Astrometric Analysis of the Position Angle and Separation of WDS 06298-1056

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Abstract

Astrometric measurements of the binary star system WDS 062998-1056 GAL240 were made to find the current position angle and separation. Images of the stars were obtained through the Las Cumbres Observatory Global Telescope Network using the 0.4-meter telescopes. The average position angle between the two stars in the system was 90.49 +/- 0.36 degrees. The average separation of the system was 7.25 +/- 0.09 arcseconds. These values are compared with reference values from Stelle Doppie. The position angle and separation values were consistent with previous measurements, and fell within an acceptable margin of error.

Introduction

The purpose of this research was to determine the current position angle and separation measurement of the double star WDS 062998-1056 GAL240. Located northeast of Sirius, these stars were first measured in 1904 at the National Astronomical Observatory of Chile by Joaquín Gallo, director of the Tacubaya Observatory from 1914-1947.

The type of system and the possible orbit of the stars in this system can be determined over time by analyzing the position angle (theta), in degrees, and the separation (rho), in arcseconds. The first measurement in 1904 shows a position angle of 83.1 degrees and separation of 7.41 arcseconds. The system was last observed in 2015, with a position angle of 90.738 degrees and separation of 7.25 arcseconds. This system has been observed 7 times over the past 117 years.

Materials and Methods

The selection of a double star for our research was completed by using the Boyce-Astro Research Assistant Double STARS Query program (Hewett et al, 2019), GAIA, along with the Washington Double Star Catalog and Stella Doppie. Due to the location and aperture of the telescope used, the following criteria were used: a right ascension (RA) between 4 and 17 hours, a declination between -80 and 80 degrees, a separation between 5-10 arcsecs, a magnitude range of 9-11, a delta magnitude of 3 or less, and a maximum of 49 historical observations with no observations later than 2015. Using these criteria, the system WDS 06298-1056 GAL240 was chosen. The historical record obtained from Dr. Brian Mason of the US Naval Observatory shows that only 7 observations have been reported, and that the system was first observed in 1904 by Joaquín Gallo.

A series of requests were made to obtain images of the selected double star using the Las Cumbres Observatory Global Telescope Network (LCOGT, Brown et al. 2013). Images were obtained via a 0.4-meter telescope with an SBIG STL-6303 camera at the Cerro Tololo Inter-American Observatory (CTIO) located on Cerro Tololo in the Coquimbo Region of northern Chile (Figure 1). Between March 12-19, 2021, 49 photographs of the system were taken, with an exposure time of 2 seconds with a clear filter.

Figure 1. The 0.4 m telescope from the Cerro Tololo Inter-American Observatory (CTIO) located on Cerro Tololo in the Coquimbo Region of northern Chile.

Results

The aperture photometry tool in AstroImageJ (Collins et al. 2017) was used to measure the position angle and separation between the primary and secondary stars. Figure 2 shows the AstroImageJ measurements of WDS 062998-1056 GAL240 taken on March 12, 2021 from CTIO.

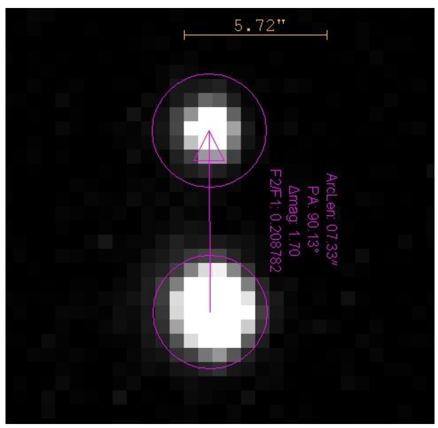

Figure 2. AstroImageJ measurements of WDS062998-1056 GAL240 taken on 3/12/2021 from CTIO

The mean, standard deviation and standard error of the mean were calculated over the 49 images taken. Table 1 shows the results of the analysis, with a position angle of 90.49 +/- 0.36 degrees and a separation between the primary and secondary components of the system of 7.25 +/- 0.09 arcseconds. The reference Stelle Doppie observations are 91 degrees and 7.3 arcseconds, respectively.

	Mean	**Standard Deviation**	**SEM**
Arc Length (seconds)	7.25	0.09	0.013
Position Angle (degrees)	90.49	0.36	0.051

Table 1: The average, standard deviation and standard error of the mean (SEM) for the 49 observations of position angle and separation, made between March 12, 2021 and March 19, 2021. Exposure time of images was 2 seconds.

Analysis & Discussion

According to the GAIA DR3 catalog parallax values indicate the stars are at similar distances (Table 2) (4.4622 and 4.5459 mas) within measurement uncertainties. The proper motions in declination are 8.138 and 6.824 mas/yr for stars A and B respectively. The values in RA are -5.190 and -4.276 are not the same within measurement error but are similar. The parallax and proper motion measurements are close enough to support the idea that these stars are a physical system (Harshaw, 2020).

	A	B
parallax (mas)	4.4622	4.5459
parallax err (mas)	0.0380	0.0151
PM RA (mas/yr)	-5.190	-4.276
PM RA err (mas/yr)	0.099	0.018
PM DEC (mas/yr)	8.138	6.824
PM DEC err (mas/yr)	0.082	0.017

Table 2. Parallaxes and proper motions for WDS 062998-1056 A and B from GAIA EDR 3

The position angle and separation as a function of time are shown in Figure 3, via Plot tool 3.19 (Harshaw, 2020). The location of the secondary star in 2021 is indicated in green.

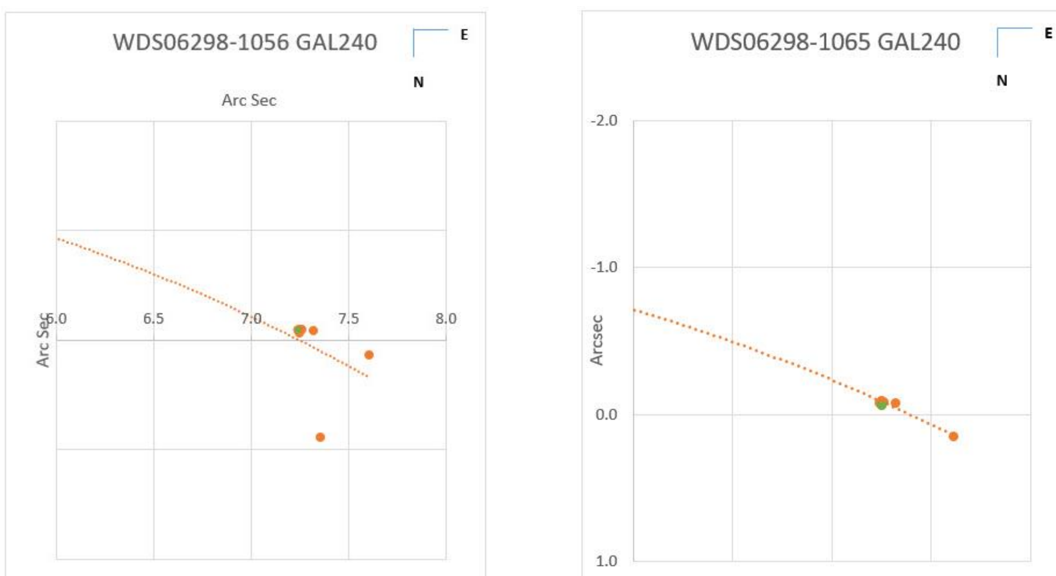

Figure 3. Position angle and separation as a function of time; from Plot Tool 3.19.

The 1904.3 data point, the lower point in the plot on the left in Fig. 3, does not appear to be congruent with the other observations, evidenced by its distance from the calculated second-order polynomial trend line. While Harshaw (2018) indicates that a linear model often results in a high R^2 value, that is not the case with the current set of data. When stars are mapped over large periods of time, their movement usually approximates a fragment of an ellipse, or a portion of a full orbit. When the full data set for binary star system WDS 062998-1056 GAL240 is fit with a second-order polynomial model the resulting fit is seen on the left diagram in Figure 3, and the R^2 value is 0.138. When the 1904.3 data point is removed and the remaining data is fit to a second-order polynomial, the figure on the right side of Figure 3 results with an R^2 value of 0.965. No literature sources were found which describe the process whereby 1904.3 was measured, and a statistical analysis of the historical data indicates that the measured position angle of this point is within three standard deviations of the mean (Table 3). Hence, while curve-fitting analysis would indicate that it is an outlier, statistics do not allow treatment as such.

	Position Angle (degrees)	***Arc Length (seconds)***
1904.03	83.1	7.411
1904.04	90.0	7.36
1999.03	90.6	7.32
1999.961	90.7	7.262
2010.5	88.9	7.61
2014.083	90.65	7.241
2014.856	90.73	7.259
2015	90.738	7.251
2021.3	90.49	7.25
Mean	**89.5**	**7.3**
Standard Deviation	**2.35**	**0.11**
Standard Error of the Mean	**0.78**	**0.038**

Table 3. Statistical treatment of historical and current measurements of WDS 062998-1056.

The weighted distance computation from the Plot Tool shows these stars are separated by 1,618 AU which provides evidence for these stars being a physical pair. According to the instructions provided by Harshaw (2020), the average separation between stars is on the order of 800 AU, with nothing farther than 5,000 AU.

According to data Table 4 from the Plot Tool, radial velocities of primary and secondary stars are shown as 42.19 and 44.21 and Stellar radii, in solar units, are shown as 1.73 and 1.10, respectively. Luminosities are shown as 5.53 and 1.27 in solar units. The star's effective surface temperatures are reported as 6722 K and 5838 K for stars A and B, respectively. The Gaia values for theta and rho are shown as 90.74 degrees and 7.27 arcseconds.

AB SEP	*1,611*	*1,626*
Rad Vel	*42.19*	*44.21*
Radius	*1.73*	*1.10*
Lumin	*5.53*	*1.27*
Teff	*6,722*	*5,838*

Table 4: Physical properties of the stars from the Harshaw Plot tool

Conclusion

Our recent measurements of the WDS 062998-1056 GAL240, by comparison with the GAIA catalog, show that it is a double star with similar motions in declination and right ascension since its last measurement in 2015. The similarity of the data from Stelle Doppie and the data gathered herein support the conclusion that the star is a physical double that is gravitationally bound. The datum from 1904 is suspected of being an outlier, but statistical analysis was inconclusive and no published evidence of improper measurements was found.

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