Double Star System WDS 02229+5835 BLL 7 (S Per)

Olivia Ho[1], Kieran Saucedo[1], Alani Bayha[1], Eliana Meza-Ehlert[1], Shakara Tilghman[1], Brian Delgado[1], Pat Boyce[2], and Grady Boyce[2]

1. High Tech High School
2. Boyce Research Initiatives and Education Foundation (BRIEF)

Abstract: Research regarding the Double Star System WDS 02229+5835 BLL 7 (S Per)] was conducted to contribute to the previous observations of the system, determine the nature of this system, and to further the science and data regarding double stars. Data was collected through careful observations of BLL 7, using Charge-Coupled Device cameras from the Las Cumbres Observatory. Researchers were able to find the current theta 20.34° and rho 69.10", on epoch 2018.832. The collected measurements and data show that this system is most likely an optical double.

Introduction

Referencing the Washington Double Star Catalog (WDS), students searched through lists of Double Star systems that met the following criteria: the right ascension (RA) of the systems were between 00 and 08 hours, the stars had a separation of at least 5" arcseconds, and magnitudes between 7 and 12. Data was requested for star systems that met these requirements, and the system WDS 02229+5835 BLL 7 was picked from those candidates.

This star was chosen due to the uncertainty regarding the gravitational nature of BLL 7 based on research using GAIA data. Thus, this unknown, as well as the extensive historical value of the system, made it an intriguing system to study. It's stellar location with an RA of 02h, and a declination (Dec) of about +57° made it visible during the time of year this study was conducted. The delta magnitude is 0.63, with S Persei as the primary star having a magnitude of 10.76 and the secondary star having a magnitude of 11.39. The separation angle (theta) from the last measurement taken in 2010 is about 69.3°, changing by 1.1° from the initial measurement in 1880 of, 68.2°.

Methods and Materials

The images were taken using a 0.4-meter telescope with an SBIG CCD requested through Las Cumbres Observatory (LCO) Observing Portal (LCO Web).

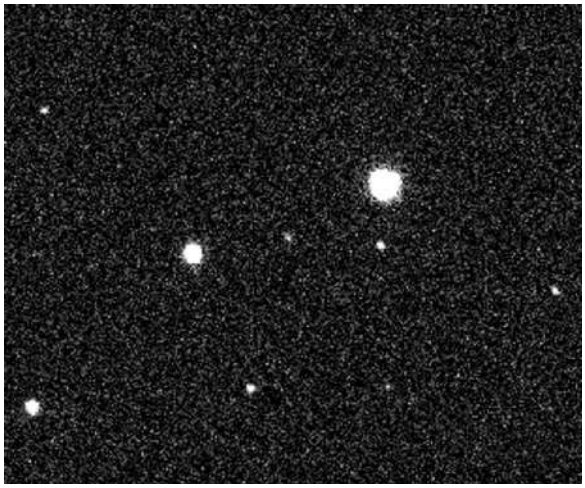

Figure 1. SDSS r' Filtered Image of BLL 7 processed through the OSS Pipeline.

LCO is a conglomeration of twenty-one telescopes across eight global locations, tasked with keeping a constant eye on the night sky. An SBIG CCD camera was used to take the images of BLL 7, Figure 1, in order to enable precise measurements.

Thirty images in total were requested from LCO, 15 using the SDSS r' filter, isolating red wavelengths, with an exposure time of eight seconds, and 15 using

Double Star System WDS 02229+5835 BLL 7 (S Per)

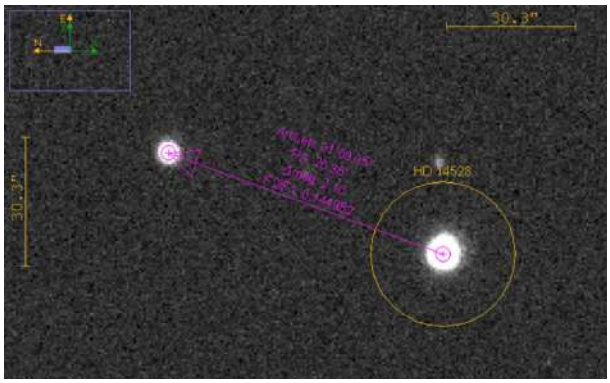

Figure 2. Image of AIJ Measurement.

the SDSS g' filter, isolating green wavelengths, with an exposure time of 12 seconds. The images were all taken on BJD 2458422.7025 using the Teide 1 telescope in Tenerife.

The images were taken and initially processed through LCO, then through the OSS Pipeline, (Fitzgerald, 2018 accepted). After getting the files from the OSS Pipeline, AstroImageJ (AIJ) was used as astrometric software that provided further information on all 30 images. Starting from the center of the primary star, a line was drawn to the rough center of the secondary star. The position angle, separation in arcseconds, RA and Dec, were then calculated by AIJ, Figure 2. This process was repeated, with each image being measured with the same method.

Data and Results

The data is exhibited in Tables 1 - 5. Table 1 shows the average position angle (theta) of the 15 SDSS r' filtered images, the 15 SDSS g' filtered images, and the compiled data from all 30 of the images together. Table 2 shows the average length of separation in arcseconds (rho). Table 3 displays the historical data on this double star with this paper's 2018 measurement included for reference. Table 4 provides Effective Temperature and Luminosity Values reported by GAIA. Figure 3 provides Proper Motion vectors provided by ALADIN10 using GAIA data.

Discussion

After an in-depth analysis, using new data brought forth by this study compared with previous measurements of this system, it was concluded that this system is most likely an optical double star system with no gravitational bond. Gravitationally bound double stars display similar parallax and proper motions, whereas these values for BLL 7 are significantly different, Table 4, when comparing the minimum, middle, and maximum possible values of both stars parallaxes. This il-

Filter	SDSS r′	SDSS g′	Across All Filters/ Images
Mean	20.32°	20.36°	20.34°
Standard Deviation	0.02	0.03	0.05
Standard Deviation of the Mean	0.013	0.003	0.009

Table 1. Theta measurements

Filter	SDSS r′	SDSS g′	Across All Filters/ Images
Mean	69.08"	69.12"	69.10"
Standard Deviation	0.06"	0.06"	0.06"
Standard Deviation of the Mean	0.015"	0.015"	0.011"

Table 2. Rho Measurements

Epoch	Position Angle	Separation
1880	20°	68.2"
1908.05	19.6°	69.193"
1908.87	19.8°	69.04"
1919.95	19.5°	69.008"
1929.89	19.4°	69.583"
1956.77	20.2°	67.206"
1989	20.2°	68.751"
1991.64	20.1°	69.08"
1999.71	20.1°	69.16"
2000.87	20.5°	69.42"
2003.652	20.5°	69.3"
2018.832	*20.34 ± .009°*	*69.10″ ± 0.011″*

Table 3. Historical Data.

Star	Temperature Effective Value	Luminosity Value
Primary	3293 Kelvin	Not Reported
Secondary	5899.50 Kelvin	25.366

Table 4. Luminosity / Temperature

Double Star System WDS 02229+5835 BLL 7 (S Per)

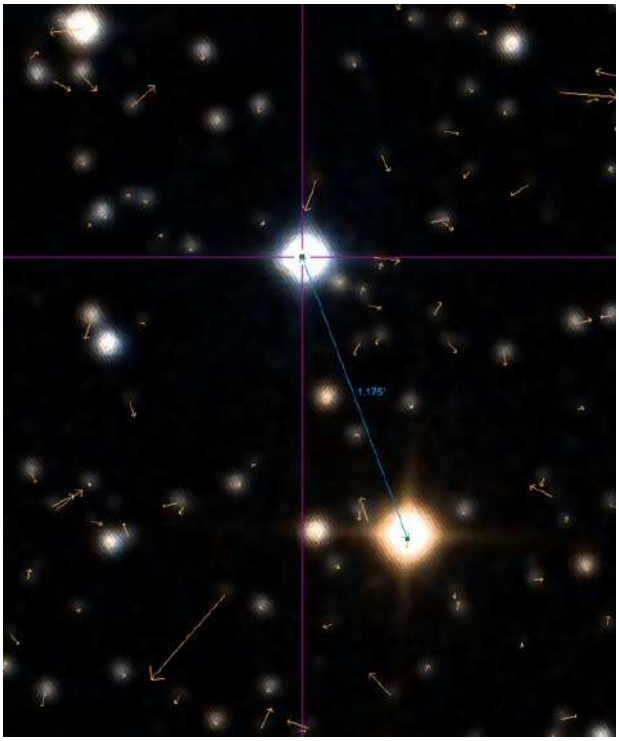

Figure 3. Image of Aladin 10 Proper Motion Vectors.

Star	Right Ascension (Proper Motion)	Declination (Proper Motion)
Primary	-0.010 ± 0.295	-2.570 ± 0.307
Secondary	-0.177 ± .081	-1.617 ± 0.083

Table 5. Proper Motion

lustrates that the smallest possible distance between these two stars is 1818.83 parsecs (calculated by taking the minimum parallax of the primary star, maximum parallax of the secondary star, and finding the difference between the two). Two stars with such a vast amount of (minimum) distance between them are most likely not gravitationally bound—especially when other data regarding this system is taken into account.

Considering the proper motion measurements from GAIA under 3 mas/year, Table 5, the analysis indicates the probability that these stars have different proper motions as well. While there is a possibility that the RA motion of both stars could be equal, the GAIA data, in its current state, points to the possibility that there may not be an overlap between the Dec motion of both stars.

Viewing the historical measurements, Table 3, shows that from the first recorded measurement in 1880 to the most recent measurements in 2018, there is only a minor difference in the position angle (20° to 20.34° ± 0.009°) with common variations through measurement history (e.g. from 1908 to 1929 the position angle drops from 19.8° to 19.4°, before increasing to 20.5° in 2000). These variations can be attributed to variations in astronomers and the methods they employed. The separation shows a change in 1" between the first recorded measurement in 1880 to the most recent measurements in 2018 (68.2" to 69.10" ± 0.011"), providing too little data to discern a distinguishable pattern. The totality of data points is plotted, Figure 4, showing no evi-

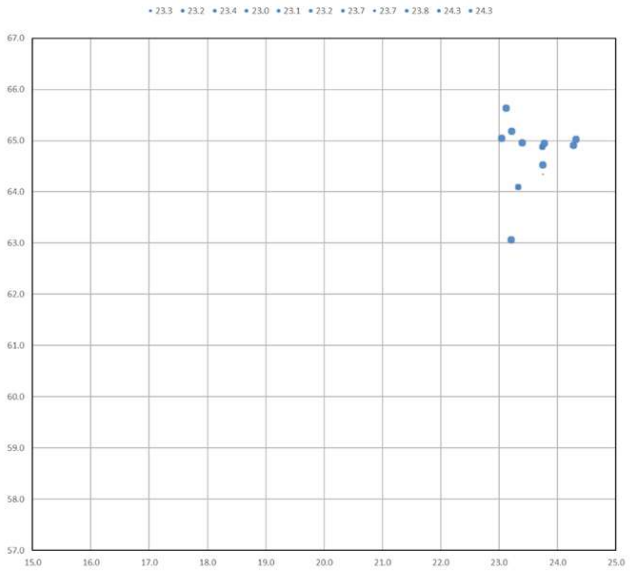

Figure 4. Historical data star positions.

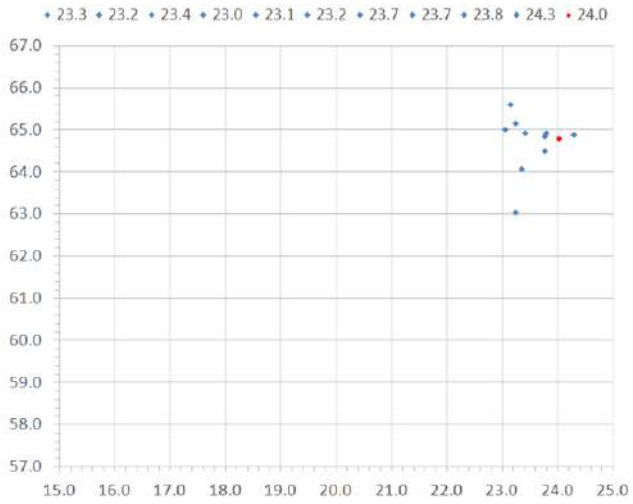

Figure 5. Historical data plotted with conducted observation marked in red.

dence of a trend line. When the 2018 data was plotted along with the historical data, shown in Figure 5, it appears evident that there has been little change over time.

The data garnered from the historical measurements as well as the recent measurement are confirmed with data from GAIA—showing that the parallax of the primary star and the parallax of the secondary star are different (putting the stars over 1818.83 parsecs apart), the proper motion of the primary star and the proper motion of the secondary star are different (the RA have a small overlap but the Dec are definitely different), the systems position angle is constantly changing (decreasing and increasing seemingly randomly), and the system's separation shows no discernable pattern (decreasing and increasing seemingly randomly)—this data helps to provide us with the conclusion that this double star system is not gravitationally bound or a common proper motion pair, but optical.

Conclusion:

WDS 02229+5835 BLL 7 is a double star system that was first measured in 1880 and most recently measured in 2018. Using CCD camera technology and the assistance of several heavily experienced mentors, this double star system was measured and researched. Considering this new data as well as historical data, it is unlikely these two stars are gravitationally bound given both stars' RA, Dec and proper motions.

Acknowledgments

The authors of this paper would like to thank Dr. Michael Fitzgerald, Richard Harshaw, and Bob Buchheim for their contributions to the seminar classes provided by BRIEF. They would also like to thank the L.C.O. network for the time and resources they spent helping make the writing of this paper a possibility. Lastly, the authors of this paper would like to thank Brian Delgado, a physics teacher from High Tech High San Diego for introducing this scientific opportunity.

References

Chapman, Allan, "Sir Robert Stawell Ball (1840-1913): Royal Astronomer in Ireland and Astronomy's Public Voice", *Journal of Astronomical History and Heritage*, **10**, 198-210, 2007.

"About LCO." Parallax and Distance Measurement | Las Cumbres Observatory, http://www.lco.global/about/.

"02229+5835 BLL 7 (S Per)." Stelle Doppie - Double Star Database, http://www.stelledoppie.it/index2.php?iddoppia=8633.

Mason, B., Wycoff, G., and Hartkopf, W. The Washington Double Star Catalog. Astrometry Department, U.S. Naval Observatory.