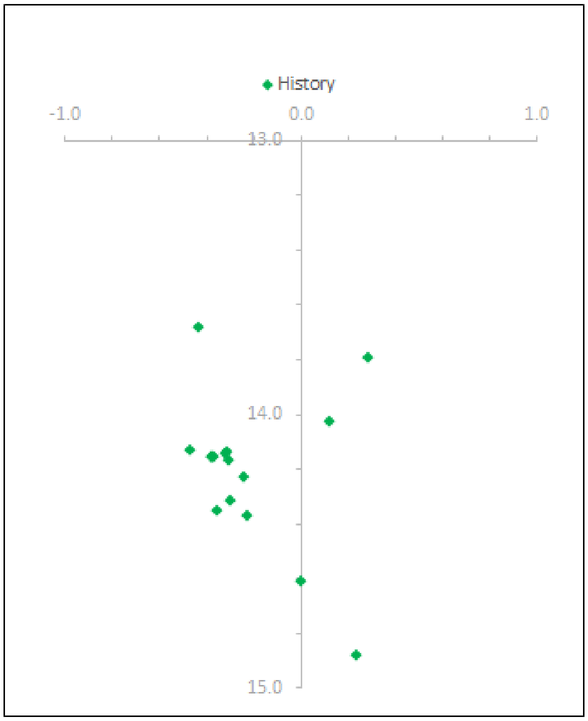
	Separation(arcseconds)	Position Angle(degrees)
Average	**36.32**	**341.59**
Standard Deviation	0.2286	0.20817
SEM (Standard Error of the Mean)	0.04990	0.046548

Analysis

Components AB

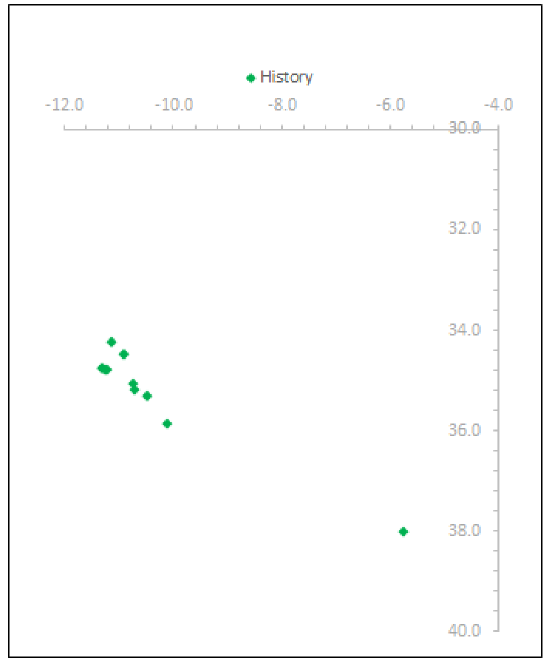
Historical data was requested from Dr. Brian Mason of the Washington Naval Observatory. The historical data was graphed into a coordinate plane using Richard Harshaw's Plot Tool 3.19.

Figure 2. Motion of Component AB in the sky



The graph above shows the movement of the secondary star around the primary star, the primary star is assumed to be stationary at 0,0 with the green dots representing the secondary star. The axes are measured in milliarcseconds. The data leads to a lot of uncertainty when determining if it has a curve or not. More data would show if the graph would curve. A quadratic regression of the points gives the formula $2.7x^2+0.14.4x-14.4$, with a R^2 of 0.23. While a linear regression gives the formula -0.3x-14.3, with a R^2 of 0.07. The R^2 of the quadratic regression is significantly higher than the linear, suggesting a curved path in the stars' movements. However, the R^2 value is significantly lower than components BC, calling into question any relationship in the graph.

Figure 3. Motion of Components BC in the sky



This graph may show the beginnings of a curve. A quadratic regression gives the equation $0.06x^2+0.45x-37.5$ with a R^2 of 0.938, while a linear regression gives the equation -0.6x-41.7 with a R^2 of 0.926. The R^2 of the quadratic is slightly higher, suggesting the stars are moving around each other, though more data would be helpful in determining a more definite curve. The secondary star does appear to move around the primary star in a way that could suggest an orbit (and therefore, a physical pair).

Discussion

For star system MLB_441 components AB, Stelledoppie has the system listed as a physical double star pair. In the GAIA DR2 data, the parallax and proper motion of each star in WDS 0115+2949 is listed. For component A of the system, the parallax is 10.2914±0.0376 milliarcseconds (mas), the proper motion in the declination direction is 27.133 mas/yr, and the proper motion in right ascension direction is 35.719 mas/yr. For component B, the parallax is 10.2123±0.0383 mas, the proper motion in declination is 27.176 mas/yr, and the proper motion in right ascension is 35.707 mas/yr (Gaia Collaboration, 2018). The proper motions of the two components are very similar, and supports the claim that the stars are likely a physical pair. However, to say for certain, the parallax data must be used.

To use the parallax data, it is helpful to convert the mas parallax into a measure of distance in parsecs. Since parsecs are equal to the reciprocal of the parallax in arcseconds, we can calculate that the distance from Earth to component A is between 96.8148 and 97.5248 parsecs. Then for component B, we find the distance from Earth to component B is between 97.5553 and 98.2900 parsecs. Using these distances, we can calculate that the minimum distance between the two stars is 0.0305 parsecs or 6283 AU. According to Richard Harshaw's paper Gaia DR2 and the Washington Double Star Catalog: A Tale of Two Databases (Harshaw 2018), most binaries are within 1000 AU and very few exceed 3000 AU. MLB_441AB is outside those boundaries and is likely to be an optical pair.

MLB_441AB appears to be an optical double star pair. Although they have matching proper motion, the distance between the two stars is larger than most double star pairs, making it unlikely that MLB_441AB is a physical double star pair.

For components C, the parallax is 0.8412±0.1542 mas, the proper motion in declination is -6.75 mas/yr, and the proper motion in right ascension is -8.867 mas/yr (Gaia Collaboration, 2018). Looking at component B data, component C is very far from component B in parallax, almost 9.4502 mas. They are also moving in opposite directions. Component C's proper motion in a negative direction in both declination and right ascension, while component B's proper motion in a positive direction for declination and right ascension.

Using the same methods as before, we can calculate the distance between components B and C in this double pair. We know component B is between 97.5553 and 98.2900 parsecs from Earth, and we can calculate that component C is between 1004.62 and 1455.60 parsecs away from Earth. We can then calculate that at a minimum the stars are 906.33 parsecs or $1.8670*10^8$ AU from each other. However, the tools that the Gaia telescope uses are unreliable at parallaxes below 5 mas so our results are inconclusive. However, even at the uppermost variance listed in Gaia the distance from component B to component C is well over the 1000 AU limit Richard Harshaw observed, supporting the claim this is an optical pair.

Regarding MLB_441BC, the data collected indicates that the pair is an optical pair. There is such a large distance between the two components it is unlikely that the stars are gravitationally bound (Harshaw, 2018).

Conclusion

Data collected in this research supports the conclusion that MLB_441AB is an optical double star pair. Despite their matching proper motions, the parallax data shows the stars are likely too far apart to be physical (Harshaw 2018), and so it is likely that MLB_441AB is an optical double star pair.

Data collected in this research supports the conclusion that MLB_441BC is an optical double star pair. The parallax of the two stars is too distant (Harshaw 2018) to be a physical pair, therefore, MLB_441BC is likely an optical double star pair.

Acknowledgments

The group would like to thank Dr. Brian D Mason for his help in obtaining the historical data existing from past observations/studies on this star system. We would like to thank Las Cumbres Observatory for the use of their telescopes. We would also like to thank Alex Howett, David Rowe, and Richard Harshaw for use of the DoubleSTARS Query. Lastly, we would like to thank Richard Harshaw for the use of his Plot Tool during the research.

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