New Astrometric Measurements of WDS 21267-2225

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Abstract

WDS 21267-2225 (SEE446) or ζ Capricorni is a double star system that has been observed only a few times. Its last measurement was carried out in 1998. On November 21, 2022, I made astrometric measurements of the position angle and separation of the double star in images taken by the T32 telescope of the iTelescope network. My measurement resulted in a separation of 16.26 arcseconds and a position angle of 14.14 degrees for the AB components. I also found a new component. I measured the separation and position angle of this new C component. I got 85.00 arcseconds in its separation and 76.34 degrees in its position angle.

1. Introduction

My observing program includes new measurements of neglected double stars of the Washington Double Star (WDS) catalog. The separation of the doubles I selected is usually greater than 5" and was usually last observed before 2005. That's why I chose the double star WDS 21267-2225, which was last observed in 1998. It looks like a standard double system, but the main star has a very close white dwarf counterpart, the existence of which was proved by Erika Böhm-Vitense in 1980.

The WDS 21267-2225, discoverer name SEE 446, is a double star system in the constellation Capricornus. It is one of the main shaping stars of the constellation. J2000 coordinates are RA 21h 26m 40.03s; Dec -22° 24' 41.0". Other designations of the main star are HD 204075, HR 8204, TYC 6372-1278-1. T. J. J. See discovered the pair in 1897. At the time, he assigned components A and B to the system. Only 5 observations have been made of this double in the past 124 years. Table 1 contains the data for the observations recorded in the WDS catalog.

Epoch	Θ (°)	ρ (")
1897.82	13.6	21.44
1899.01	13.8	21.51
1900.38	12.1	21.12
1933.78	12.7	20.21
1998.52	11.9	17.29

Table 1: Historic data

2. Equipment and Methods

The images of the double star were acquired by the T32 telescope, located in Siding Spring, Australia. The CCD camera for T32 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. With exposure times of 60 s and luminance filter were taken 10 images. Figure 1 shows the instrument. Source: iTelescope.net.

Figure 1: The T32 telescope

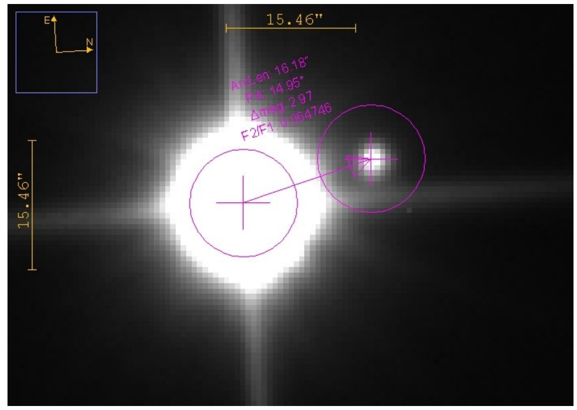

Figure 2: Measurement with the AstroImageJ.

For measurements, I used AstroImageJ (Collins et al, 2017). 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. I adjusted the brightness and aperture sizes individually to get the best results. All images were measured as shown in Figure 2.

I obtained astrometric data of the stars from the online databases of GAIA DR3 and Simbad (Gaia Collaboration, 2022 and Wenger et al, 2000). I analyzed these with Plot tool Excel spreadsheets (Harshaw, 2020) and Rowe-Harshaw (RHS) Excel spreadsheet (Harshaw, 2018). I rounded the values obtained by measurements and calculations to 2 decimal places.

3. Data

Table 2 contains the measurement data of WDS 21267-2225. Table 2 contains the measurement data for WDS 21267-2225. At the bottom of the table, I have given the mean, the standard deviation, and the average error. In the table, I also indicated the measurement of the possible C component, as well as the position angle and separation calculated from the Gaia coordinates.

Slice	AB ρ (")	AB Θ (°)	AC (")	AC Θ (°)
1	16.01	14.01	84.95	76.38
2	16.21	14.46	84.99	76.34
3	16.27	14.70	85.00	76.38
4	16.85	11.86	85.00	76.41
5	16.14	14.47	85.02	76.37
6	16.11	14.68	85.05	76.37
7	16.25	14.17	84.80	75.98
8	16.25	14.11	85.01	76.42
9	16.26	14.96	85.10	76.34
10	16.28	13.95	85.03	76.37
Mean	**16.26**	**14.14**	**85.00**	**76.34**
Avg Err	0.12	0.52	0.05	0.07
Std Dev	0.22	0.86	0.08	0.13
Gaia data	**16.73**	**12.78**	**85.10**	**76.19**

Table 2: My measurement data

I collected astrometric data from the Gaia DR3 and Simbad databases, which I summarized in Table 3. Here you can also see the calculated proper motion data. Table 4 contains the properties of stars. I have already included the properties of the possible C component.

Comp	RA	Dec	Parallax mas	Px err	PM RA mas/yr	PM Dec mas/yr	PM mas/yr	Rad vel km/s	G mag
A	321.6667758	-22.411215	7.35	0.2702	-3.87	23.70	24.01	2.10	3.53
B	321.6678879	-22.40668352	0.65	0.0186	-9.62	-14.01	16.99	7.70	11.66
C	321.6916059	-22.40557252	7.85	0.0436	-3.69	22.81	23.11	1.88	12.54

Table 3: Astrometric data

Comp	App Mag	Abs Mag	Lum⊙	Rad⊙	M⊙	T-eff K°
A	3.53	-2.14	626.32	26.57	5.72	5 125
B	11.66	0.73	44.17	6.90	2.68	5 357
C	12.54	7.01	0.13	0.42	0,60	4 403

Table 4: Properties of stars

Knowing the physical parameters of the stars, I placed them on the Hertzsprung-Russel diagram (HRD). As shown in Figure 3, components A and B are located between the giants, and the supposed C member is located on the main sequence. I also indicated the position of the Sun. The markings do not reflect the color and magnitude of the stars.

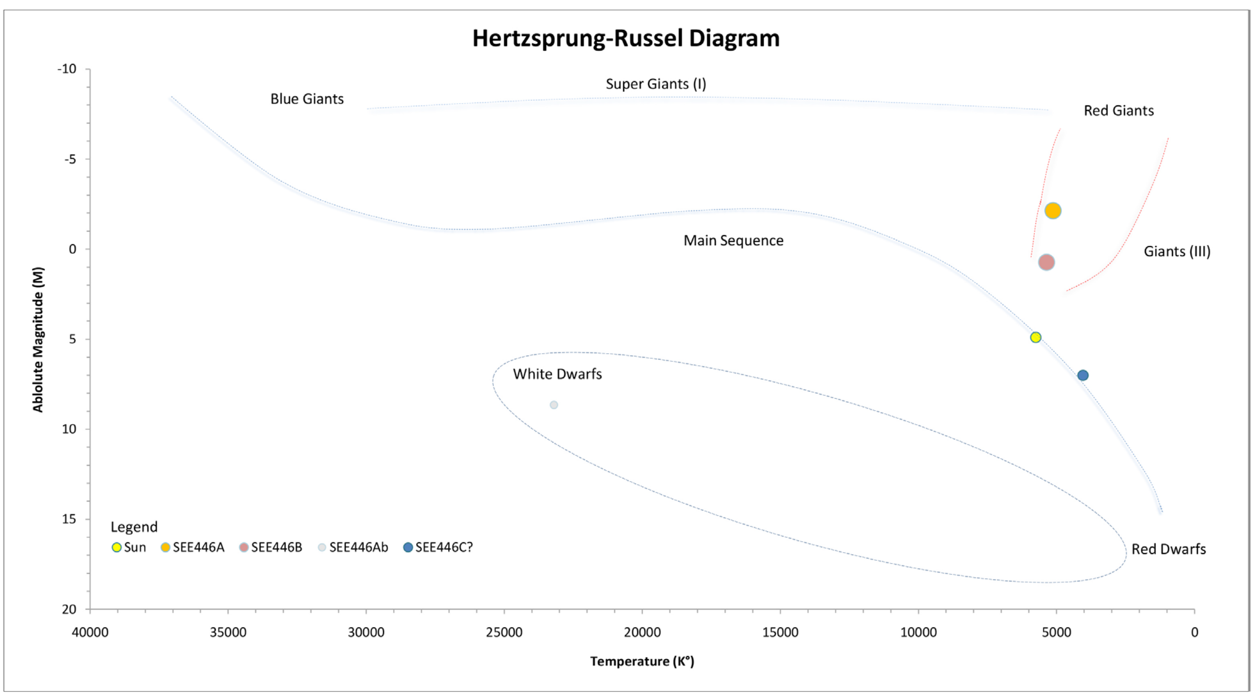

Figure 3: Hertzsprung-Russel diagram

There is extremely little information about the white dwarf next to member A. In her 1980 article, Erika Böhm-Vitense gives calculations and data based on her own observations. At that time, she calculated the surface temperature of the white dwarf at 23,200 K°, its absolute magnitude at 8.64 m, and its mass at 0.94 Mʘ (Erika Böhm-Vitense, 1980).

4. Discussion

In this paper, I have made extensive use of Richard Harshaw's articles and method of establishing the physical relationship between the stars. As a first step, I analyzed the distance data between the stars. I will ignore the dwarf star next to A component for the time being because its gravitational bond is not in question. In Table 5, we can see the distance data of the components in AU, in parsec and in light-years. The rPM column is a measurement number proposed by Richard Harshaw (Harshaw, 2018) to estimate whether the members of a binary star have nearly the same spatial motion. In a double star system, if rPM is less than 0.2, then it is likely that the stars will move together in space. Since it is less than 0.2 here, it is probable that the stars have a common proper motion. I got the maximum distance data using the Plot tool Excel spreadsheet.

Comp	AU	Parsec	Light-year	rPM
AB	25 656	0.124	0.406	0.1291
AC	11 578	0.056	0.183	0.1442

Table 5: Distances

Analysis of the AB pair

As a second step of the analysis, I visualized the collected data graphically. The graph of the measurements data shows a large discrepancy, but a clear pattern can be we discovered, this we can see in Figures 4 and 5. I marked my measurement in red, the position calculated from the Gaia coordinates in yellow, historical data in green.

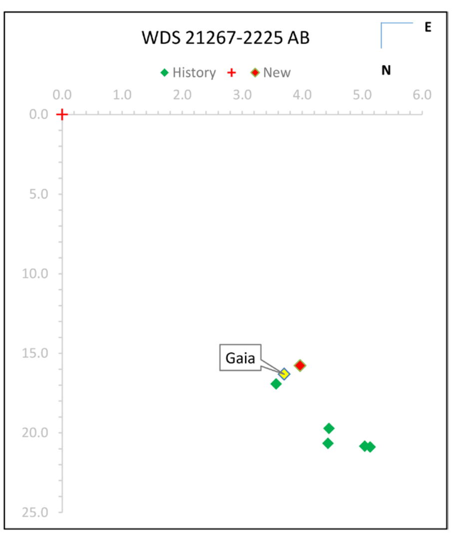

Figure 4: Graph of AB pair

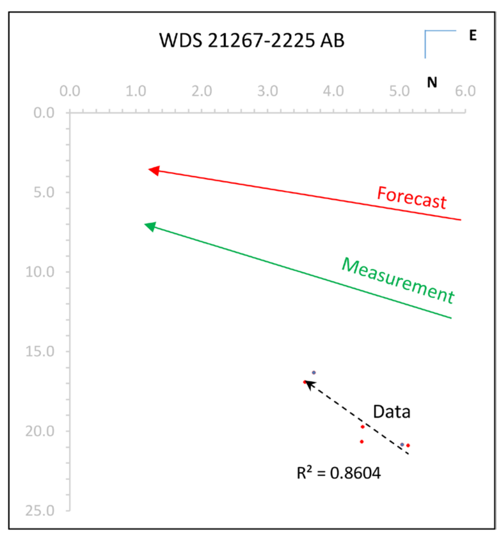

Figure 5: Pattern in the data

The vectors shown in Figure 5 do not run parallel, this suggests that the movement of the stars is influenced by the gravitational force between them. The direction and magnitude of the linear trend line of the data is slightly different from the previous vectors, based on the high R2 value, this vector matches the measurement data well.

If I plot the position angles and separations broken down by year, then a different pattern is formed, as shown in Figures 6 and 7.

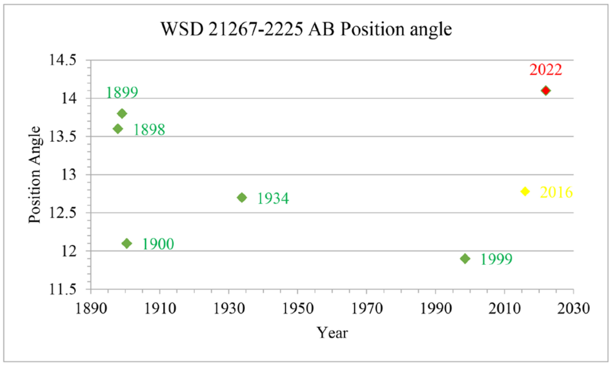

Figure 6: Position angle of AB pair

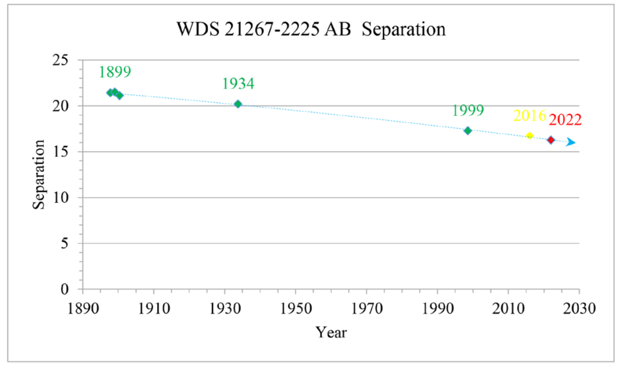

Figure 7: Separation of AB pair

The position angles show a large variance, I could not discover a correlation between them. However, there is a clear trend line in the separation. Analysis of the rPM number and vectors shows that there is a high probability of a gravitational bond between the two stars. In Table 6, I show the differences between last and my new measurement for the pair. For the brightness values, I used the G magnitude of the Gaia DR3 database. In the last column, I show the average difference.

Epoch	Δρ	ΔΘ	ΔMag1	ΔMag2	Avg diff
1998.52	1.03	2.24	0.21	0.84	0.99

Table 6: Differences

The White Dwarf

As I wrote earlier, we have little information about this white dwarf star, but its orbital elements are known, so we can well depict its orbit, which is shown in Figure 6. I highlighted the position of the white dwarf in 2022.

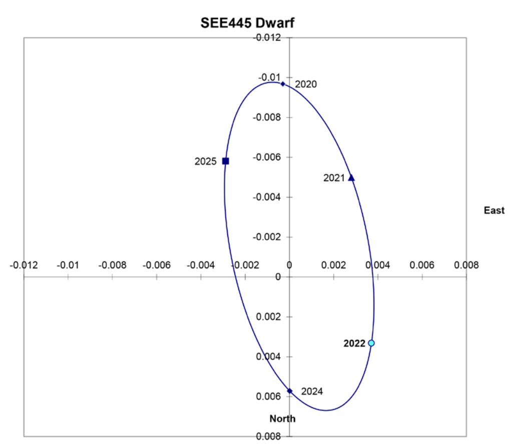

Figure 6: Orbit of the white dwarf

The new possible C component

I compared the parallaxes of the stars in the environment of A member with the parallax of ζ Capricorni. I saw that the parallax value of the star marked 2MASS 21264598-2224204 is approximately equal to it. Therefore, I analyzed the relationship between the two stars with the Plot tool Excel spreadsheet. Figure 7 shows the position of the new C member in my image. Figure 8 shows the same sky area in the blue filter image of the ALADIN DSS. I marked the position of C component in both images. For the analysis, I used the Plot tool Excel spreadsheet and the Rowe-Harshaw (RHS) Excel spreadsheet.

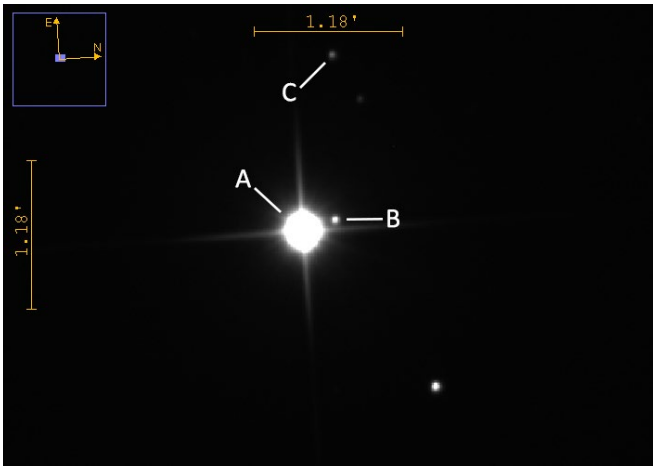

Figure 7: The new component in my image

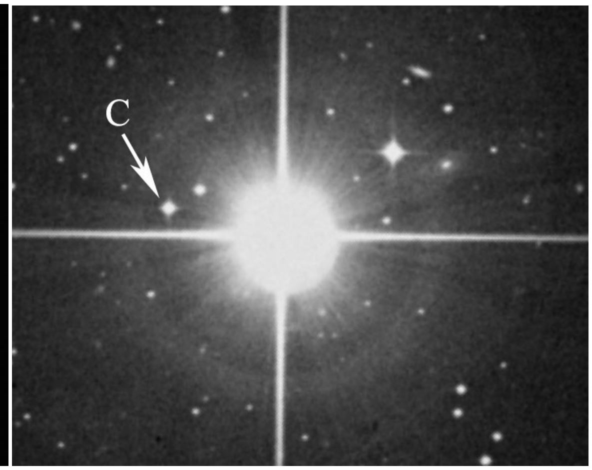

Figure 8: The new component on the DSS image

There is no overlap between the distance data calculated from the parallax. The distance of A component from the Sun is between 131 and 141 pc, and that of C component is between 127 pc and 128 pc. The average distance between the stars is 11,119 AU.

I plotted the motion vectors in Figure 9. I increased the magnitude of the vectors to 10X for better visibility, The angles of the vectors are the same as the calculated ones. Red color is the predicted one, green color is the measured vector. The direction of the vectors is converge, which predicts a physical connection between the two stars. The uncertainty is great because I only have two data on the relationship between the two stars so far. One calculated from the Gaia coordinates and the other is my measurement.

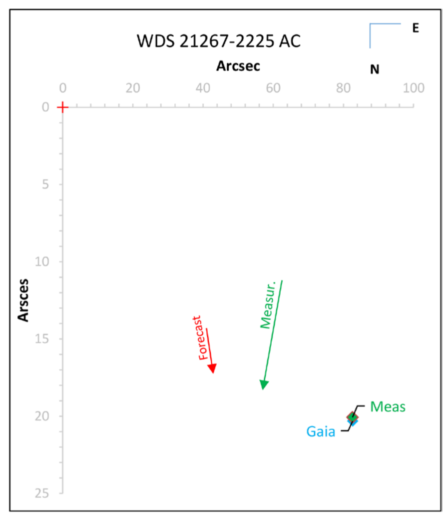

Figure 9: Motion vectors

I used the Harshaw supplement to the RHS spreadsheet to establish the physical binding between the individual components. The Harshaw rating is a metric for that. The closer it is to 1, the higher the probability of the gravitational bond.

Comp	Harshaw Rating	Physical?
AB	0.6347	Maybe
AC	0.8449	Y?

Table 7: Examination of physical relationship

5. Conclusions

In the AB pair relation, the duality is doubtful, the physical connection cannot be established clearly. In the AC relation, the chance of a physical connection is 84%, which supports that this star can be considered a new member of WDS 21267-2225.

Acknowledgements

This work has made use of data from the European Space Agency (ESA) mission Gaia https://www.cosmos.esa.int/gaia, processed by the Gaia Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement.

This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory. Special thanks to Dr. Rachel Matson for the historical data.

References

Erika Böhm-Vitense (1980) The White Dwarf Companion of the Barium Star ζ Capricorni. The Astrophysical Journal, 239: L79-L83, 1980 July 15.

Harshaw, R. (2018). Gaia DR2 and the Washington Double Star Catalog: A tale of two databases. Journal of Double Star Observations, Vol. 14 No. 4. Page 734-740. October 1, 2018.

Harshaw, R. (2020) Using Plot Tool 3.19 to Generate Graphical Representations of the Historical Measurement Data. Journal of Double Star Observations Vol. 16 No. 4. Page 386-400 September 1, 2020.

Collins, K.A., Kielkopf, J.F., Stasstun, K.G., & Hessman, F.V. (2017). AstroImageJ: Image Processing and Photometric Extraction for Ultra-precise Astronomical Light Curves. The Astronomical Journal, 153(2).

Zotti, G., Hoffmann, S. M., Wolf, A., Chéreau, F., & Chéreau, G. (2021). The Simulated Sky: Stellarium for Cultural Astronomy Research. Journal of Skyscape Archaeology, 6(2), 221–258.

Bonnarel, F. et al. (2000) The ALADIN interactive sky atlas. A reference tool for identification of astronomical sources. Astronomy and Astrophysics Supplement, v.143, p.33-40.

Mason, B., (2018) “The Washington Double Star Catalog”, Astrometry Department, U.S. Naval Observatory.

Wenger, M. et al. (2000) The SIMBAD astronomical database. The CDS reference database for astronomical objects. Astronomy and Astrophysics Supplement, v.143, p.9-22.

Astronomisches Rechen-Institut, Heidelberg. ARI's Gaia Services: https://gaia.ari.uni-heidelberg.de/singlesource.html

Gianluca Sordiglioni's (SDG) StelleDoppie: https://www.stelledoppie.it/

iTelescope.net robotic telescope network: https://www.itelescope.net/