The Position Angle, Separation, and Additional Component of STF 1300

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Abstract

Images of the double star system WDS 09013+1516 STF 1300 were taken using the robotic telescope at the Boyce Astro Robotic Observatory (BARO), Dixon Astronomical Remote Observatory (DARO), and Mount Wilson Observatory 60-inch telescope (MWO). Speckle Interferometry was used to derive the position angle and separation of the pair. We observed a position angle of 177.57 degrees and a separation of 4.989 arc seconds. We detected evidence of an additional component, warranting further observations to assess for a third gravitationally bound star.

1. Introduction

First documented in the eighteenth century, visual double stars occur in the night sky when two stars appear to be near each other as viewed from Earth (Dugan et al, 2019). Optical double stars appear near one another but have no physical relationship, often due to a large true distance between the two, whereas physical double stars often, but not always, exhibit similar motion (Nugent, 2022). If physical double stars are gravitationally bound, they are binary stars.

Binary stars are of interest because they provide a way to obtain the mass of stars (Dugan et al, 2019). By solving the orbit of a binary star system, Kepler's Third Law can be used to find the combined mass of the system, and individual masses can be calculated given the distance of each star to the system's barycenter. By plotting mass versus luminosity for many binary stars, the Hertzsprung Russell diagram can be refined, helping to further the understanding of the relationship between mass and luminosity. This can enable researchers to infer the mass of other stars with a higher degree of accuracy (Weise et al, 2020).

In this paper, we use the technique of speckle interferometry to resolve a close binary system. Although we have access to the Las Cumbres Observatory (LCO) global telescope network, its 0.4-meter telescopes cannot resolve stars closer together than 5 arcseconds. Therefore, we used speckle interferometry and data taken from the Boyce Astro Robotic Observatory telescope to conduct astrometric measurements. The process of speckle interferometry involves taking the Fourier transform of each image. The result of each Fourier transform is a power spectrum in the Fourier domain for that image. All these power spectra are then averaged to get an autocorrelation. Further analysis, in the form of bispectrum phase reconstruction, is then done to recover the single bispectrum image (Altunin et al, 2021).

2. Target Selection

STF 1300 was selected from a list of known binaries within 40 parsecs. This list was generated using the Gaia Double Star DataBase and Access Tool (Risin, et al. in prep). The list was sorted to only include targets between 5 and 17 hours in right ascension, magnitude between 7 and 13, and separation between 2 and 5 arc seconds. This list was generated using the Gaia Double Star DataBase and Access Tool (Risin, et al. in prep). STF 1300 was selected because of its optimal right ascension during the available observation time. Because of this, the target was able to be observed by Boyce Astro Robotic Observatory (BARO), Dixon Astronomical Remote Observatory (DARO), and Mount Wilson Observatory (MWO).

3. Instrumentation and Procedures

The Boyce Astro Robotic Observatory (BARO) is a Planewave Corrected Dahl-Kirkham (CDK) 17 and is shown in Figure 1. It has a focal length of 2929mm and an aperture of 432mm. The mount is an equatorial Planewave L-500 Mount, shown in Figure 2. There are two cameras currently attached to the Optec Perseus instrument rotator and are shown in Figure 3. The cameras share a Finger Lakes Instrument Atlas Focuser. We used a ZWO ASI 1600 CMOS 16 megapixel camera with a 2.5X Barlow to take images of our target. This has an 8.3’ by 6.3’ field of view with a 0.1072 arcsecond per pixel image scale. The Sloan R′ filter was used for our observations.

Figure 1: BARO Planewave CDK-17 Telescope (Boyce, 2021).

Figure 2: Planewave L-500 Equatorial Mount on BARO (Boyce, 2021).

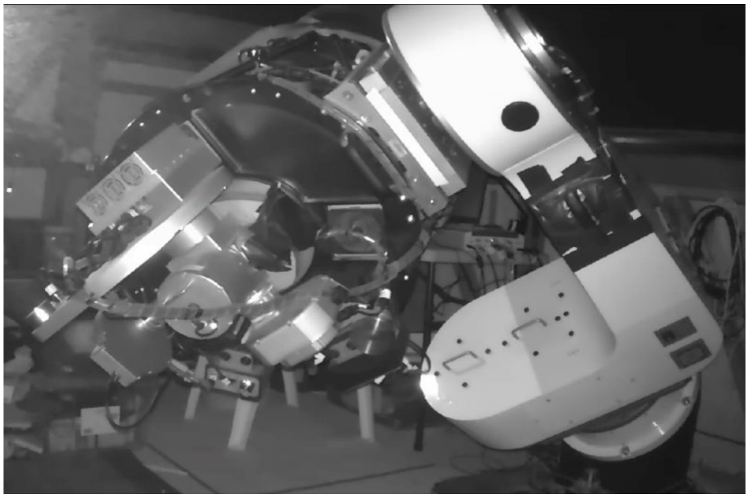


Figure 3: Cameras on the Optec Perseus rotator (Boyce, 2021).

The Dixon Astronomical Remote Observatory (DARO) is a roll-off roof observatory with a pier mounted 8-inch aperture 1500 mm focal length Ritchey- Chretien (RC) telescope, and is shown in Figure 4. There is an 80 mm refractor that is mounted with the RC for guiding and plate solving. The two telescopes are mounted on an iOptron CEM-60 mount. An 8-position filter wheel contains red, green, blue, Ha SII, OIII, and light pollution filters. The Sloan r′ filter was used for observing our target. Two cameras are attached to the two telescopes, and the ZWO was used for our observations. The RC has a cooled ZWO 1600 and the refractor has an Orion Star Shoot guide camera. The focuser for the RC is a ZWO EAF focuser. For speckle imaging, a 3x Barlow lens is used on the RC resulting in a plate scale of 0.1614 arcseconds and a field of view of 10 arcminutes.

Figure 4: The RC and Reflector on DARO (Dixon 2022).

The Mount Wilson Observatory 60-inch Telescope is a 60-inch reflector. A ZWO ASI 6200MM camera with an Astronomik 642BP filter is shown in Figure 5. The telescope has an f/16 bent Cassegrain focus, eliminating the need for a Barlow. The camera was not cooled due to the short exposures and fairly constant external temperature.

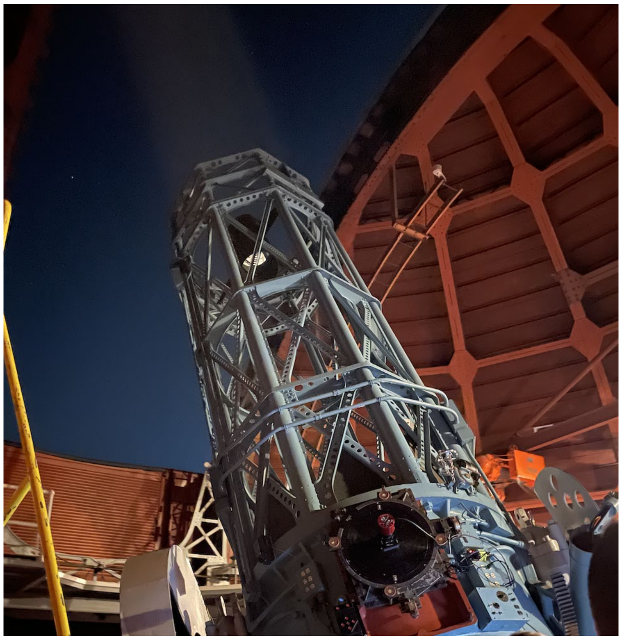


Figure 5: The camera on the MWO 60-inch telescope.

In observing our targets, many short integrations were used to perform speckle interferometry. Speckle interferometry is a process of image reduction that uses short exposures and Fourier transforms to resolve close and faint double stars (Rowe et al., 2015).

SiTechZWO cam software was used to take images and the data were reduced using Speckle Toolbox 1.14 (Rowe et al, 2015). The data reduction used speckle images taken in a 256 by 256-pixel region of interest (ROI) mode and were made into FITS cubes. These FITS cubes were then processed with bispectrum phase reconstruction and then their position angle and separation were determined (Risin et al, 2022).

4. Results

STF 1300 was observed in February of 2022 on BARO. To estimate the expected position angle, the difference between two position angle values from the surrounding years' predictions in the 6th orbit catalog was multiplied by the fraction of a year that had passed between the initial prediction and the observation taken in this study. We then added that value to the initial prediction measurement. To estimate the expected separation, we repeated the same process, using the difference in separations between the two predictions instead. These values are shown in Table 1. The two equations below show the process used to find these values (Bush et al, 2018).

Equation 1: $(178.0^o - 178.2^o) \times (\frac{35}{365}) + 178.2^o = 178.18^o$

This equation returns the expected value of the position angle at the time of our observation given the difference between the predicted values from the beginning of 2023 (178.2 degrees) and 2022 (178.0 degrees), multiplied by the fraction of how far through 2022 the observation was taken (35/365), added onto the predicted position angle value at the beginning of 2022.

Equation 2: $(4.986'' - 4.993'') \times (\frac{35}{365}) + 4.993'' = 4.992''$

Table 1. Sep and PA values of STF 1300AB on Gaia (2015.5), Ephemeris, BARO, DARO, and MWO. Observations were conducted between Feburary and April 2022. C is a new component not prior observed by Gaia and is reported as new.

Telescope	PA (deg)	Sep (arcsec)
Gaia (a,b)	179.19	5.037
Ephemeris (a,b)	178.18	4.992
BARO (a,b)	177.57	4.989
DARO (a,b)	166.765	4.9485
MWO (a,b)	177.98	5.008
MWO (a,c)	194.65	5.808
MWO (b,c)	249.47	1.758

Figure 6: RA and Dec of STF 1300AB. The red point represents the observation on BARO, the yellow point represents the observation at MWO and the purple point represents the observation on DARO.

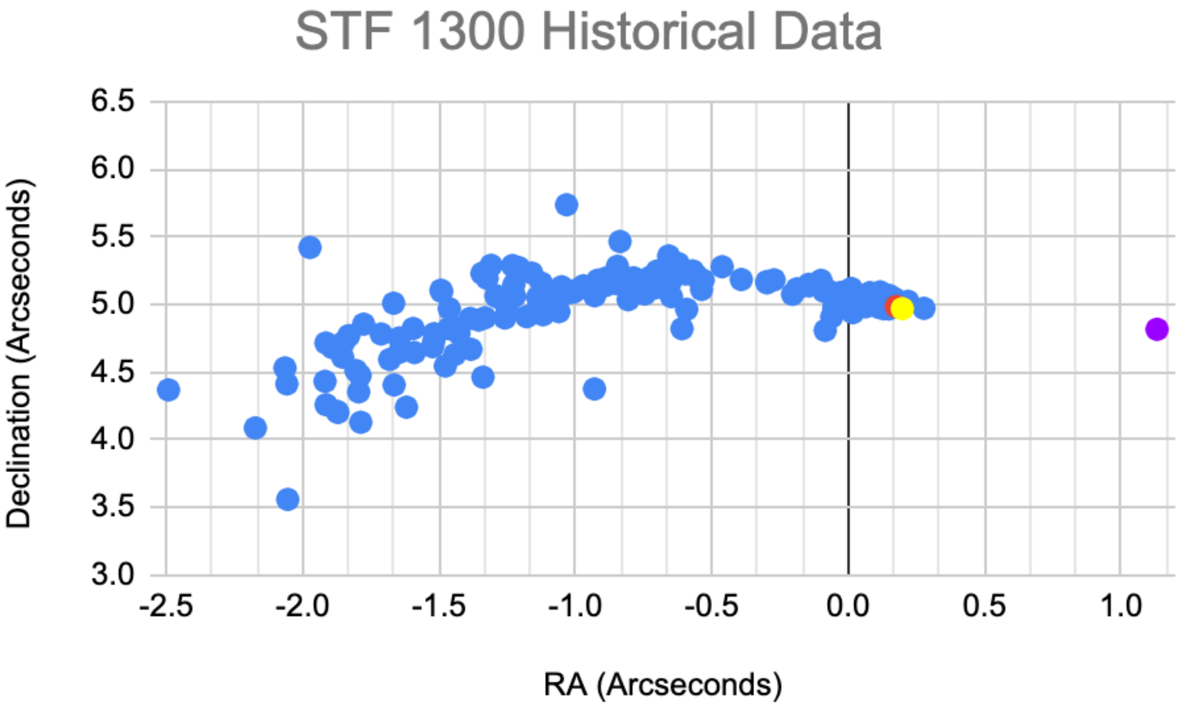


Figure 7: Image of Bispectrum Phase Reconstruction of STF 1300 from BARO

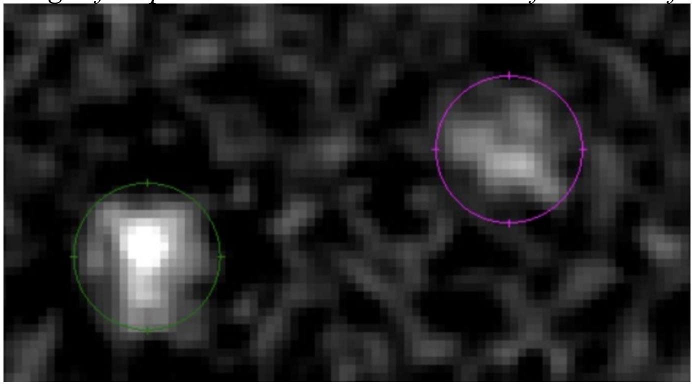


Figure 8: Image of Bispectrum Phase Reconstruction of STF 1300 from DARO

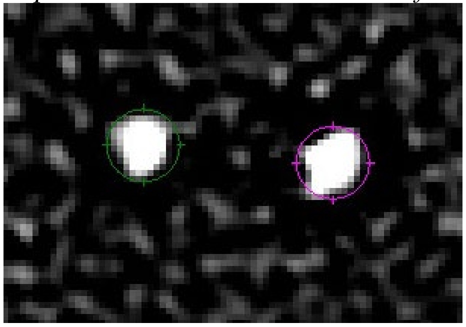


Figure 9: Solved orbit for system STF 1300 (Izmailov, 2019).

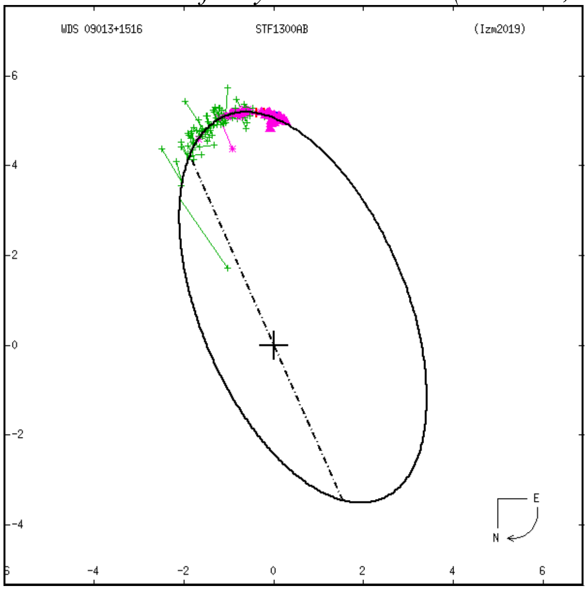
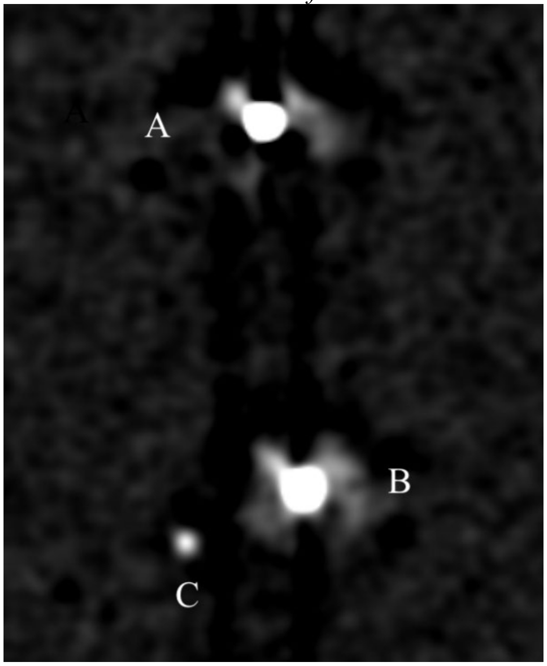


Figure 10: Image of Bispectrum Phase Reconstruction from Mount Wilson Observatory 60 In telescope.



5. Analysis

The absolute magnitude of the primary and secondary stars are 7.41 and 7.58 respectively, and the B-V magnitudes are 1.58 and 1.65. Both stars are G type main sequence stars by the Hertzsprung-Russell relationship, and each has a mass of approximately one solar unit. The system's escape velocity is given by the equation below.

Equation 3: $$v_{escape} = 2G \times (M_{primary} + M_{secondary}) \div sep$$

Equation 3 returns an escape velocity of about 1,544 m/s, slightly greater than the relative movement of 1,457 m/s. This is an estimate as the third component would affect this calculation if it is bound to the system.

When observed with BARO, the position angle and separation were similar to the predicted values when a 180º angle correction was applied. The separation is also aligned with the predictions from the ephemeris and when plotted in Figure 6, falls along the path of the orbital trend. However, when observed on BARO, as seen in Figure 7, elongation of the secondary was observed, suggesting a possible additional component. The observations on DARO (shown in Figure 8) were off by approximately 11 degrees in position angle but contained a similar separation to the other observations. This variation from the other two measurements suggests calibration problems with the telescope, so we will not include this measurement as part of the one we report here.

When observed at MWO with the 60-inch telescope, a third companion was viewed, as seen in Figure 10, with a separation of 1.758 and a position angle of 249.47. The position angle and separation between the primary and secondary were similar to the BARO values and the ephemeris, confirming the accuracy of our measurements. The new component requires further observation to confirm whether it is gravitationally bound or simply just optical.

The new component has a position angle of 249.47 and a separation of 1.758 relative to the secondary component of the system. It has a position angle of 194.65 and a separation of 5.808 relative to the primary.

6. Conclusions

In this study of STF 1300 we measured a position angle of 177.57 degrees and a separation of 4.989 arcseconds from BARO for the A and B. The measurement of STF 1300 from BARO is in line with the predictions from the calculated ephemeris. We observed a position angle of 177.98 and a separation of 5.008 on the Mount Wilson 60-inch telescope for the A and B components. We measured a position angle of 249.47 degrees and a separation of 1.758 arc seconds between the new component and the B component.

The elongation of the secondary was able to successfully indicate a third component and shows the utility of small telescopes in the discovery space for new components. The new companion was not previously observed by Gaia, probably because it is so much dimmer than its companion. Using small telescopes to observe binaries shows a discovery space for new components. Further research can use the findings of this study to create new observation programs for large telescopes.

7. Acknowledgments

The assistance provided by Dr. Rachel Matson of the U.S. Naval Observatory was greatly appreciated. Dr. Matson provided the study with historical data on the systems being investigated. The past data came from the Washington Double Star Catalog, which is maintained by the U.S. Naval Observatory. Specifically, the speckle interferometry used in this study was accomplished with the Speckle Toolbox written by David Rowe. In order to coordinate the observation of the targets and reference stars in our study, the SIMBAD Astronomical Database, and the Aladin Sky Atlas were used. The targets studied in this paper were chosen from the Gaia Double Stars Target List, created in December of 2021 by Rick Wasson. Astrometric measurements from the Gaia space telescope were also used in this study. Thank you to Rohan Satapathy, Liam Dugan, Dave Rowe, Rick Wasson, Reed Estrada, and Pat Boyce for help with programming, observing, and advising. Thank you to Tom Meneghini for the use of the Mount Wilson Observatory telescope and for assistance with observations.

8. References

Altunin, Ivan, et al (2021). “Comparison of Recent Small Telescope Speckle Interferometry with Gaia and Archived 3.8-Meter UKIRT J-Band Image Astrometry”. 17(2).

Bush, Mitchell, et al (2018). “Astronomy Observations of STF 1321AB”. 14(1). http://www.jdso.org/volume14/number1/Bush_38_42.pdf

Dugan, Owen, et al (2019). “CCD Measurements and Reclassification of WDS 07106 +1543 to an Optical Double”. 15(1). http://www.jdso.org/volume15/number1/Dugan_119_129.pdf.

Izmailov, I. S. “The Orbits of 451 Wide Visual Double Stars.” *Astronomy Letters*, vol. 45, no. 1, 2019, pp. 30–38., doi:10.1134/s106377371901002x.

Nugent, Richard (2022). “Optical or Binary? An Investigation of 21 WDS Systems”. 18(1). http://www.jdso.org/volume18/number1/Nugent_41_51.pdf

Risin, Sophia, et al (2022). “Observations of Potential Gaia Red Dwarf Binaries in the Solar Neighborhood—III”. Journal of Double Star Observations. 18(1). http://jdso.org/volume18/number1/Risin_30_40.pdf

Risin, Sophia, et al (2022). “Gaia Double Star Data Base and Access Tool.” *In prep.*

Rowe, David A., and Genet, Russell M., 2015, “User’s Guide to PS3 Speckle Interferometry Reduction Program”, JDSO, 11, 266-276.

Weise, Caroline, et al (2020). “Reevaluating Double Star STF 619”. 16(2). http://www.jdso.org/volume16/number2/Weise_105_112.pdf