Astrometric Measurements of Double Star System WDS 01001+4443

Puneet Sethi[1], Srivatsa Krishna[2], Stephen Rajkumar Inbanathan.S[3], Pat Boyce[4]

1. VGU, Jaipur, India
2. IIST, Thiruvananthapuram, India
3. Post Graduate and Research Department of Physics, The American College, Madurai-625002, India
4. Boyce Research Initiatives and Education Foundation (BRIEF)

Abstract: We performed astrometric measurements on WDS 01001+4443 to determine whether it is a binary or a visual double. Las Cumbres Observatory Haleakalā telescope at epoch 2023.87 was used to determine its position angle, delta magnitude and arc length through detailed measurements which were 192.98°±0.62° position angle, separation of 7.91″±0.112″ and delta magnitude of 0.909±0.07. We then compared these measurements with historical measurements to confirm if the system is gravitationally bound.

Introduction:

Our Topic of Interest is the Double Star System WDS 01001+4433 and determining if it is a binary or double Star. The Double Star System WDS 01001+4433 was first observed in 1794 by Friedrich Georg Wilhelm von Struve (Encyclopaedia Britannica, 1998).There have been 137 observations for this pair. The system was first categorized as a double star by William Herschel. The initial position angle of the system was 180 degrees and since then it has changed by a magnitude of 13.9 degrees making it 193.9 degrees.

The separation also changed from 8.0 in 1794 to 7.88 in 2022. The star system has a delta magnitude of 0.73 where the primary star has a magnitude of 6.04 and secondary star has magnitude of 6.77. It belongs to Spectral Class B9.5V+A2V(blue-white/white) which tells us about its characteristics like temperature, chemical composition, and intrinsic luminosity. This system was chosen because even after observing it for 228 years and having 137 observations it is still in orbital grade of 5. According to the 6th orbital catalog grading method, Grade 1 is considered to be definitive, it has the highest quality data, a large orbital coverage, and a good amount of several observations. Whereas Grade 5 is categorized as indeterminate with poor quality of data, limited observational data, and less orbital covering. For this particular system, there are a large number of observations, yet it still retains a grade of 5. For example, a grade 1 orbit is shown in Figure 1, and for comparison, we show the orbital solution of WDS 01001+4433 from the WDS Historical Catalog (Hartkopf 2001) at grade 5. In these images, the cross represents the primary star and the secondary star is orbiting around it. In the grade 1 image, one can observe the whole orbit whereas in grade 5 there is only a short arc traced. Notice that there are several colors used in it, each color is associated with the technique used to measure it. Blue dots were measured by speckle interferometry, pink was measured using photographic, and green with a micrometer. Green lines have the least accurate type of measurements whereas blue has the best measurement.

WDS 01001+4443 is located at 01h 00m 03.56s +44° 42' 47.7". The image of the system can be seen in Stellarium in figure 2. The yellow ring represents our WDS system. Figure 3 shows the image of the system in AIJ.

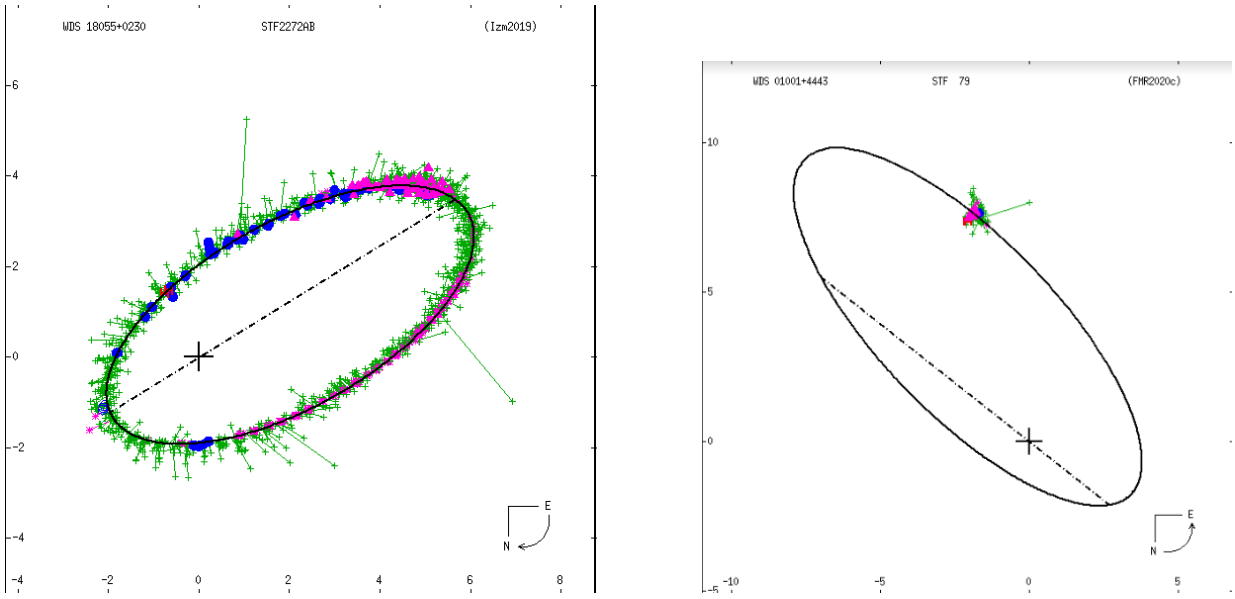

Figure 1: Grade 1 Orbit(left) next to Grade 5 Orbit of WDS 01001+4443(right)

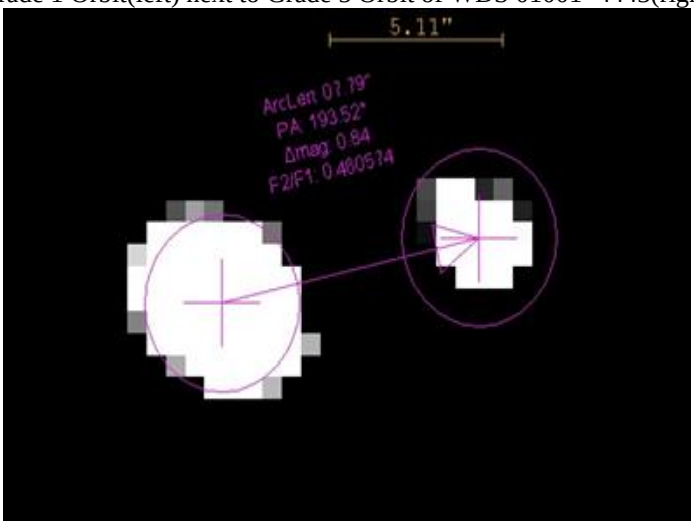

Figure 2: Image of WDS 01001+4443

Figure 3: Image of WDS 01001+4443 using AIJ

Equipment and Methods

Images of WDS 01001+4443, were acquired with the 0.4-meter reflective telescope (Figure 4) of Las Cumbres Observatory (LCO) located in Haleakalā, Hawaii, United States. On 15th November 2023, (epoch 2023.87) 12 images through Sloan u, Sloan r, and Sloan g filters with 4 images each and different exposure times given below in a Table1. The images were then processed through the OSS pipeline (Fitzgerald 2018) for image clean up followed by AstroImageJ (AIJ) further image processing and measuring. Using AIJ (Collins 2017) we determined the position angle, separation distance, and delta magnitude of all the images. Statistical mean was calculated for the values of position angle, separation distance, and delta magnitude to ensure accurate measurements using the Basic Stats Calculator in Excel.

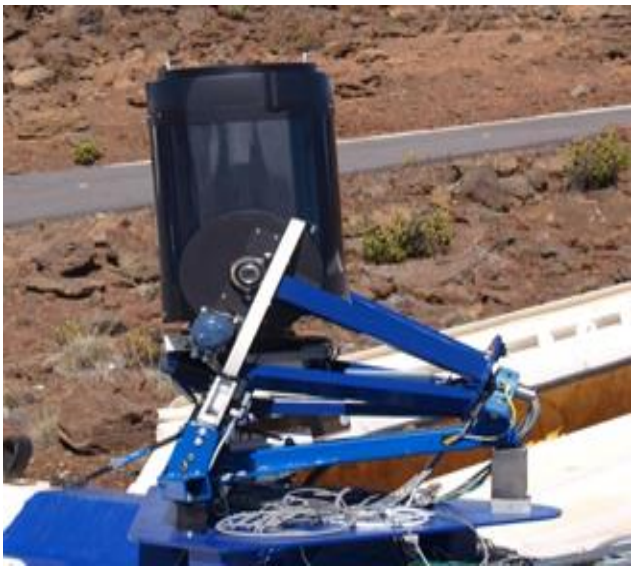
Figure 4: 0.4m Telescope LCO Haleakala

Observations					
WDS 01001+4443				Discoverer	STF 79
Date	Epoch	Observatory	Filter	Exposure time	Measured Images
11/15/2023	2023.87	LCO Haleakala	Sloan u	50s	2
11/15/2023	2023.87	LCO Haleakala	Sloan u	75s	2
11/15/2023	2023.87	LCO Haleakala	Sloan r	0.3s	2
11/15/2023	2023.87	LCO Haleakala	Sloan r	0.46s	2
11/15/2023	2023.87	LCO Haleakala	Sloan g	0.5s	2
11/15/2023	2023.87	LCO Haleakala	Sloan g	0.32s	2

Table 1: Data Table

Results

For our position angle, separation distance, and delta magnitude we took our 12 measurements of epoch 2023.87 and took the mean, standard deviation, and standard deviation of the mean which is shown in Table 2. Our position angle came out to be 192.98±0.621 degrees, separation of 7.91±0.112 arcseconds, and a delta magnitude of 0.909±0.077.

WDS 03470+4126 STF 79				
Epoch	Measurement	Theta(degrees)	Rho(arcseconds)	Delta Magnitude(sloan r)
2023.87	Mean	192.98	7.91	0.909
	Standard deviation	0.621	0.112	0.077
	Standard error of the Mean	0.179	0.032	0.022
2022	Last Meaurement	193.9	7.88	0.73

Table 2: Position Angle, Separation, and Delta Magnitude Measurements of 01001+4443 STF 79 on 2023.87

Discussion

Stellar apparent separation is the closest distance both stars can be in the sky. This physical property helps us to determine whether they are close enough to be physically bound. Studies have shown the maximum separation for two stars to be gravitationally bound is 1 light year. The apparent separation was calculated using distance in light years and separation angle, for our system we first converted our parallax distance which we got from Gaia to light years, Table 3. The parallax distance of our primary and secondary stars is 6.72 and 6.77 milliarcseconds respectively which in light years came out to be 484.97 and 481.06. We already know the separation angle and using both we calculated the apparent separation which is given in Table 3.

Convert the separation angle into an apparent separation distance by small angle approximation - use this calculator		
Input the separation angle between A and B in arcseconds	7.91	
Input the distance to the A or B star in light years (1 above)	484.61	
RESULT	0.0186	apparent separation in light years

Table 3: Apparent Separation

The apparent separation tells the closest they can be is 0.0186 which is a indicator for a double star to be a gravitationally bound binary. Table 4 gives us the error bars in distance in both parsec and light years.

Results	Parsecs			Light Years		
	- 1 Std Error (SEM)	Mean	+ 1 Std Error (SEM)	- 1 Std Error (SEM)	Mean	+ 1 Std Error (SEM)
Star A	147.60	148.60	149.62	481.167	484.441	487.761
Star B	146.85	147.49	148.15	478.715	480.833	482.970

Table 4. Errors in distance

The probability of the system to be within 1 Light year was found out to be 13.3%, Table 5, and the closest approach approximation is 3.92 light years. Calculating the probability whether they are within 1 light year in the radial direction can tell whether there is a high probability that they are gravitationally bound or not.

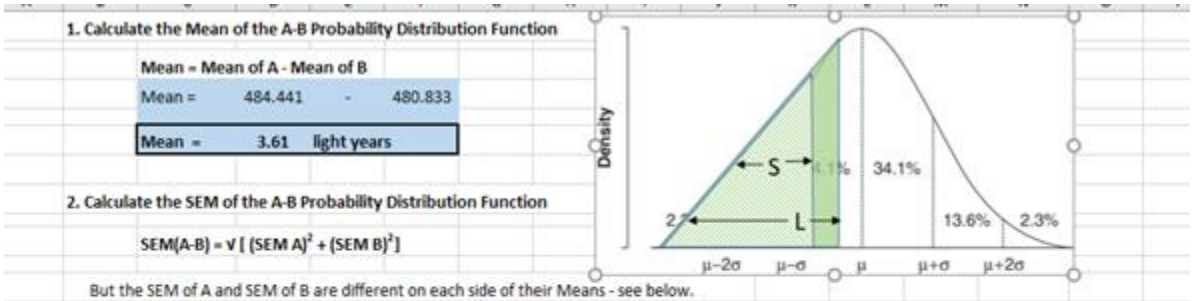

Table 5. Probability calculator

The Harshaw statistic (Harshaw, 2016) is calculated to determine if the system is binary or visual double. It is a statistical tool to do a quantitative measurement of the degree of similarity for the Proper Motion of two close stars (Harshaw, 2014). If the value is close to zero, they are likely to move together; on the other hand if it is close to 1 they are not bound together. We used the Harshaw statistics tool and got the value of 0.024388 which is close to 0 rather than one which can give us a hint that they are likely gravitationally bound. Table 6 shows the proper motion of both stars and Table 6 is Harshaw Statistics Value.

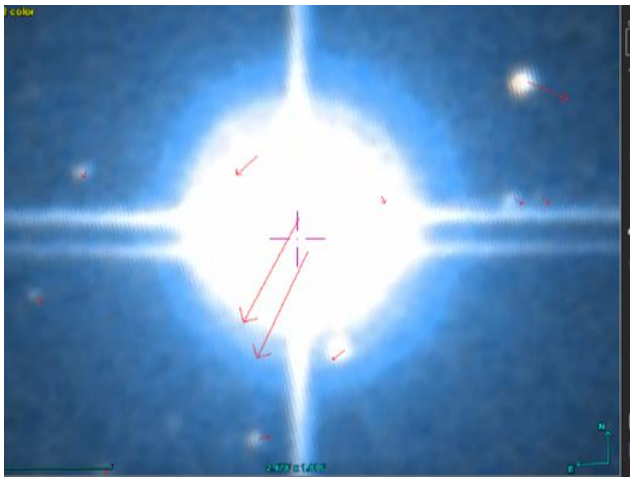

Figure 5: Proper motion image

Star Name	Proper Motion RA	Proper Motion Dec
STF 79 A	12.671	-23.581
STF 79 B	11.521	-24.209

Table 6: Proper Motion for Component Stars.

	Proper Motion Data				Vector Differences				Vector Sum				
									A Star		B Star		Sum of Star
	A Star		B Star		difference (A-B)		sum of squared	square root	sum of squared	square root	sum of squared	square root	Vector Square
	RA	Dec	RA	Dec	RA	Dec	differences		vectors		vectors		Roots
Star Name	12.67	-23.58	11.52	-24.2	1.15	0.62	1.7069	1.3065	716.5453	26.76836	718.3504	26.8021	53.5704
	Harshaw Statistic:		Vector Difference/Vector Sum		=			0.024388					

Table 6: Harshaw statistic value

We plotted all the historical data (Harshaw 2020) requested from the US Naval Observatory, Figure 6, with our primary star at origin. Figure 7 shows the plot of historical data with our new measurement as a yellow star and is zoomed for better clarity. The plot also provides a good understanding and can help us to prove our double star system indeed is a binary.

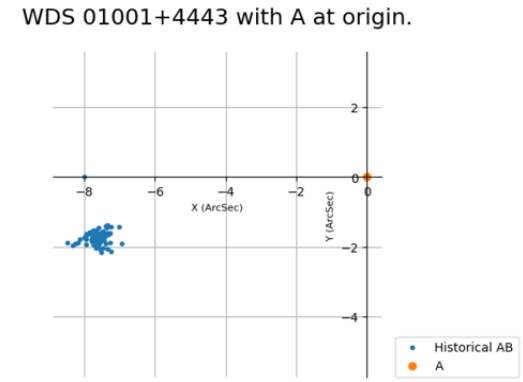

Figure 6 Plotting of historical data with A as origin

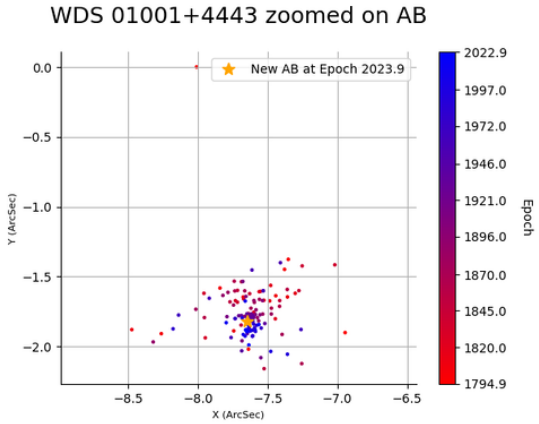

Figure 7 Plotting of historical data with A as origin(Zoomed)

Conclusion

Our test results were varied. Apparent separations for the system was found to be 0.0186 light years which is within 1 lightyear suggesting they can be gravitationally bound; further probability calculator calculates the probability of them to be within 1 light year and it came out as 13.3 % which is a good indication for them to be gravitationally bound. Using Harshaw statistics the rpm value was found out to be 0.024388 which is very close to 0 tells us the system is likely to be gravitationally bound.Our plots suggest that the system is binary rather than a visual double. So, all the above parameters be it Apparent Separation, probability calculator, Harshaw stats calculator and plotting the historical data, they all suggest the system is a binary system.

In conclusion, using the new measurements of the system using the LCO telescope and after analyzing it and comparing it to historical measurements we can say our system WDS 01001+4443 is indeed a binary system.

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