New Measurements of the WDS 15232+3017 (STF 1937)

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Abstract

The quintuple system WDS 15232+3017 was observed using the iTelescope network's T19 telescope to make new measurements of the system's angular separation and position. WDS 15232+3017 AB,C has an average angular separation and position angle of 76.84" and 357.14°, AB,D 218.06" and 39.77°, AB,E 213.73" and 130.20°. These measurements, combined with parallax and proper motion data from Gaia DR3 and SIMBAD, suggest that the stars are physically relationship. It was not possible to measure AB, it is outside the resolution limit of the telescope used.

1. Introduction

The goal of this research was to provide additional measurements of angular separation and position angle to determine whether the components of WDS 15232+3017 form a binary system. Furthermore, to provide new measurement data for the WDS on the components AB,C, for AB,D and AB,E. WDS 15232+3017 is registered as a quintuple system with components A, B, C, D, E. There are 8 observations of stars C and D each, and 1 observation of star E in the WDS. The number of observations of the AB components is over 1 000, and the orbit elements are also known for this. In this paper, the various orbit solutions are illustrated, and the calculated angular separation and position angle for the year 2023 are also given.

2. Brief History

WDS 15232+3017 was discovered by Sir William Herschel in 1781. The first successful measurement of AB was made by Friedrich von Struve in 1827. The first successful measurement of component C was made in 1856, and component D in 1879. The star marked E was added to the system in 2000. In the WDS, the last observation for stars C and D was in 2006, for star E in 2000.

3. General Description

WDS 15232+3017 (STF 1937) is in the constellation Corona Borealis, Bayer's name is Eta CrB, Flamsteed's is 2 CrB. It is listed in the SIMBAD database as HD 137107, SAO 64673, GL584A, Tyc 256-01366-1. Its celestial coordinates are 15h 23m 12.23s +30° 17' 17.7". The distance of the primary star from Earth is between 17.86 and 16.72 parsecs (SIMBAD, Wenger et al, 2000).

There are a very close double stars here, which we consider to be the main star. It has two similar type companions further afield, as well as a brown dwarf.

4. Equipment and Methods

The images were acquired by the T19 telescope, located in Beryl Junction, Utah, USA, at an elevation of 1 570 meters. The CCD camera for T19 is an FLI-PL 16803 with a resolution of 0.63" per pixel, housing an array 4096 by 4096, with a FOV of 43,2 by 43,2 arcminutes. The CCD camera is mounted on a Planewave 17 Corrected Dirk-Kirkham (CDK) OTA, with a focal length of 2 912 mm with an aperture of 431 mm and a focal ratio of f/6.8.

First, 10 images taken on July 4, 2023 (2023,512) with 60s exposure time and luminance filter. Second, on July 12, 2023 (2023,526), 10 images were taken with an exposure time of 120s and luminance filter. Figure 1 shows the instrument. Source: iTelescope.net.

Figure 1: The T19 Telescope

For measurements, was used AstroImageJ (Collins et al, 2017) software. The FITS files were calibrated using my astronomy.net key within the software. At this point, the program shows the images with the correct skyline, and allows for accurate separation and position angle measurement. Was adjusted the brightness and aperture sizes individually to get the best results.

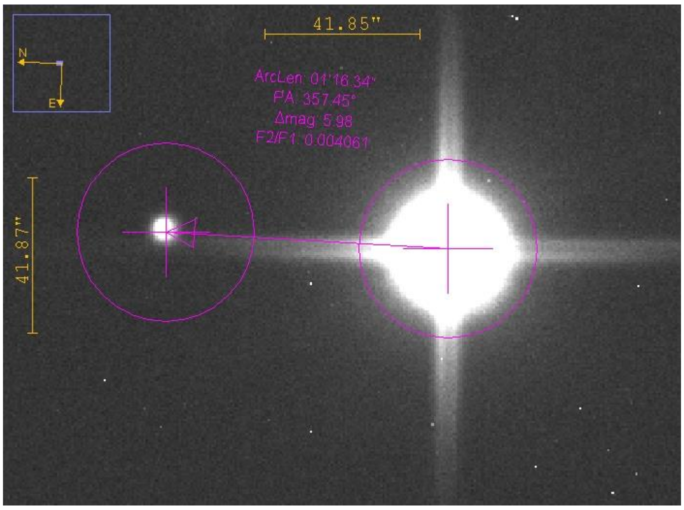

Figure 2: AstroimageJ during measurement.

All images were measured as shown in Figure 2. Was obtained astrometric data of the stars from the online databases of GAIA DR3 and SIMBAD (Gaia Collaboration, 2022 and Wenger et al, 2000). Was analyzed these with Plot tool Excel spreadsheets (Harshaw, 2020) and Rowe-Harshaw (RHS) Excel spreadsheet (Harshaw, 2018). Was rounded the values obtained by measurements and calculations to 2 decimal places.

Was also used the interactive sky atlas ALADIN (Bonnarel et al, 2000), the Stellarium software (Zotti et al, 2021) for the research. Was received the WDS data on the Stelle Doppie (Sordiglioni) website, and the detailed data sets were requested from the USNO.

The latest DR3 release database of the ESA Gaia space observatory only contains data on components C and D. The satellite only measured the G,B,R magnitudes and exact position of component A. No data is available for component B. The SIMBAD database operated by the University of Strasbourg, on the other hand, contains more data than this, although they are not the most recent, but they provide a good starting point for performing the calculations. The Kirkpatrick et al study published in 2000 provides more information about the brown dwarf. Since there are no T-eff data for the AB pair, average surface temperatures corresponding to their spectrum type (G2V) were used. There is no exact surface temperature for the brown dwarf either, the mentioned study only puts it between 1300 and 1600 K°. It was calculated using the average of these two values.

The parallax data for star A is 1995, but the Hipparcos satellite provided a new parallax value for the two stars (A and B) in 2007. It was assumed that there is no great distance between them, since they appear very close, so the error-corrected parallax was given to component B as well. The data appearing in different sources and at different times cannot provide a sufficiently certain result, but this state reflects our current knowledge of the stars of the system. If there will be more accurate measurements of the stars in the future, the following findings may of course change.

5. Data

Figure 3 shows an image of WDS 15232+3017 with the components marked. Unfortunately, the E component is difficult to notice because it is more visible in the IR spectrum. This caused difficulties during the measurement, so the result is uncertain.

The AB components do not separate in the picture, they look like one star. However, the other components were well measurable. Component E is only noticeable as a faint speck of a few pixels.

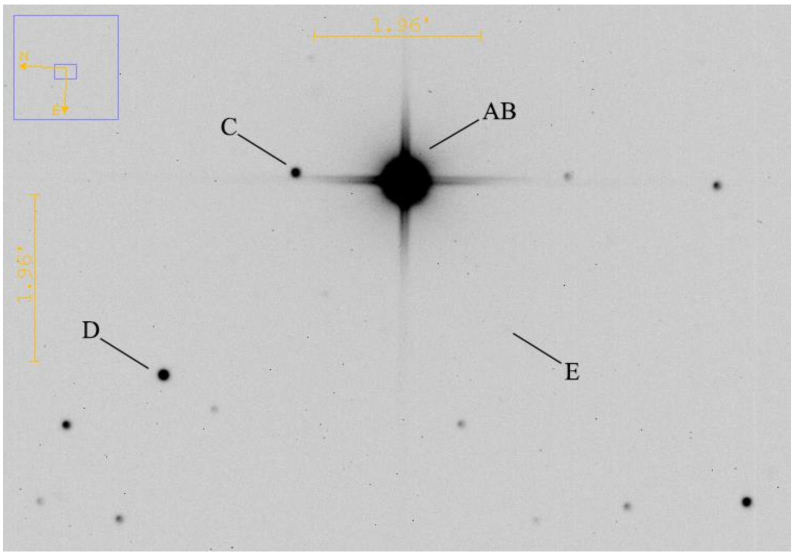

Figure 3: The WDS 15232+3017 system

The following table (Table 1) summarizes the results of measurements made in the images. The average (Mean), standard error (STE) and standard deviation (STD) of the measurements are given individually. The angular separation and position angle calculated from the coordinates from the Gaia and SIMBAD databases are also indicated with the 2016 epoch. (Gaia). The difference between the brightness of the two stars was also calculated from data in databases.

Table 1: Summary of results

	AB,C			AB,D			AB,E		
	Sep"	PA°	Δ mag	Sep"	PA°	Δ mag	Sep"	PA°	Δ mag
Mean	76.84	357.14	6.02	218.06	39.77	5.46	213.73	130.20	10.37
STE	0.04	0.04	0.04	0.06	0.01	0.04	2.07	0.80	0.48
STD	0.05	0.05	0.05	0.07	0.02	0.05	2.82	1.08	0.61
Gaia	75.11	357.70	7.89	217.82	40.32	7.01	189.96	136.33	10.55

The recent measurements have been compared with the latest observations at WDS. The differences are shown in the following table.

Table 2: Deviations from WDS

Comp	**Epoch**	**Δ Sep"**	**Δ PA°**
AB,C	2006	3.10	98.54
AB,D	2006	0.40	1.13
AB,E	2000	20.23	6.20

6. Discussion

First, based on the collected data, the astrophysical properties of the components were determined using the Plot tool in the Excel spreadsheet. These are summarized in Table 3.

Table 3: Astrophysical properties

Comp	**Rad (ʘ)**	**Mass (ʘ)**	**Lum (ʘ)**	**Spect**	**T_{eff} K°**	**Abs Mag**
A	1.30	1.14	1.72	G2V	5 830	4.25
B	0.99	1.00	1.00	G2V	5 830	4.83
C	1.27	1.12	1.59	G	5 656	4.33
D	6.94	2.75	48.53	G	5 820	0.63
E	0.02	0.04	0.00	L8V	1 450	14.71

The mass values were estimated with the Plot tool, this Excel spreadsheet also estimated the spectrum type of components D and C in the "Spect" column. With the help of this data, the components could also be placed on the HRD (Figure 4).

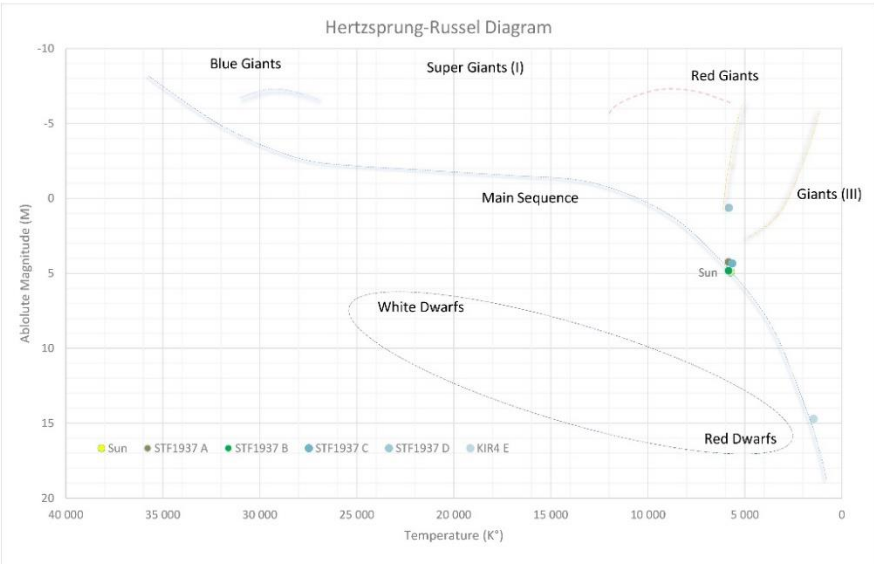

Figure 4: Components on the HRD.

The stars in the system WDS 15232+3017 are in the main sequence and are solar-like. The exception is star D, which is a giant star. The component E is also on the main sequence, but at the bottom of it.

The results of the detailed examination of the relationship of the components to each other are summarized in Table 4. First, some explanation for the table.

- The "Overlap" column shows the correlation between the distance between the two stars. Parallax errors must also be considered. In this way, it can be determined whether there is an overlap in the distance of the stars from the Earth.
- The "Wtd Sep" column shows the projected distance between the members as seen from Earth. The value is given in astronomical units (AU).
- The next two columns are a theoretical limit. They show how large the gravitational limit calculated from the mass of the stars can be. The first column shows the gravitational limit of the primary star, and the second the gravitational limit resulting from the mass of the two stars. In practice, we do not know where such a border between the stars might lie, but some theoretical value must be taken into account in order to establish the physical relationships. If the values of the "Wtd Sep" column do not exceed those of the two columns, the interaction between the two stars is likely. The value is given in astronomical units (AU).
- The column "V_{esc}" shows the escape velocity of the system, and the next column shows the difference in radial velocities. The values are in km/s. If the latter is smaller than the former, then a physical connection between the stars is possible.
- The "V_{orb}" and "V_{obs}" columns contain the values of the maximum orbital velocity and the observed orbital velocity calculated from the historical data of the observations. The values are in km/s. If the observed velocity does not exceed the orbital one, then a physical connection is possible.
- The column "∑ Prob" shows the aggregated possibility of gravitational interaction in percentage. Here you can see that there is a gravitational interaction between each member of the system.

Table 4: Relationships of components

Comp	Overlap	Wtd Sep	M_A Limit	$\sum M_{tot}$ Limit	V_{esc}	ΔRV	V_{orb}	V_{obs}	∑ Prob
AB	15%	40	3 061	11 587	9.71	1.36	7.54	0.04	95.05%
AB,C	-98%	2 619	3 061	12 253	1.24	26.63	0.96	20.77	86.96%
AB,D	-95%	7 687	3 061	21 073	0.95	138.04	0.74	1.66	89.90%
AB,E	-6%	3 464	3 061	6 380	0.78	No RV	0.60	0.94	88.82%

In the case of AB components, the gravitational bond exists since it is a very close pair. Even the E component has an overlap, but it is much less than the former. While there is no overlap in the case of members C and D.

The projected separation does not exceed the aggregate limit for any component. But the D and E components are already beyond the gravitational binding limit of the A star. Their weighted value is a maximum of 2.5 %.

Only for the AB components, the possibility of gravitational bound is shown by the difference between the escape velocities and the radial velocities. Unfortunately, radial velocity is not available for component E.

This is also the case for the relationship between the maximum orbital velocity and the orbital velocity calculated from historical observational data. Thus, the different velocities do not show the possibility of gravitational bound, except for the AB component. The maximum weighted value of the speed correlation is 5%.

The appendix of the RHS Excel spreadsheet gives a binarity probability from the distance and proper motion values of the components. The weighted value of the various indicators indicating the existence of a gravitational bond was added to this probability (see above). An additional maximum of 2.5% was assigned to the R^2 value indicating the fitting of the trendline. This is how the aggregated probability was formed.

From the historical data received from the USNO, the Plot tool drew the diagrams shown in Figure 5 per pair. For the AB components, the more than 1000 observations nicely show the orbit of the B component. Here the gravitational bound is clear. The fit of the trend line to the data points is also very high for the other components also. Furthermore, the length and direction of the resulting motion vectors are the same, with only component E showing a difference in direction and length. These very well indicate the possibility of a physical relationship between the stars.

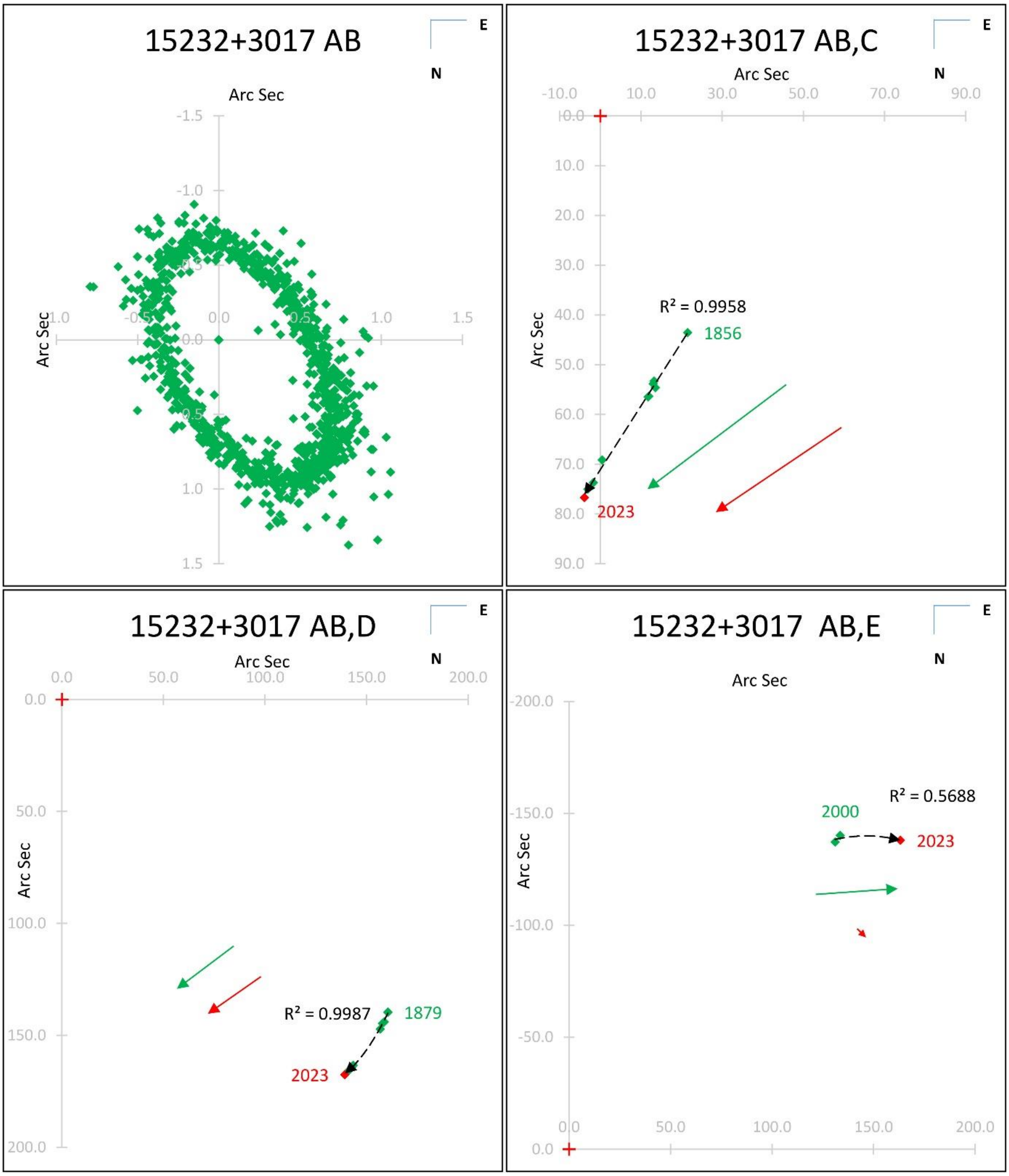

Figure 5: Historical observations of components.

Among the data points, the new observation was marked in red. The date of the first observation was also indicated. The red vector is predicted based on the proper motions, and the green one is the vector calculated based on the measurements. An orbit calculation was also performed for the AB component. This was compared with the orbit shape received from the USNO. Figure 6 shows that the two orbits have the same shape.

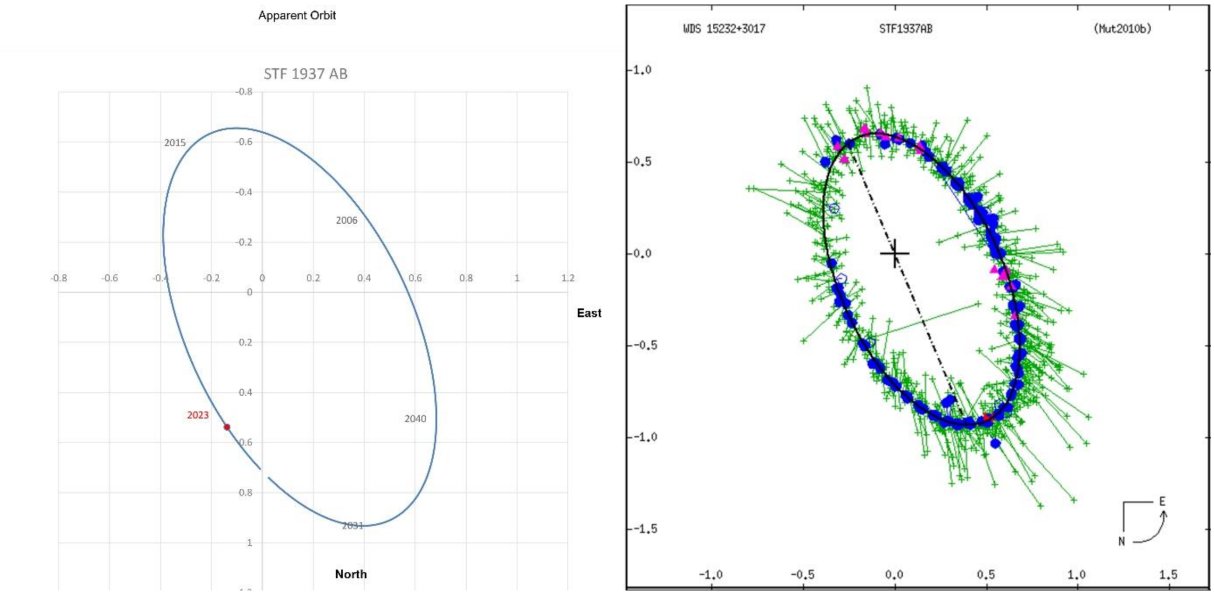

Figure 6: Orbit solutions.

During the orbit calculation, for the position of component B in 2023, an angular separation of 0.52" and a position angle of 340.81° results were obtained.

Plotting the angular separation relative to the year of observation gives a good impression of the uniformly receding motion of the secondary stars.

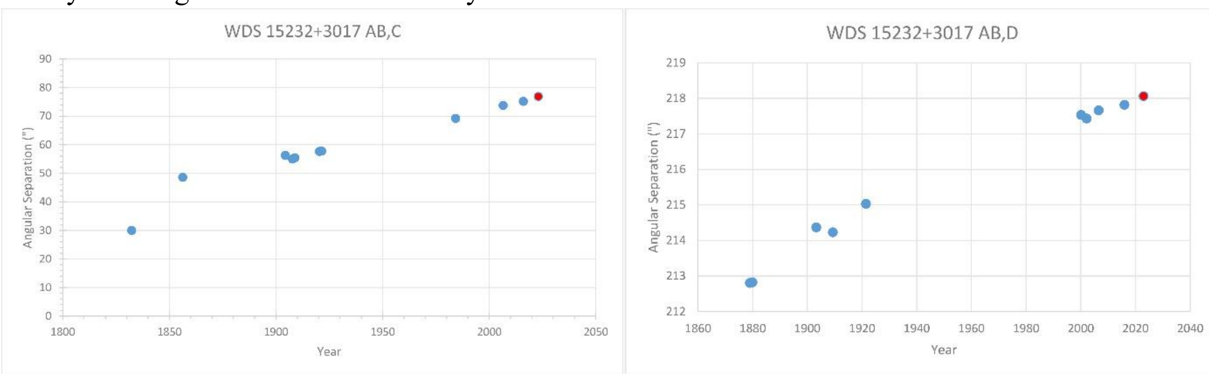

Figure 7: The motion of the secondary stars in WDS 15232+3017 relative to the primary stars. Historical data is shown in blue and current test results in red.

7. Conclusion

During the research, the latest angular separation and position angle of the components of the WDS 15232+3017 quintuple system were determined. It has been established that the stars of this system are gravitationally bound.

8. Acknowledgements

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