Astrometric Data of Double Stars WDS 14358-4641 R 248AB

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Abstract: Our team performed astrometric measurements of the double stars WDS 14358-4641 R 248AB (R 248AB) from 16 images captured through the Las Cumbres Observatory telescope network (LCO). With these measurements we found R 248AB to have a 289.8° ±0.9° position angle and a separation of 5.24" ±0.1" during the 2021.268 Besselian Epoch. Although estimates in the difference in parallax support the classification as an optical double, the trend in separation, low Harshaw (2014) statistic in proper motion, significant mass, and nearly identical radial velocities suggest R 248B is exhibiting evidence of linear motion towards R 248A with the potential for wide separation gravitational interaction.

Introduction

This research performed a series of astrometric measurements on a double star system to update the historical data and determine the likelihood of it being gravitationally bound. Candidate selection was based on historical data of both stars including parallax, proper motion, difference (Δ) in magnitude, position angle (θ) and separation (ρ) to the secondary star.

We selected our candidate using the Washington Double Star Catalog (WDS), the European Space Agency (ESA) Gaia Archive, and the Simbad Astronomical Database to search and filter through historical data. The candidate was selected based upon having a separation greater than 5 arcseconds, a difference in magnitude of less than 5, and a right ascension between 12 and 18. Separation distance and difference in brightness were essential for obtaining optimal resolution for the telescope and Charge-Coupled Device (CCD) equipment used while the right ascension of 12-18 enabled us to observe the system in the spring. After selecting our candidate, we requested historical data through the United States Naval Observatory (USNO) and obtained reference images from Gaia DR3 using Aladin Sky Atlas v12.060. Utilizing the Simbad references we managed to find the Sydney Observatory Double Star Results 1871-1881 where WDS 14358-4641 R 248AB (R 248AB) was originally cataloged by Russell, H. C., (1882) in 1874. Double star R 248AB was selected because it fit all of the search criteria and exhibited a consistent proper motion.

Methods and Materials

The images were captured through the LCO utilizing a modified Meade 0.4-meter compound telescope with a V Bessel Filter. A total number of 16 images were captured on April 7th, 2021 processed and calibrated through the Our Solar Sibling pipeline (OSS) developed by Fitzgerald (2018). We then analyzed and measured each image twice for a total of thirty-two combined measurements to minimize human related errors with the auto-centering feature in AstroImageJ v2.4.1, Figure 1 is an example of a single measurement performed.

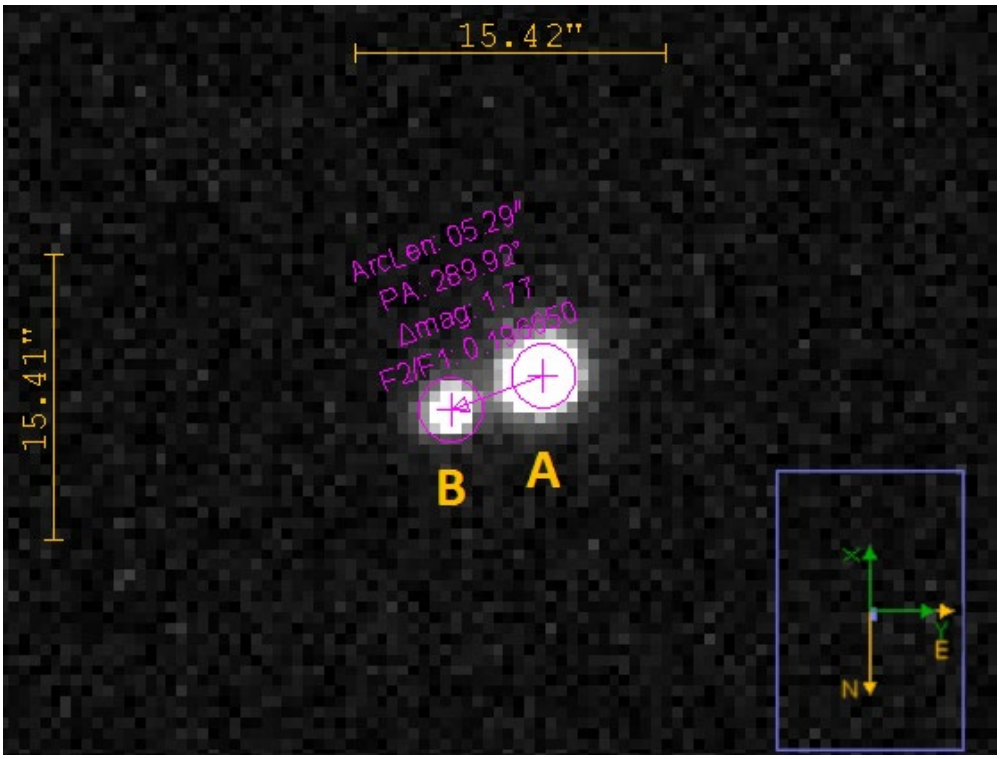

Figure 1. Sample measurement of R 248AB with V Bessel Filter in AstroImageJ v2.4.1

Results

From the 16 images, 32 total measurements were performed to calculate a mean position angle (Theta) of 289.8° ±0.9°, and mean separation (Rho) of 5.24" ±0.1", Table 1. Included in Table 1 is the mean theta and rho from Gaia DR2 and DR3 data gathered by taking 5 measurements each using the measuring tool in Aladin v12.060.

WDS 14358-4641 R 248AB				LCO kb84, 16, V filter (P/N JOHN-V-XX)			Measurement Results		
Observation	Theta (degrees)	STDEV	STDEV.S	Rho (arcseconds)	STDEV	STDEV.S	Δ Mag	STDEV	STDEV.S
Epoch 2021.268	289.8	0.91	0.16	5.24	0.12	0.02	1.73	0.08	0.01
Gaia DR3 via Aladin v12.060	290.12	0.28	0.12	5.35	0.02	0.008			
Gaia DR2 via Aladin v12.060	289.94	0.23	0.1	5.37	0.009	0.004			
Epoch 1999.38	290.6			5.32					
Epoch 1992.0	290.33			5.362					

Table 1. R 248AB Measurement Results

Discussion

We set out to compare our measurements of R 248AB by graphing them against historical measurements provided by Brian Mason at the United States Naval Observatory. There have been a total of 14 astrometric observations including our own since the original 1874 entry with the last four likely to consist of more precise measurements. To distinguish between more accurate measurements, Rick Wasson suggested we isolate 1992 and post data to examine for evidence of linear or orbital motion between the two stars. There does appear to be a trend when comparing the arguably more precise 1992-2021 measurements effectively extending the vector of the suspected wide separation motion, Figure 2.

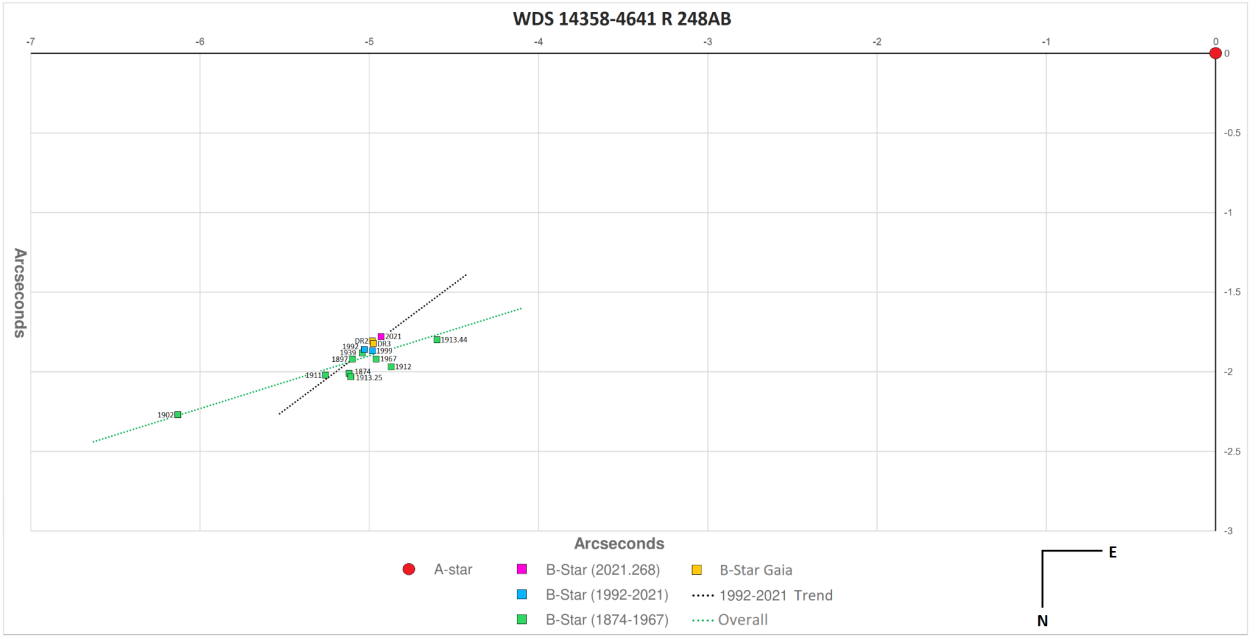

Figure 2. Graph depicting trends in R 248AB Historical Data

Both stars exhibit nearly identical radial velocities with RV(A) = -52.05 (±4) km/s and RV(B) = -42.04 (±8) km/s respectively Table 2. Considering the potential inaccuracies of early doublestar measurement techniques and parallax uncertainties, the relatively date sequenced graphing leads us to believe there is a possible trend in its projected trajectory suggesting linear motion.

HD127975A (R 248A) Gaia Data									
	ra	ra_error	dec	dec_error	parallax	parallax_error	pmra	pmdec	radial_velocity
Gaia DR3	218.9408507	N/A	-46.68555514	N/A	1.760683968	N/A	-11.94512003	-4.123622789	-52.04955
Gaia DR2	218.9408532	0.04515608026	-46.68555465	0.05991621248	1.879370927	0.07323386542	N/A	N/A	N/A
Gaia DR1	218.9408558	0.3079723254	-46.68555391	0.2094366781	1.390329615	0.3389843306	N/A	N/A	N/A

HD127975B (R 248B)									
	ra	ra_error	dec	dec_error	parallax	parallax_error	pmra	pmdec	radial_velocity
Gaia DR3	218.9388159	N/A	-46.68503458	N/A	1.632720049	N/A	-11.57596147	-3.571253846	-42.041172
Gaia DR2	218.9388183	0.04891720825	-46.68503409	0.0698178289	1.701482218	0.09840336996	N/A	N/A	N/A

Table 2. Gaia DR1, DR2, and DR3 Data for R 248AB

By combining the Gaia DR3 proper motions of pmra(A) -11.95, pmdec(A) -4.12 and pmra(B) -11.58, pmdec(B) -3.57 we calculated a significantly low Harshaw (2014) statistic of 2.7×10^{-2} suggesting these two stars are moving together, Figure 3, Table 3.

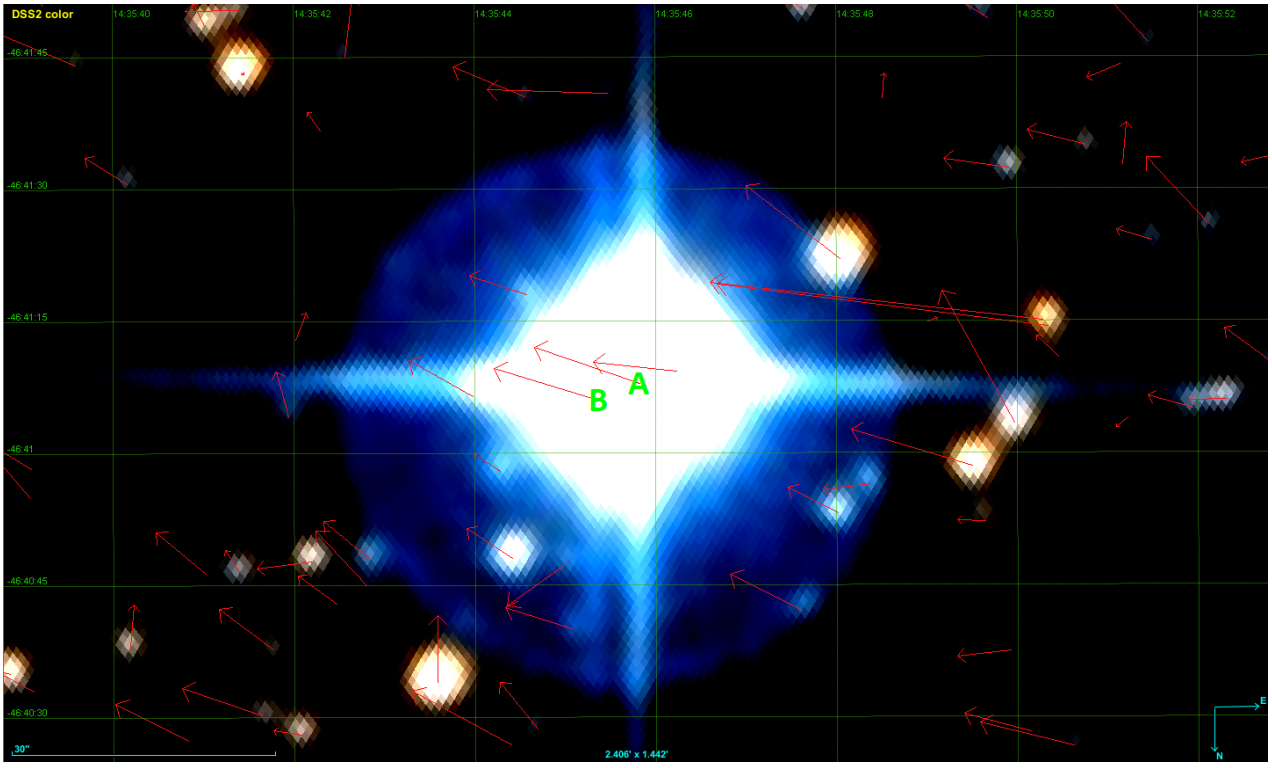

Figure 3. Aladin10 v12.060 image of R 248AB showing the Gaia DR3 proper motion vectors

It is worth mentioning in Figure 3 we noticed similar proper motion vectors of neighboring stars with varying ranges of parallax.

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
-11.945	-4.124	-11.576	-3.571	-0.369	-0.553	0.44197	0.6648	159.6904	12.63686	146.7558	12.1143	24.7511
Harshaw Statistic:				Vector Difference/Vector Sum		=	0.026859					

Table 3. R 248AB Gaia DR3 Harshaw Statistic Calculator

Based on Gaia DR3 parallax data alone, we found a standard error of mean separation of 145.157 light years and a closest approach approximation of 57.19 light years with a 0.1% statistical chance of these stars being within 1 light year of each other in the radial direction, Table 4.

	Inputs		Light Years		
	Parallax (msecs)	**Std Error (SEM)**	**-1 Std Error (SEM)**	**Mean**	**+1 Std Error (SEM)**
Star A	**1.7607**	**0.0457**	**1804.694**	**1851.536**	**1900.875**
Star B	**1.6327**	**0.0253**	**1966.224**	**1996.693**	**2028.12**
Difference	**N/A**	**N/A**	**161.497**	**145.157**	**127.246**

Star	Mean	-1 SEM	distance	Mean	+1 SEM	distance	Mean SEM	
A	1851.536	1804.694	46.842	1851.536	1900.875	49.338	48.090	light years
B	1996.693	1966.224	30.468	1996.693	2028.120	31.427	30.948	light years

SEM(A-B) = Square Root of [48.090 squared 30.948 squared]

SEM(A-B) = 57.19 light years

Table 4. Gaia DR2 Parallax Data for R 248AB

After taking the mean, standard error, and standard distributions we plotted the values on a normal distribution graph for a probability analysis of the stars parallax, Figure 4, showing some overlap around the 1st standard deviation of both targets.

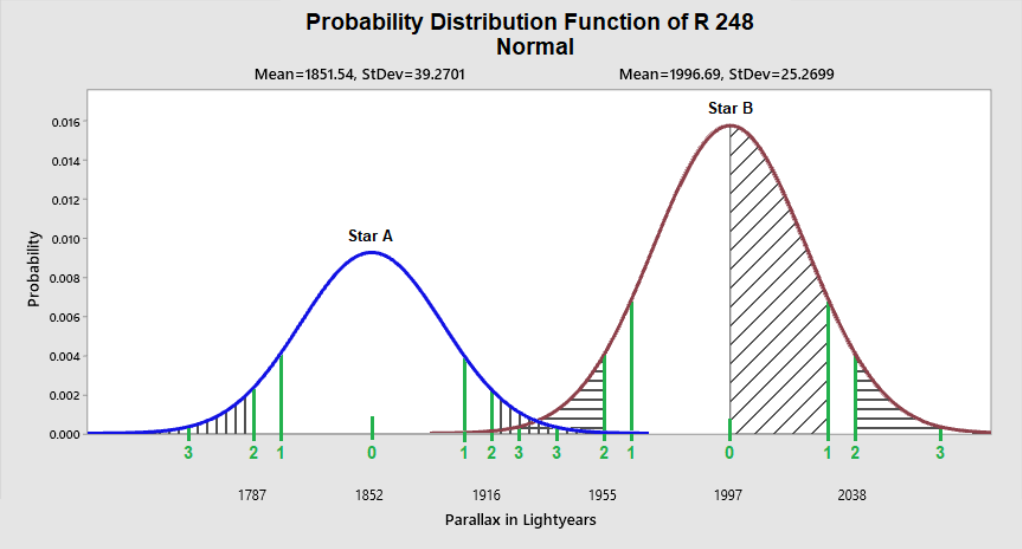

Figure 4. Graph comparing DR3 parallax of R 248AB

Further analysis was done using Plot Tool 3.19C (Harshaw 2020) where we compiled all available data and found that although the following characteristics suggest an overlap is unlikely, Figure 5, an analysis from the 6th Orbital Catalog of over 6000 stars suggests an average separation range of 800 AU to 5000 AU. Given a weighted distance result (WTD SEP) of 3,189 AU, our target and companion falls within this 5000 AU suggested range. Proxima Centauri for example is approximately ~13,000 AU from Alpha and Beta with both R 248A and R 248B being significantly more massive.

WDS 14358-4641 (DISC)

PM ANALYSIS				A Star Px, G2	B Star Px, G2	Wtd Distance		ABS MAG MODULE		
PM P RA, mas		-12	Parallax	1.76	1.63	OVERLAP	-20		STAR A	STAR B
PM P DEC, mas		-4	PXerr	0.05	0.03	RANGE	69	Mag App	8.28	9.94
PM C RA, mas		-12	Err %	3%	2%	% O-LAP	-29%	Dist Pc	568	612
PM C DEC, mas		-4	MIN DIST	554	603			Mag Abs	-0.49	1.01
First Yr Obs		1874.43	MEAN	568	612	WTD PX	1.70	Lum	136.274	34.170
Last Yr Obs		2021	MAX DIST	583	622	WTD DIST	589	RADIUS MODULE		
Years Obs'd		146.57	AB SEP	3,073	3,314	WTD SEP	3,189		STAR A	STAR B
Result. θ	Q =	0.67	Rad Vel	-52.05	-42.04			Lum (⊙)	136.274	34.170
	θr =	33.71	Radius	0.00	0.00	NO OVERLAP		T-eff	7,853	9,140
Quadrant Adj		0	Lumin	0.00	0.00			Rad (⊙)	10.013	4.648
	ρ by PM =	0.10	Teff	7,853	9,140			MASS FUNCTIONS		
	θ by PM =	33.71	G Mag	8.28	9.94	Est Lum Class		Mass/Lum Est	4.07	2.74
First X, Y	2.01	-5.12	B Mag	0.00	0.00	(WDS)		M <0.43 M⊙	16.05	8.80
Last X, Y	-4.93	-1.78	R Mag	0.00	0.00	A	A	M <2 M⊙	3.42	2.42
	ρ by Meas	7.70	B-R Index	0.00	0.00			M < 20 M⊙	3.70	2.49
	θ by Meas	295.72	DR2 Theta	290.56				M > 55 M⊙	0.00	0.00
			DR2 Rho	5.41		Estimated Mass ⇧				

Figure 5. Analysis of R 248AB using Plot Tool 3.19C (Harshaw 2020)

Further observations are being planned as a number of closely neighboring stars appear to exhibit similar proper motions leading us to suspect R 248AB as a potential candidate for a multi-star system or loose cluster formed together and now spreading apart.

Conclusion

While current parallax data suggests that this system is an optical double, close separation bias and parallax uncertainties may skew lesser known wide separation data that may take hundreds or thousands of years to notice a significant change before an orbital motion may be perceived. Our measurements appear to be consistent with previous observations while exhibiting nearly identical radial velocities with a low Harshaw statistic from similar proper motions being a significant indicator of a being gravitationally bound. Although the gravitational interaction of these two stars remains uncertain, the significant mass, shared proper motions, comparable radial velocities, and date sequenced trends show evidence of linear motion making follow up measurements worth performing in the future.

Acknowledgements

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