Unveiling a Binary Star: New Astrometric Analysis of WDS 01497+5355 ES 761

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Abstract

This study presents new measurements for the position angle and separation of the WDS 01497+5355 ES 761 double-star system. Our data includes information from our observations, the Gaia Data Release 3 mission, and historical records. The results reveal a position angle of 253.3° and a separation of 6.4". Additionally, we used parallax and the ratio of proper motion (rPM) metrics to determine if the system is gravitationally bound. Our analysis suggests that the system may not be binary.

1.0 Introduction

Double stars are pairs that seem near each other when viewed from Earth. These can be categorized into two types: binary stars and optical doubles. Binary stars are physically bound by gravity, whereas optical doubles are not gravitationally linked but only appear close together in the sky (Marcel et al., 2024).

More than 50% of the stars in our galaxy are binary stars (Kroupa, 1995), which means that studying binary stars is important in understanding stellar evolution, determining the stellar mass in the system, distance determination, and understanding how the stars are formed (Li and Han, 2008).

This paper will discuss our target double star, WDS 01497+5355 ES 761. It is located in the Perseus constellation with coordinates RA = 01h 49m 39.60s, Dec = +53° 54' 52.8. We analyzed historical data for this system from different sources like the Washington Double Star Catalog (Mason et al., 2001), the Gaia Data Release 3 mission (Gaia Collaboration et al., 2022), Stella Doppie, and even the Las Cumbres Observatory. We compared our new studies with the previous one (The first observation was in 1909) to analyze and detect any important details.

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. The primary and secondary stars' magnitudes, parallax, and proper motion were taken from the Gaia database. The rPM was calculated using the system's adequate motion values.

	Gaia G_{mag}	Parallax (mas)	Distance (parsec)	Proper Motion (mas/yr)	rPM
Primary Star	8.9725	0.2078	4812.3	pmra -1.219 pmdec -1.663	0.36992
Secondary Star	13.5866	0.1480	6756.8	pmra -0.461 pmdec -1.748	

Table 1 column of Proper Motion lists the proper motion (PM) of the double star system in both Right Ascension (RA) and Declination (Dec) in mas (milli-second of arc). These values were used to derive the ratio of proper motions (rPM) metric, a concept introduced by Harshaw (2016). The rPM is calculated as the difference in proper motions between the primary and secondary stars, divided by the larger of the two proper motions. This metric evaluates how different the proper motions are relative to the larger motion. Stars with an rPM less than 0.2 are likely to be Common Proper Motion (CPM) pairs, those with an rPM between 0.2 and 0.6 have Similar Proper Motion (SPM), and those with an rPM greater than 0.6 have Different Proper Motion (DPM). For example, ES 761 has an rPM value of 0.36992, indicating it is an SPM pair.

The equations to calculate rPM:

$$Resultant = \sqrt{(RA_{pri} - RA_{sec})^2 + (DEC_{pri} - DEC_{sec})^2}$$

$$Vector = \sqrt{RA^2 + DEC^2}$$

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

Where the RA represents the Right Ascension, DEC represents the Declination for both primary and secondary stars. The pri in RE_{pri}, DEC_{pri} is for Primary stars, and sec in RE_{sec}, $DEC_{sec\ is}$ for secondary stars.

1.1 Target Selection

To select a specific double star system for observation, we utilized the Stelle Doppie website, which provided access to the Washington Double Star Catalogue. We first narrowed our search to right ascension values between 1 and 13 hours, corresponding to the night sky visibility of the target stars. Additionally, we cross-referenced our selection using the Stellarium database. The telescope employed was a 0.4 m LCO instrument. However, we did not specify a particular declination since there are multiple 0.4 m LCO telescopes located in both the northern and southern hemispheres. The stars we selected had been last observed before 2015, enabling us to detect any changes in their characteristics. The angular separation between the binary components ranged from 5 to 10 arcseconds to facilitate resolving the two stars in the images taken by the LCO telescope. Also, we selected the magnitude of the primary star to be between 9 and 11 to be observed by the telescope. We selected 01497+5355 ES 761 (HD 232538) out of 250 results because:

1. Its nature is uncertain
2. It has a noticeable separation from the last measurement
3. Its last observation was in 2014 which means it will have a more noticeable separation and position difference

2.0 Methodology

On July 8, 2024, we used the 0.4m LCO telescope located at Tenerife to take 10 images of our targeted double star with an exposure time of 2 seconds each. We used the 0.74 arcseconds/pixel with a 1x1 binning mode and 1.9° x 1.2 ° field of view. We decided to use the Bissell-V filter, which is in the visible region, in our observation. The LCO processed all image files automatically using their BANZAI pipeline.

After processing the images, we use the AstroImageJ program to ensure that our system is a double star and to determine its separation and position. To do this, we opened the Aperture Photometry settings and made our aperture size 4 pixels. One of the advantages of using AstroImageJ is that it can automatically help the user determine the star's centroid. Our aperture size was large enough to enclose the stars, and they did not overlap. After adjusting the aperture and slewing to the double star, we dragged the cursor from the center of the primary to the secondary star to obtain the Position (PA) and the separation (Sep) (Figure 2).

We requested historical data for the systems from Dr. Rachel Matson at the Washington Double Star Catalog and plotted the new and historical measurements.

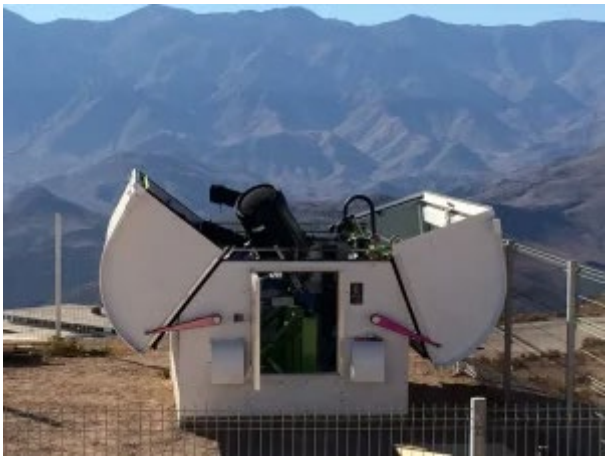

Figure 1: 0.4 m telescope located at one of Las Cumbres Observatory's sites

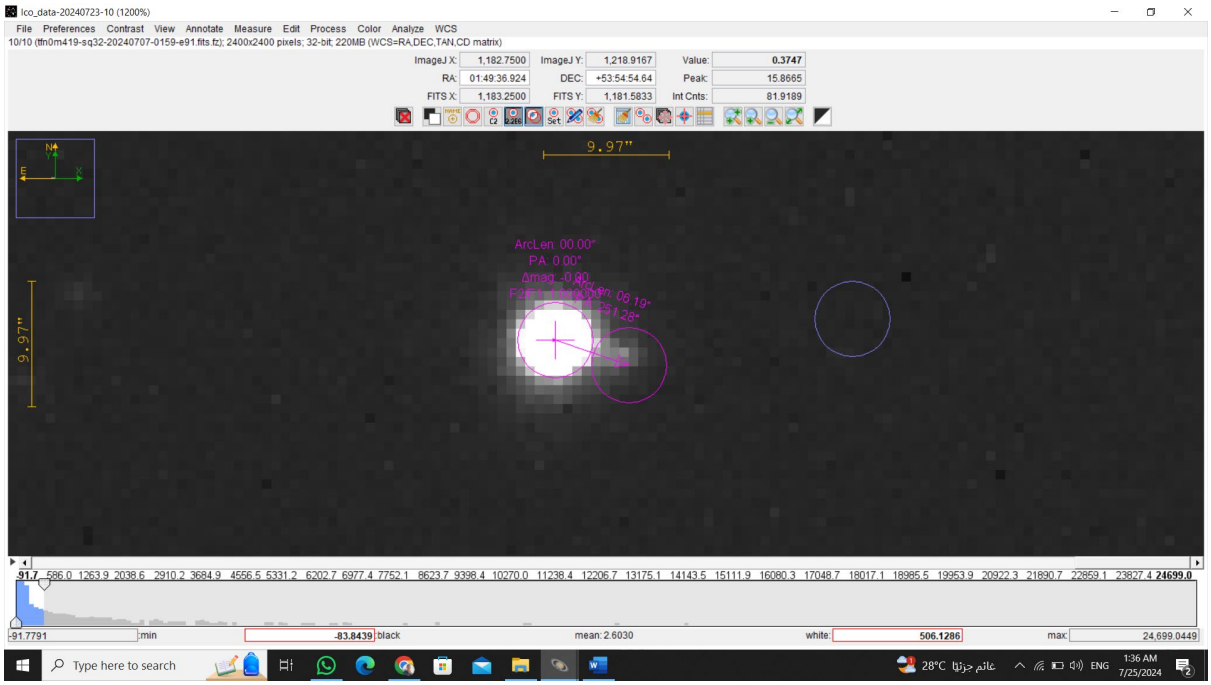

Figure 2: Sample image of 01497+5355 ES 761 (HD 232538) double star system from AIJ

3.0 Observation

Table 2 below presents the new measurements derived from our images, while Table 3 provides a summary of the statistics for these measurements.

Table 2: New measurements of WDS 01497+5355 ES 761 (HD 232538) derived from our images

No	PA (°)	Sep (")
1	252.3	6.54
2	251.5	6.40
3	249.3	6.49
4	256.7	6.28
5	251.8	6.07
6	255.7	6.24
7	257.2	6.65
8	251.6	6.87
9	254.8	6.33
10	251.3	6.19

Table 3: Mean, standard deviation, and Standard error of the mean of our measurement 01497+5355 ES 761 (HD 232538)

Double Star	Date	Images		PA (°)	Sep (")
WDS 01497+5355 ES 761 (HD 232538)	8th of July, 2024 2024.5191	10	Mean	253.3	6.40
			Standard Deviation	2.50	0.225
			Standard Error of the Mean	0.79	0.071

4.0 Discussion

We present the findings from our investigation of WDS 01497+5355 ES 761 (HD 232538), a double star system, which reveals a newly measured position angle of 253.3° and a separation of 6.4". The previous values were 256.36° and 5.151". The variations in our new measurements compared to historical data are shown in Table 4 and illustrated in the graph in Figure 3. The system has been observed five times, with contributions from Zacharias et al. (2015), Espin (1910), and Argue et al. (1992).

Table 4 lists the systems' historical data sent by the Washington Double Star Catalog. They have different numbers of decimal places

Year	Position angle (°)	Separation (″)
1909.90	249.6	4.92
1986.86	255	4.77
2000	256.9	5.29

2013.81	256.18	5.316
2014.79	256.36	5.151
2024.5191	253.3	6.4

Table 4 presents historical data from the initial observation of WDS 01497+5355 ES 761 in 1909 to our most recent data contribution in 2024. Examining the star system's separation shows a progressively irregular increase over time. This inconsistency is mainly attributed to atmospheric effects, data noise, and overall measurement uncertainty. The graphical representation of this trend is illustrated in Figure 3, with blue data points representing the historical data and the red point indicating our data contribution. Based on this trend, we anticipate a continued increase in separation in the future.

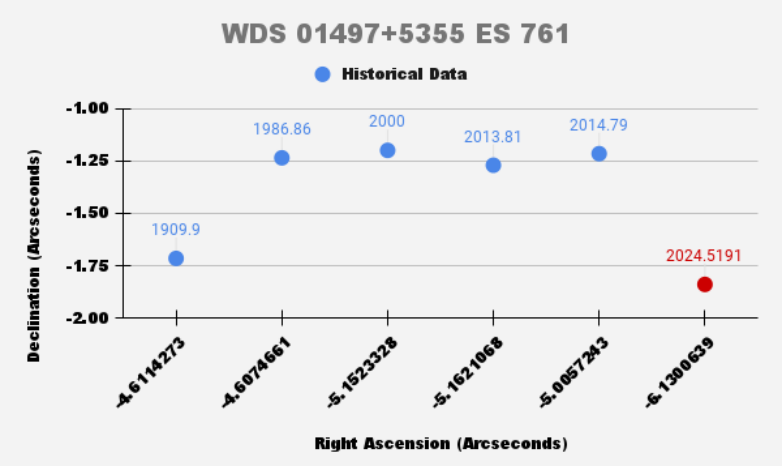

Figure 3: Plot of historical data and the new measurements of WDS 01497+5355 ES 761 (HD 232538)

The parallax values for the primary and secondary stars of the WDS 01497+5355 ES 761 system are 4812.3 pc and 6756.8 pc, respectively. These values suggest that the stars are not close to each other or gravitationally bound.

The ratio of proper motions of the system, presented in Table 1, is 0.36992. This implies the system is a Similar Proper Motion (SPM) pair. According to Harshaw (2016), SPM pairs may indicate a binary system.

The plot in Figure 3 does not show any orbital trend, as the data points form a curve but not around the origin of the graph, and Table 4 indicates an increasing separation within the system. The data from the rPM and parallax, lead us to conclude that the system is not binary and not gravitationally bound.

5.0 Conclusion

In conclusion, this study focused on the double star system WDS 01497+5355 ES 761, analyzing its position angle and separation, comparing these measurements with historical data, and calculating the parallax and proper motion for both the primary and secondary stars. The key findings of our investigation are as follows:

The updated position angle and separation of the system are 253.3° and 6.4″, respectively, compared to the previous values of 256.3° and 5.151″. While the separation is increasing, it does so in a random pattern, suggesting that the two stars may continue to drift apart in the future.

The two stars are approximately 1944.5 pc apart, indicating they are not close to each other and not gravitationally bound.

The ratio of proper motion (rPM) metric is 0.36992, which is above 0.2 but below 0.6, implying that the system is a Similar Proper Motion (SPM) pair.

The curve in the Figure 3 plot does not emanate from the origin, which suggests that the system is not in orbit around each other. Based on this observation, along with the values we obtained for the system's rPM and parallax, we conclude that the system consists of optical double stars.

We suggest conducting additional studies to monitor the dynamic changes in the system's parameters, which will help to confirm our conclusions and dee/pen our understanding of this celestial system.

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