# New Observation and Physical Nature of Ternary Star WDS 06009-2100 BC

Deborah S. Morgan[1], Ana Amaya[2], Brielle Stringham[3]
1. South Sevier High School, Monroe, UT
2. Nevada Connections Academy, NV
3. Desert Ridge High School, Mesa, AZ

**ABSTRACT**

The Las Cumbres Observatory Global Telescope Network (LCOGT) was utilized to obtain measurements of theta and rho for the double star system WDS 06009-2100 BC. When compared to the ten previous measurements of the system and the parallax data from the Gaia EDR3, WDS 06009-2100 BC is more than likely an optical binary rather than a physical binary.

## 1. INTRODUCTION

The history of the star system WDS 06009-2100 is one that begins with the astronomer John Herschel. He first observed the system in 1835 while continuing the work started by his father searching for double stars (Case, 2011). It wasn't until 1917 that the system was discovered to have not a binary but ternary nature. This paper will focus on the BC components of this system. The last published observations for stars B and C were made in 2015.

The system, labeled as WDS 06009-2100 BC, resides between the constellations of Canis Major and Lepus as seen in Figure 1, below. The A component of this system is classified as an A5IIIn (white, giant) spectral type (Mason et al., n.d.). No other spectral classifications have been made for B or C. The goal of this research was to identify if the star system components B and C, were a physical or non-physical binary system. Along with this main objective, we also hoped to add more information to the existing database of the Washington Double Star (WDS) catalog in order to contribute to future studies.


*Figure 1. Location of WDS 06009-2100I near Lepus and Canis Major using Stellarium (Zotti et al. 2021.)*

## 2. METHODS

The WDS catalog was used to identify possible binary candidates for this study. Binary star systems meeting the following criteria were identified: right ascension (RA) being between 4 and 17, declination between -80 and 80 degrees, magnitude of the primary star being between 8 and 12, with the difference of the value of magnitude of the companion star between 2 and 3.

Based on these criteria, WDS 06009-2100 BC was selected. Star B has a magnitude of 9.31 and C a magnitude of 12.5. The coordinates for this pair are 06:00:51.20 -21:00:28.1 placing them well within the selected criteria for RA and declination. Historical data from the system was requested from Brian Mason with the U.S. Naval Observatory, resulting in ten usable historical observations.

The Las Cumbres Observatory Global Telescope Network (LCOGT) (Brown, T. M. et al. 2013) was used to obtain images of WDS 06009-2100 on March 17, 2022. Images were taken by the 0.4m SBIG telescope, Teide 1, part of the Teide Observatory (Figure 2.) and LCOGT network located on the Canary Islands at 28º 18′ 00″N and 16° 30′ 35″W. The LCOGT Exposure Time Calculator ((“Las Cumbres Observatory Exposure Time Calculator.,” n.d.) was used to determine and set the time of exposure for 15 seconds. Ten images were taken using the red (Rp) filter with 1x1 binning. The LCOGT reduced and plate solved the images using the BANZAI pipeline (Las Cumbres Observatory, n.d.).

*Figure 2. Teide Observatory in Izaña, Tenerife (Canary Islands, Spain).*

AstroimageJ (Collins et al., 2017) was used to make the astrometry measurements for separation and position angle. Our team utilized AstroimageJ by importing the ten images from the LCOGT network, opening the seeing profile for each image, identifying the best radius for the aperture setting, then taking the rho and theta measurements from stars B to C. Special consideration towards avoiding using overexposed images was also taken by checking the seeing profile for each image. Each image was analyzed for a total of 10 measurements used to calculate the mean, standard deviation, and standard error as shown in Table 1.

## 3. DATA AND RESULTS

| WDS no. | Date | Number of Images | | Position Angle (°) | Separation (″) |
|---|---|---|---|---|---|
| 006009-2100BC | 03-17-2022 | 10 | **Mean** | 62.95 | 33.36 |
| | | | **Std. Dev** | 0.37 | 0.29 |
| | | | **Std. Error** | 0.12 | 0.09 |

*Table 1. Summary of mean, standard deviation and error of position angle in degrees and separation in arcseconds for WDS 06009-2100 BC.*

The average separation for BC is 33.36 arcseconds with a standard deviation of 0.29 arcseconds and the average position angle is 62.95 degrees with a standard deviation of 0.37 degrees. These results are similar to those found in the historical data of the stars' previous observations. The ten historical observations of both the average separation distance and position angle, from the U.S. Naval Observatory, are recorded and arranged in Table 2.

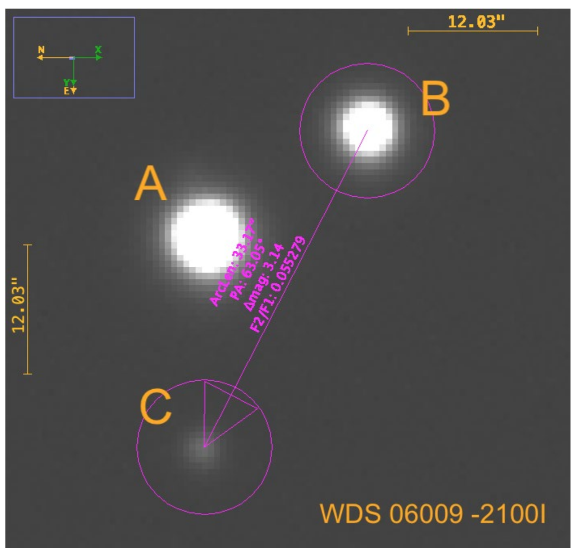


*Figure 3. Image from AstroImageJ showing ternary nature of WDS 06009-2100 with star components A, B, and C.*

| Historical Measurements for WDS 06009-2100 BC | | |
|---|---|---|
| **Epoch** | **ρ Position Angle (°)** | **θ Separation (″)** |
| 1917.14 | 62.7 | 32.709 |

| | | |
|---|---|---|
| 1920.04 | 62.6 | 32.736 |
| 1920.08 | 61.4 | 33.69 |
| 1921.01 | 60.9 | 33.069 |
| 1987.63 | 61.24 | 33.461 |
| 1987.94 | 63.3 | 33.66 |
| 1999.03 | 62.9 | 33.61 |
| 1999.820 | 62.9 | 33.568 |
| 2000.930 | 62.9 | 33.600 |
| 2015.0 | 63.0 | 33.63 |
| **2022** | **62.95** | **33.36** |

*Table 2. Summary of historical measurements of position angle in degrees and separation in arcseconds for WDS 06009-2100 BC with the addition of the 2022 measurement.*

Finally, the Plot Tool 3.19 (Harshaw, 2020) was used to generate a graphical representation of the historical data as shown in Figure 4. Figure 4 does not display a typical pattern indicative of either an optical or physical pair. The plotted points are haphazard and difficult to follow chronologically. Various years have been labeled to demonstrate the inconsistency in comparative movement.

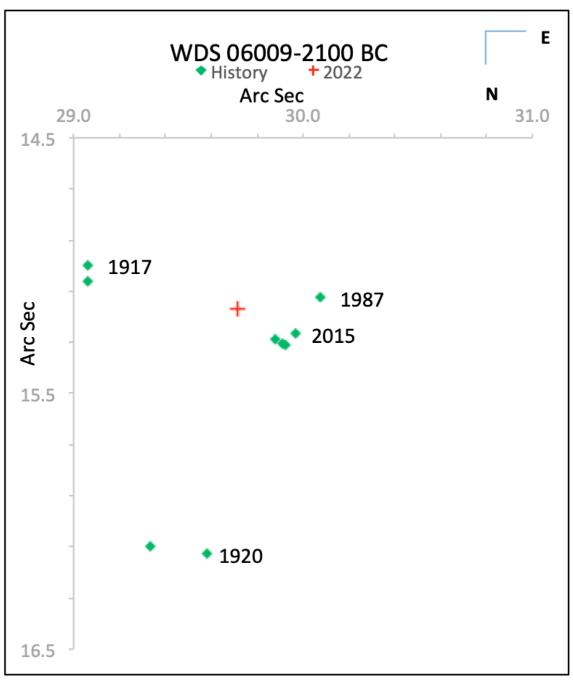


*Figure 4. Graphical representation of historical data with new data plotted for WDS 06009-2100 BC.*

## 4. DISCUSSION

Statistically, parallax within errors, proper motion, and other techniques used to analyze components AB of this ternary system, indicates that the AB pair is physical; however, through proper motion or other techniques, components AC have been categorized as unphysical so it seems apparent that BC falls into this same categorization.

| | Gaia EDR3 Measurements | | | |
|---|---|---|---|---|
| | **Parallax** (mas) | **Parallax Error** (mas) | **Distance** (pc) | **Distance** (ly) |
| **Star B** | 4.1324 | 0.0137 | 241.2-242.8 | 786-791.5 |
| **Star C** | 0.8306 | 0.0126 | 1186-1223 | 3866.3-3987 |

*Table 3. Results from the third Early Gaia Data release (Gaia Collaboration, 2020).*

After comparing results of the observations with historical data and Gaia data, the likelihood of the pair not being gravitationally bound becomes apparent. Historical data on this ternary system shows that the secondary star, B, and ternary star, C, have not followed an expected arc indicative of a physical system, as shown in Figure 4. The parallax and proper motion, as shown in Table 3, are also too dissimilar indicating this system as an optical double.

By comparing the parallax and proper motion of two stars, a determination can be made as to whether a system is optical or binary. Referring back to Table 2, the parallax measurements from the Gaia EDR3 for star B is 4.13 mas and for star C is 0.083 mas. In light years, this translates to a distance of 786-791.5 light-years and 3866.3-3987 light-years, respectively. The vast separation in parallax values suggests the stars are not gravitationally bound.

## 5. CONCLUSIONS

The data for stars B and C of this ternary system, including the lack of any trend indicative of an orbit on the historical graph and the vast difference in parallax values from the Gaia data, suggests that the BC components of WDS 06009 -2100 are likely an optical binary pair rather than a gravitationally bound orbiting pair.

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This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory. Additionally, this work makes use of the Stellarium planetarium and AladinLite programs, as well as observations from the Las Cumbres Observatory global telescope network and data from the European Space Agency (ESA) mission Gaia (https://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement. Images were analyzed using AstroImageJ, an open source software that is distributed under the terms of the GNU General Public License. It incorporates ImageJ components which are in the public domain.

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