New Astrometric Measurements of the Position Angle and Separation of the Double Star System WDS 15453-4949 B 2365

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Abstract

This paper investigates the double star system WDS 15453-4949 B 2365, located in the Norma constellation. We obtained new measurements of the position angle and separation through our observations, the Gaia Data Release 3 mission, and historical data. Our findings, when compared with the historical data, reveal that both parameters change erratically over time. However, an analysis of the parallax and proper motion values of the stars suggests that they exhibit Similar Proper Motion (SPM) and are not gravitationally bound. We conclude that they form a physical double pair. We recommend future studies to monitor changes in system parameters to confirm or reject our conclusion and gain a better understanding of the nature and dynamics of the system.

1.0 Introduction

Double stars, a significant aspect of stellar astronomy, consist of pairs of stars that appear close together when observed in the sky. They are broadly classified into physical doubles, which lack gravitational binding and are chance alignments, and binary stars, which are gravitationally tethered and orbit around a common center of mass. Binary stars are abundant in our Milky Way galaxy. They are crucial in understanding stellar evolution, mass transfer processes, and gravitational interactions. The study of double stars provides astronomers with valuable insights into the formation and development of stars (Kaib and Raymond, 2014).

Our target double star is WDS 15453-4949 B 2365. Initially observed in 1903 (Urban et al., 1998), the system is located in the constellation Norma with coordinates RA = 15h 45m 19.60s and Dec = - 49° 48' 34.1". For this research, we analyzed historical data of the system from the Washington Double Star Catalog (Mason et al., 2001), data from the Gaia DR3 mission (Gaia Collaboration et al., 2022), and new data from the Las Cumbres Observatory.

Table 1 shows known information about the stars studied. The data is collected from Gaia Data Release 3 and the Washington Double Star Catalog.

Table 1 presents the Right Ascension (RA) and Declination (Dec) obtained from the Washington Double Star (WDS) catalog. The magnitudes of the primary and secondary stars were sourced from the Gaia Gmag database, while the parallax and proper motion of both stars were extracted from the Gaia catalog. Additionally, the ratio of proper motion (rPM) was computed based on the proper motions of the entire system.

	Parallax (mas)	Distance (parsec)	Proper Motion (mas/yr)	rPM
Primary Star	1.1952	836.68	pmra = -2.828 pmdec = -2.400	0.596
Secondary Star	0.7957	1256.755	pmra = -0.888 pmdec = -1.336	

In the analysis of the double star system presented in Table 1, the proper motion data is systematically examined, and the ratio of proper motions (rPM) metric is calculated. This metric, introduced by Harshaw in 2016 and detailed by the equations below (Equations 1-3), quantifies the disparity between the proper motions of the primary and secondary stars. Specifically, the rPM is defined as the magnitude of the difference between these proper motions, divided by the larger magnitude of the two proper motions. In scientific terms, it gauges the relative divergence of the two proper motions to the magnitude of the larger motion.

$$Resultant = \sqrt{(R_{pri} - R_{sec})^2 + (D_{pri} - D_{sec})^2} \tag{1}$$

$$Vector = \sqrt{R^2 + D^2} \tag{2}$$

$$rPM = \frac{Resultant}{Vector} \tag{3}$$

Equation (1) calculates the Resultant, representing the square of the difference between the proper motions in Right Ascension R_{pri} and Declination D_{pri} of the primary and secondary stars. Equation (2) computes the Vector, which is the square of the proper motions' magnitudes in both Right Ascension and Declination. The rPM, as expressed in Equation (3), is then derived by dividing the Resultant by the Vector. For interpretation, if the rPM value is less than 0.2, the stars are likely a Common Proper Motion (CPM) pair. A value between 0.2 and 0.6 suggests Similar Proper Motion (SPM), while a value exceeding 0.6 indicates Different Proper Motion (DPM). Applying this criterion, the double star system B 2365, with an rPM metric of 0.596, is identified as having Similar Proper Motion (SPM) pairs, indicating a separate motion between the primary and secondary stars.

1.1 Target Selection

We utilized Stelle Doppie, a platform accessing the Washington Double Star Catalog (WDS), to carefully choose our target double-star system, WDS 15453-4949 B 2365. To ensure comprehensive observability throughout our study period, we defined a right ascension (RA) range spanning from 16 hours and above to 5 hours. This range was validated using Stellarium Sky simulation software. The absence of declination (Dec) limitations was due to the availability of 0.4m LCO telescopes across both hemispheres.

Considering the observational capabilities of 0.4m LCO telescopes, we restricted the primary star's magnitude to fall between 9 and 11, with a limit of 20.5 magnitudes. Conversely, the magnitude of the secondary star remained unspecified, with the deliberate aim of achieving a magnitude difference (Δmag) of less than 4 for enhanced visibility. Furthermore, we carefully selected a separation between 5 and 10 arcseconds to ensure clear resolution in LCO images.

WDS 15453-4949 B 2365 became the central focus of our investigation due to several noteworthy factors:

1. Limited historical observations, with only four instances documented from its first observation in 1903 to the last in 2016.

2. A significant temporal gap of approximately 8 years since the most recent measurement, allowing for potential relative motion between the two stars.

3. The uncertainty surrounding the nature of this system.

2.0 Methodology

On February 6, 2024, we conducted observations using the 0.4m Sutherland Observatory, a part of the Las Cumbres Observatory's Global Telescope (LCOGT) network, to investigate the target system. The instrument employed for this observation was the SCICAM QHY600. We obtained a series of ten images of the system, with each exposure lasting 2 seconds. The optical configuration included a central 30x30 mode and a V filter.

The SCICAM QHY600 instrument is equipped with specific optical elements to facilitate precise imaging. Using a Bessell-V filter during observations aids in capturing images within a specific wavelength range, enhancing the quality of data obtained.

After data acquisition, image processing was performed using the LCOGT's BANZAI pipeline, ensuring automated processing of all acquired images. This standardized processing method guarantees consistency and reliability in the analysis of observational data.

Measurement of the separation and position angle of the observed system was conducted using the AstroImageJ software (Collins, 2017). By employing AstroImageJ, we could automatically identify each star's centroid, enabling precise determination of the position angle and separation.

After obtaining the measurement data from the Washington Double Star Catalog and collaborating with Dr. Rachel Matson, a comparative analysis was conducted. The plotting and visualization of both new and historical measurements were performed using Google Sheets This approach allowed for a flexible and customizable representation of the system's behavior over time.

Figures showcasing the 0.4m telescope at an LCOGT site and a sample image of the observed double star system captured through AstroImageJ are provided for reference (Figures 1 and 2, respectively).

Figure 1: 0.4 m telescope located at one of Las Cumbres Observatory's sites.

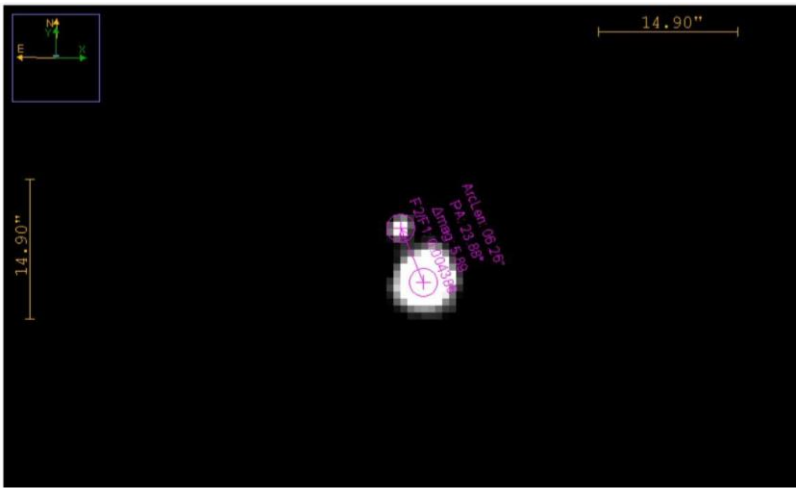

Figure 2: Screen capture of an example measurement taken in AstroImageJ for B 2365

3.0 Observation

Table 2 shows the new measurements derived from our images and Table 3 is a summary of statistics for our measurements.

Table 2. New measurements of WDS 15453-4949 B 2365 derived from our observations.

S/N	PA (°)	Sep (")
1	23.9	6.26
2	24.8	6.18
3	24.5	6.01
4	24.1	6.08
5	24.9	6.31
6	25.7	6.08
7	23.5	6.17
8	25.4	6.34
9	26.3	6.07
10	23.9	6.14

Table 3. Mean, standard deviation, and Standard error of the mean of our measurements

Double Star	Date	Images		PA (°)	Sep (")
WDS 15453-4949 B 2365	6^{th} of February 2024 (2024.101)	10	**Mean**	24.7	6.16
			Standard Deviation	0.86	0.104
			Standard Error of the Mean	0.27	0.033

4.0 Discussion

In our study, we examined the double star system WDS 15453-4949 B 2365, focusing on determining its position angle and separation, which we found to be 24.7° and 6.16", respectively. The previous values were 24.4° and 5.34". Based on historical data, and our new measurements, we illustrate the variation in the separation of the two stars in Table 4 and plotted in Figure 3.

Table 4: WDS 15453-4949 B 2365 historical data from the Washington Double Star Catalog.

Year	PA (°)	Sep (")
1903.5	21.1	5.54
1999.44	24.4	6.24
2010.5	25.6	6.07
2016	24.4	6.26
2024.101	24.7	6.16

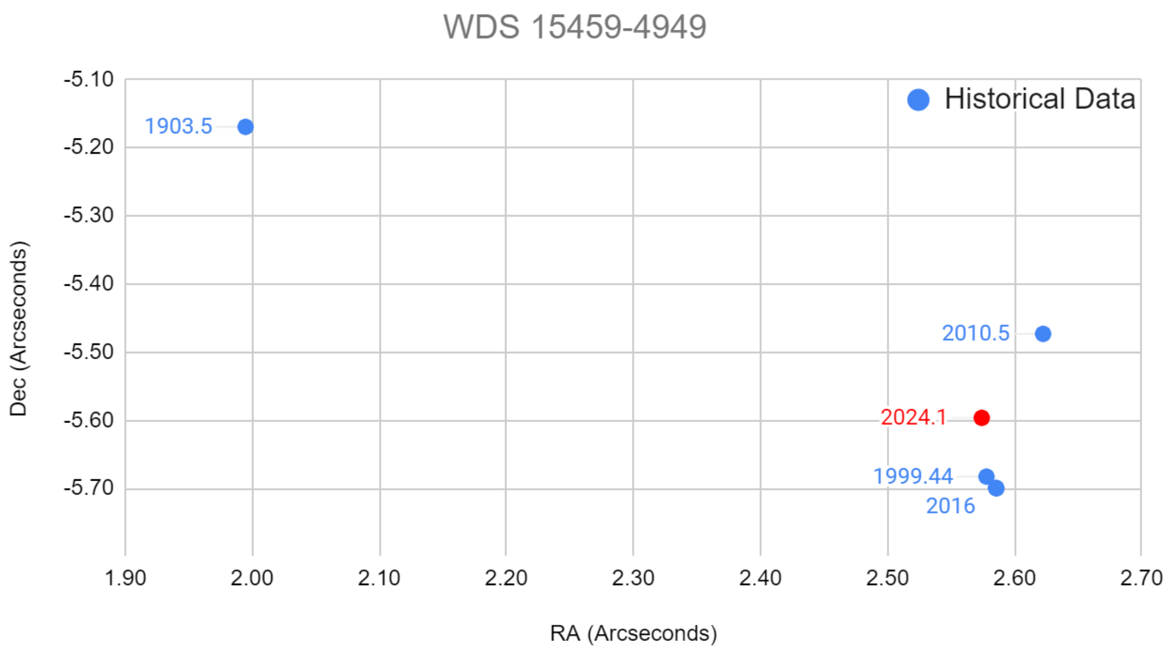

Figure 3: Cartesian plot of historical data (blue points) and the new measurements (red data point) of WDS 15453-4949 B 2365. Each data point is labeled with the corresponding year.

Table 4 shows data from 1903 to 2024. We measured the position angle and separation of the star system and then compared it with historical data. Given that the stars involved are cataclysmic variable stars, it is anticipated that their photometric changes may introduce variability into the positional data. However, our analysis indicates fluctuations beyond what might be solely attributed to these photometric changes. Additionally, all the data points, including ours, have some errors due to atmospheric effects, noise in the data, and measurement uncertainty. Figure 3 illustrates this trend where the blue data points represent historical data, and the red data point denotes our new measurement. Based on this pattern, we expect that both parameters will continue to fluctuate, with considerations for both photometric changes and measurement uncertainties.

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Another important feature of the B 2365 double star system is the parallax values of the primary and secondary stars, which are 1.1952 mas and 0.7957 mas, respectively. These values indicate that the systems are not near each other

Also, the proper motions (in RA and Dec) of the system, as shown in Table 1 and used to determine the ratio of proper motion (rPM) metric, yielded a value of 0.596. This suggests that the system is a Similar Proper Motion (SPM) pair. Star systems that exhibit SPM move together and are co-located in space without being gravitationally bound to each other. They share a common history or origin. Such pairs are often referred to as 'physical doubles,' even though they are not binary systems (Harshaw, 2016).

However, Figure 3 does not exhibit any curvature, and Table 4 indicates that the system parameters are varying unpredictably. Nevertheless, the data from the rPM and parallax measurements lead us to propose that the system consists of physical doubles that are not relatively close to each other. We recommend conducting further studies on this system to confirm or disprove our observation.

5.0 Conclusion

In this paper, we have observed the double star system B 2365, which is located in the constellation of Norma. We have used various sources of data, such as historical data from the Washington Double Star Catalog, data from the Gaia Data Release 3 mission, and new data from the Las Cumbres Observatory global telescope. We measured the position angle and separation of the star system and compared our results with the historical data.

We have also analyzed the parallax and proper motion values of the system and used the ratio of proper motion metric to classify the system. Our results show that the position angle and separation of the star systems change unpredictably over time and that the parallax and proper motion values indicate that the systems are not close to each other.

However, our results also show that the system does not exhibit any curvature, and the ratio of proper motion metrics suggests that the system is a Similar Proper Motion pair. This is not indicative of a binary star system. Therefore, we conclude that the system is not a binary star but rather a physical double, where the stars may or may not be near each other but are not gravitationally bound. We recommend conducting additional observations of the system to either confirm or reject our conclusion and gain a better understanding of its nature and dynamics.

Acknowledgments

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References

Collins, K., et al. (2017). AstroImageJ: Image processing and photometric extraction for ultra-precise astronomical light curves (expanded edition). *arXiv e-prints*. Retrieved from https://doi.org/10.48550/arXiv.1701.04817

Gaia Collaboration, A. Vallenari, A. G. A. Brown, et al. (2022). Gaia Data Release 3: Summary of the content and survey properties. *arXiv e-prints*. Retrieved from https://arxiv.org/abs/2208.00211

Kaib, N. A., & Raymond, S. N. (2014). Very wide binary stars as the primary source of stellar collisions in the Galaxy. The Astrophysical Journal, 782(2), 60. https://iopscience.iop.org/article/10.1088/0004-637X/782/2/60/meta

Harshaw, R. (2016). CCD Measurements of 141 Proper Motion Stars: The Autumn 2015 Observing Program at the Brilliant Sky Observatory, Part 3. *Journal of Double Star Observations*, 12(4), 394–399. Retrieved from http://www.jdso.org/volume12/number4/Harshaw_394_399.pdf

Sordiglioni, G. (2024). WDS 15453-4949 B 2365. *StelleDoppie*. Retrieved from https://www.stelledoppie.it/index2.php?iddoppia=63793

Urban, S. E., Corbin, T. E., Wycoff, G. L., Martin, J. C., Jackson, E. S., Zacharias, M. I., & Hall, D. M. (1998). The AC 2000: The Astrographic Catalogue on the System Defined by the Hipparcos Catalogue. *The Astronomical Journal*, 115(3), 1212. Retrieved from https://iopscience.iop.org/article/10.1086/300264