New Quadruple System in Cassiopeia

Zsolt Szamosvári
Hungarian Astronomical Association Double Star Section
H-2500 Esztergom, Hungary.
szamos.photo@gmail.com

Abstract

During the new measurement of the double star WDS 00376+5649 (STI 1398), I found two new components, so it is a quadruple system. Based on the new measurement of the AB component, I found that the separation is 14.24 seconds of arc, the position angle is 89.76 degrees. Among the new members, the AC separation is 10.81 arcseconds, the position angle is 3.24 degrees, the AD separation is 9.17 arcseconds, the position angle is 54.13 degrees, the BC separation is 22,95, the position angle is 249.63 degrees, and the BD separation is 8.82 arcseconds, the position angle is 307.21 degrees.

1. Introduction

The double star is in the constellation Cassiopeia, 30 arcminutes from the BU 1349 (Shedar) system. Its J2000 coordinates are 00h 37m 36.68s +56° 49' 12.6". Figure 1 shows the location of STI 1398.

The Simbad catalog knows it as TYC 3662-1333-1 star. Unfortunately, there is no data on neighboring stars in this catalog.

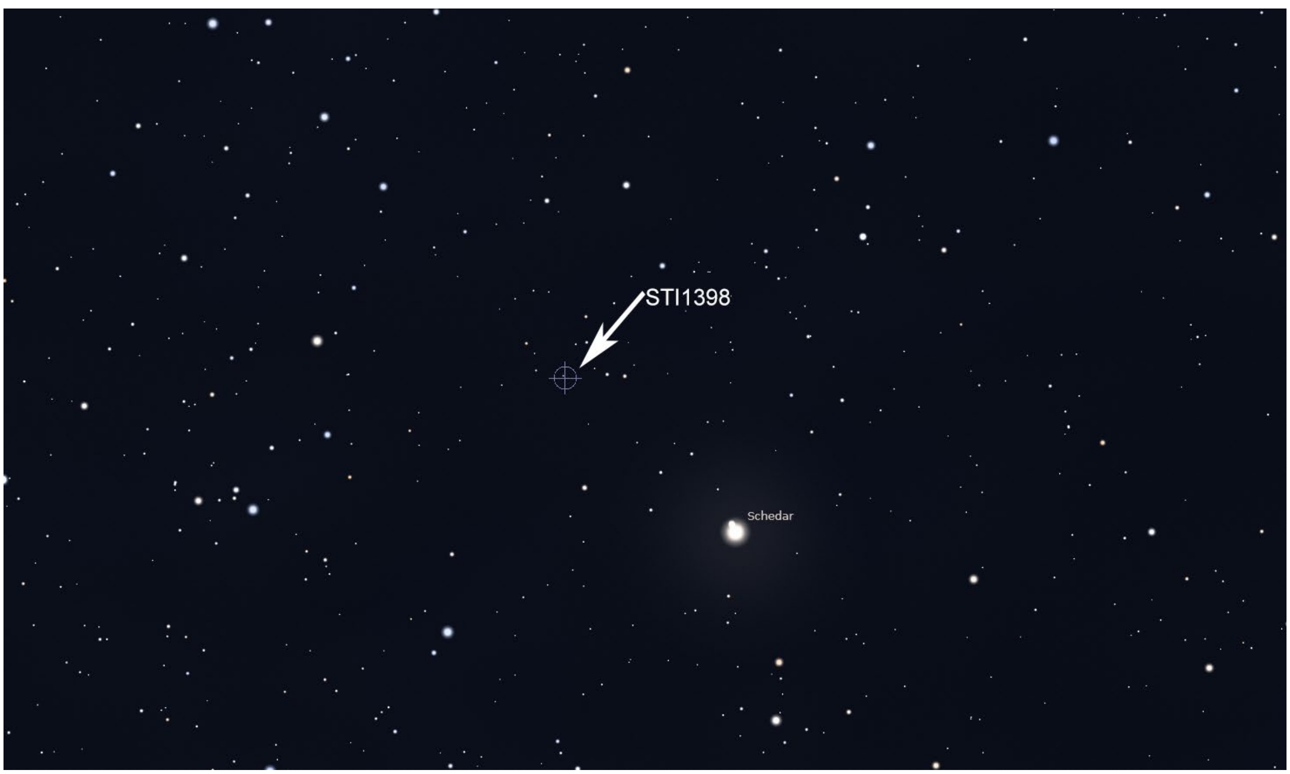

Figure 1: STI 1398 is a double star location in the sky. (Stellarium, Zotti, 2021)

The pair were discovered by Father Johan Stein in 1911 at the Vatican Observatory. It was entered into the Washington Double Star (WDS) catalog as WDS 00376+5649 (STI 1398). At the time of the discovery, Father Stein considered only components A and B to be part of the system. Over the past 111 years, only 10 observations have been made of stars. The last measurement was made in 2015.

On October 28, 2022, I took images of the binary star BU 1349 (Shedar) with the T68 robotic telescope of the iTelescope network. The telescope is in New Mexico, USA. In the images, I noticed a closed group of stars. I identified this with the double star STI 1398. I measured the double star, but I was wondering if there was a physical bond between the surrounding stars or if they just seemed optically close to each other. That's why I looked up the star data in the Gaia DR3 database and found that based on their parallax data, they can be close to each other in space, not just apparently. I thought it worthwhile to do more research on the subject. The DSS image in Aladin also showed the group of stars in a similar way as my image.

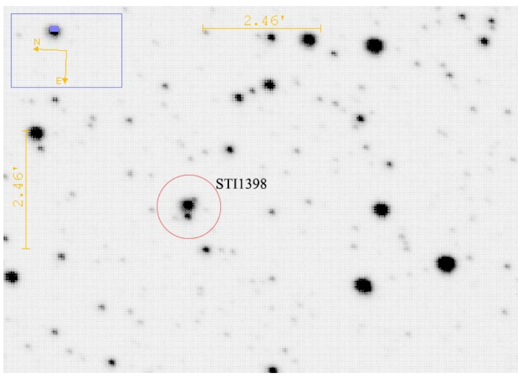

Figure 2: Image of STI 1398 by telescope T68

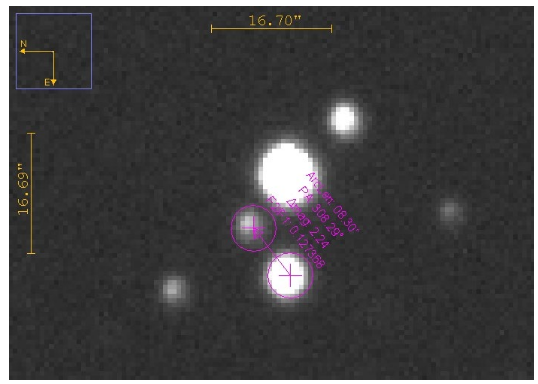

Figure 3: AstroimageJ during measurement

Unfortunately, the resolution and quality of the images taken by the T68 telescope did not allow for a more detailed examination, so I had to take new pictures, now with the T19 telescope. This instrument is superior in all its functions to the previously used telescope T68. The new images were taken on November 13, 2022. The resolution and quality of the images produced were adequate.

2. Equipment and Methods

The images of the double star were acquired by the T19 telescope, located in Mayhill, New Mexico, USA, at an elevation of 2 225 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. With exposure times of 60 s and luminance filter were taken 10 images. Figure 4 shows the instrument. Source: iTelescope.net.


Figure 4: The T19 telescope

For measurements, I 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. I adjusted the brightness and aperture sizes individually to get the best results.

All images were measured as shown in Figure 3. 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.

I also used the interactive sky atlas Aladin (Bonnarel et al, 2000), the Stellarium software (Zotti et al, 2021) for the research. I received the WDS data on the Stelle Doppie (Sordiglioni) website. Since this research was not about the relationship between AB stars, I did not consider it necessary to request the USNO for the historical data of the double stars STI 1398, I took them from Stelle Doppie's website.

3. Data

I assumed that there was a possible interaction between the members of the group, so I performed measurements of separation and position angle in each image, for each component. My measurement result is shown in Table 1. In it I publish the average value of the separation and position angle, as well as the average error and standard deviation and the values of the separation and position angle calculated from the Gaia coordinates.

Comp	Meas	mean	Avg	Err	Avg	Dev	Gaia	coord
	Sep (")	PA (°)	Sep (")	PA (°)	Sep (")	PA (°)	Sep (")	PA (°)
AB	**14.24**	**89.76**	0.26	0.29	0.47	0.48	14.17	89.84
AC	**10.81**	**223.16**	0.02	0.11	0.03	0.13	10.89	223.08
AD	**9.17**	**54.13**	0.23	2.03	0.27	2.50	8.96	55.20
BC	**22.95**	**249.63**	0.05	0.09	0.08	0.16	22.68	46.76
BD	**8.82**	**307.21**	0.14	1.11	0.21	1.32	13.88	41.33
CD	**19.59**	**47.70**	0.28	0.43	0.37	0.51	23.03	249.70

Table 1: Measurement data

I collected astrometric data from the Gaia DR3 and Simbad databases, which I summarized in Table 2. Here you can also see the calculated corresponding motion data. Table 3 contains the properties of stars.

Comp	RA	Dec	Parallax mas	Px err	PMRA mas/yr	PMDEC mas/yr	PM mas/yr	G mag
A	9.402830888	56.82016894	0.72	0.0256	-5.16	-1.24	5.31	11.35
B	9.4100210	56.82017982	0.57	0.0325	0.95	-1.18	1.52	13.21
C	9.399056903	56.8179598	0.55	0.0207	-2.09	0.21	2.10	14.45
D	9.406566663	56.8215901	0.89	0.0276	-8.17	-1.84	8.37	15.18

Table 2: Gaia data

Comp	App Mag	Abs Mag	Lumʘ	Radʘ	Mʘ	T-eff K°
A	11.35	0.63	48.50	5.51	2,75	9 221
B	13.21	1.97	14.06	3.16	1.93	8 146
C	14.45	3.16	4.66	1.90	1.41	7 479
D	15.18	4.92	0.92	1.00	0.98	5 320

Table 3: Properties of stars

I placed the stars on the HRD based on the available data, as shown in Figure 5. On the graph, I tried to display the size and color of the stars.

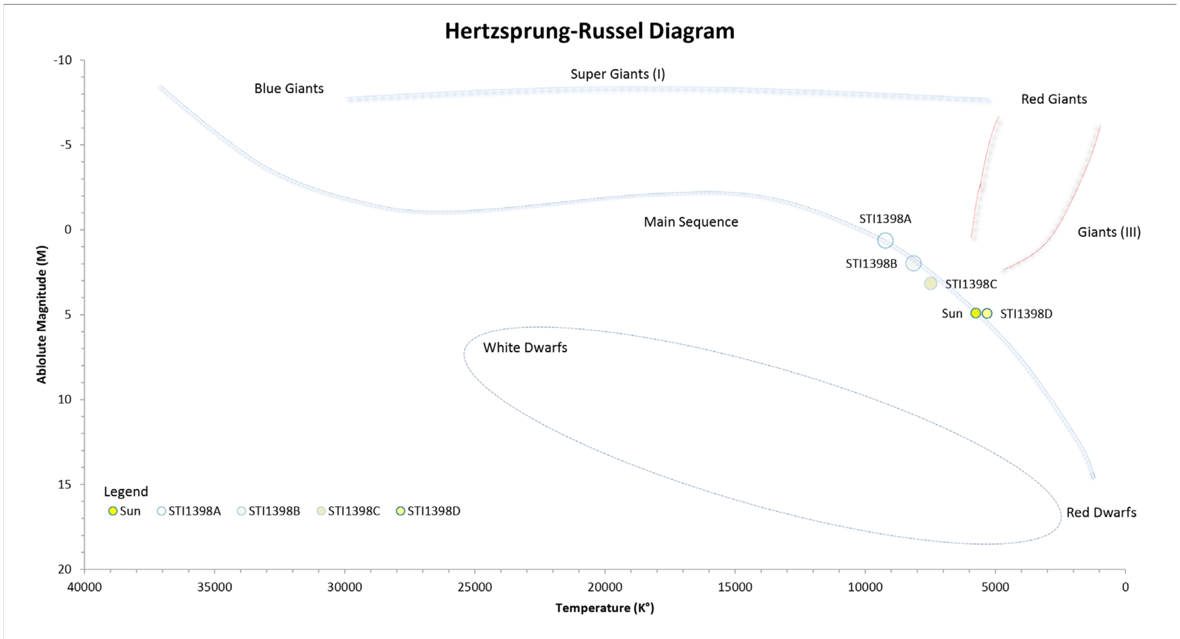

Figure 5: Hertzsprung-Russel Diagram

4. Discussion

The biggest question in double star astrometry is whether there is a gravitational bond between the members of a system? In this paper, I tried to solve this problem by analyzing the distance between stars based on parallax data, as well as considering the vectors of proper motion.

I calculated the separation and position angle between the stars based on the Gaia DR3 coordinate data corresponding to the 2016 measurements, the values of which are in the last columns of Table 1. Thus, two measurement results have already been obtained for the members. After that, I created a table of the Plot tool for all possible correlations. From this I got the minimum distance values between members, which I summarized in table 4. I also specified the distance between each member in AU, parsec, and 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.

Comp	AU	Parsec	Light-year	rPM
AB	19 738	0.0957	0.3121	0.1186
AC	15 169	0.0735	0.2399	0.0127
AD	10 112	0.0490	0.1599	0.0827
BD	9 586	0.0465	0.1516	0.1162
BC	40 404	0.1959	0.6389	0.0625
CD	21 539	0.1044	0.3406	0.1274

Table 4: Distance data

If the rPM in a double star system, 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 this value using the RHS Excel spreadsheet. Analysis of the data on the distance between the members showed that there is overlap only for BC components. For the other members, there is no overlap in the distances, also considering parallax errors. Proper motion vectors also demonstrate different spatial movements of members. However, is that the distance between members is much less than 1 parsec. The rPM data also suggest that there is a chance of interaction between members.

I have slightly modified the Rowe-Harshaw Excel Spreadsheet (RHS) (Harshaw, 2018) to suit my own needs. I used Harshaw's supplement for RHS to calculate the physical relationships between the components. The decision that helped me make was what I called the Harshaw rating. The closer to 1 its value, the higher the probability that the pair is physical. The calculated values are shown in Table 5.

Comp	Harshaw rating	Physical?
AB	0.6898	Y?
AC	0.5685	**Maybe**
AD	0.6755	Y?
BC	0.8505	Y
BD	0.5454	**Maybe**
CD	0.4549	??

Table 5: Physical bound?

What was surprising to me, the case of the BC members. They have the greatest separation, yet their parallax and their proper motion show that there is certainly a gravitational bond between them. The probability of bonding between AB and AD members is mid-high. In the case of AC and BD components, the probability of physical contact is perhaps possible, and among CD members it is questionable.

Based on the above data, in my opinion the STI 1398 system looks as shown in Figure 6.

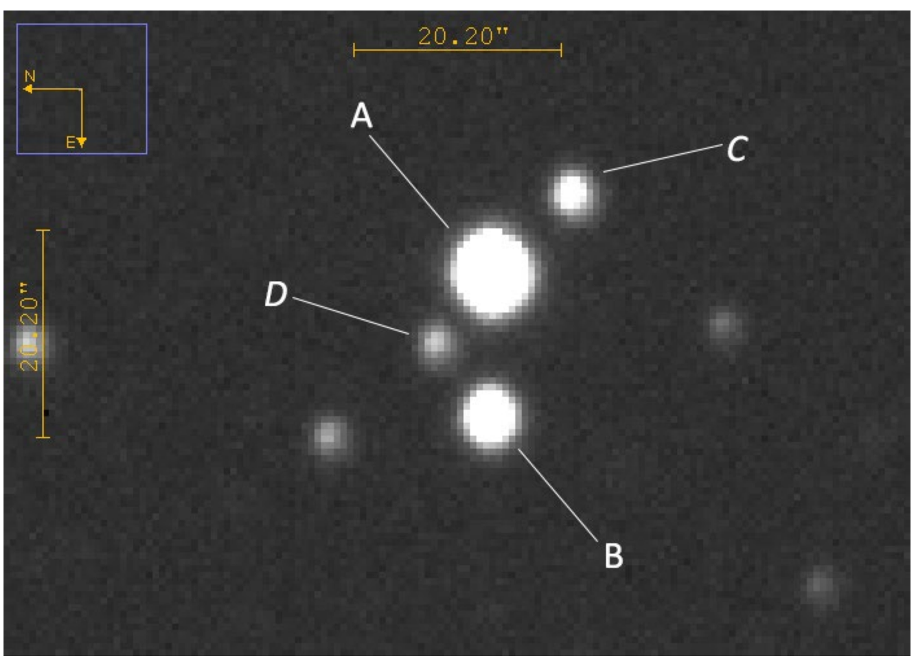

Figure 6: The quadruple system.

5. Conclusions

The probability of physical interactions is 69% for the AB pair, 57% for the AC pair, 68% for the AD pair, 85% for the BC pair, 55% for the BD pair, and 45% for the CD pair. Based on the available data and calculations, it can be stated that STI 1398 pair is more like a quadruple system.

Acknowledgements

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

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