# Measurements of the Position Angles and Separations of the Double Stars WDS 16579+4722 AB and AC Components

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**Abstract**: Researchers at Cuesta College measured the position angle and separation of the multiple star system WDS 16579+4722, AB and AC components, using images requested from the Las Cumbres Observatory. The images were captured using a SBIG STX6303 CCD camera mounted to a robotic 0.4-m telescope at the Las Cumbres Observatory in Tenerife, Spain. Data collected will assist in determining if this is a binary or optical double star system. Thirty observations were analyzed using AstroImageJ software. The measured position angle of the AB components was 63.87 degrees and the separation was 5.65 arcseconds. The measured position angle of the AC components was 261.53 degrees and the separation was 112.37 arcseconds. The AB measurements differed from the expected values based on past observations; this difference could be due to the CCD images being out of focus or may be accurate within the range of recently collected data.

## Introduction

Double stars are pairs of stars that, as viewed from earth, appear close to each other in the night sky. Double stars may be a binary star system, in which two stars orbit a common point, or may simply be optical doubles. Optical doubles are near one another as they appear in the sky, but in reality, these stars are vastly distant from each other. Numerous observations and measurements over a long period of time can reveal a relationship (or lack thereof) between the two stars and solidify classification. If the stars are binary, they will have a curved trajectory over time their orbits can be calculated. If their true distance from the earth is determined, the system mass (combined mass of both stars) can be calculated. Both system and stellar mass are key to understanding the properties and life cycle of a binary star system (Genet, et al. 2016).

The AC components of the double star WDS 16579+4722 were first observed in 1823 by James South and John Frederick William Herschel published in the journal “Philosophical Transactions of the Royal Society” (Herschel & South 1824). In 1908, components B and D were first observed by Robert G. Aitken at the Lick Observatory just outside of San Jose, CA (Aitken 1945). The most recent observation of both the AB and AC components were completed in 2017 by Jocelyn Sérot (Sérot 2018).

To create a list of readily measurable stars to choose from, the Washington Double Star Catalog (WDS) was filtered with the following properties in mind: a primary star dim enough that the secondary star is easily observable, a secondary star bright enough to be clearly seen, a separation great enough that stars are clearly defined from one another, and lastly, the double star’s coordinates are viewable from the Las Cumbres Observatory telescopes. From this pared list, WDS 16579+4722 was selected based on its limited number of observations, existence of many outlying measurements, and relatively undefined orbital solution (see Figure 1). This star was selected as past data does not conclude beyond a doubt that the stars are binary. If new observations follow the elliptical orbit and bend to the left it may confirm that it is a binary relationship,

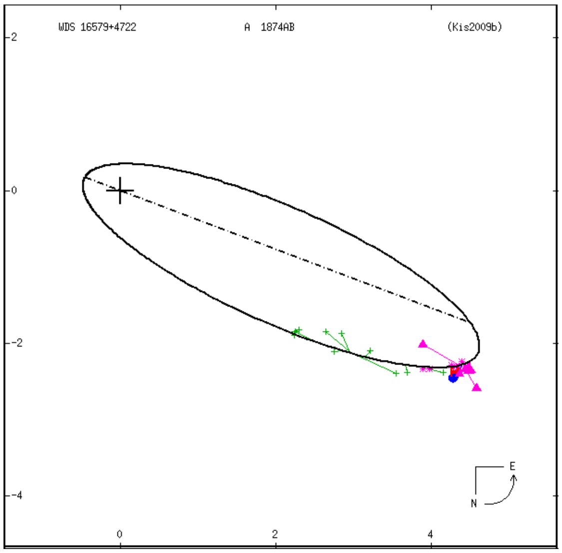


*Figure 1. Orbital Diagram of WDS 16579+4722AB*

whereas if the new point continues straight on, it may suggest the stars are not in a binary relationship.

## Equipment and Procedures

CCD images were requested via robotic telescopes at the Las Cumbres Observatory (LCO, see Figure 2). Wholly modified Meade 0.4-m telescopes using custom equatorial mounts and SBIG STX6303 CCD imagers captured 30 images on November 1st, 2018: 10 each of 1 second, 0.75 second, and 0.5 second exposures from the Las Cumbres Observatory in Tenerife, Spain. Additionally, on this day, data from all published observations of WDS 16579+4722 was requested from Dr. Brian D. Mason of the United States Naval Observatory (USNO) to use in comparison with new data.

LCO images were converted to .fits files and analyzed using the AstroImageJ 3.2.1 software. Before measuring the position angle and separation of WDS 16579+4722, each of the 30 images had to be “plate-solved”; their precise orientation and scale determined using reference data from surrounding stars. Plate-solving was completed using Astrometry.net. Once plate-solved, two measurements of the PA and SEP of the primary and secondary (AB) and primary and tertiary (AC) components of WDS 16579+4722 were recorded in a separate table for each image in Google Sheets. An aperture setting of 4 pixels was used for the AB measurements and an aperture setting of 8 pixels was used for the AC measurements. Early measurements were made using aperture settings that were too small or too large for their respective components and yielded flawed data; these images were re-evaluated with appropriate aperture settings. The raw data was then used to create Tables 1 and 2.

*Figure 2. Telescope at Los Cumbres Observatory, Tenerife, Spain*

## Results

Table 1 shows the average PA and SEP of 2 measurements for each of the 30 images of WDS 16579+4722AB analyzed. The average SEP was 5.65 arcseconds and the average PA was 63.87 degrees.

Table 2 shows the average PA and SEP of 2 measurements for each of the 30 images of WDS 16579+4722AC analyzed. The average SEP was 112.37 arcseconds and the average PA was 261.54 degrees.

Figures 3 and 6 show the AB and AC components as viewed and measured in AstroImageJ. Note the

*(Text continues on page 300)*

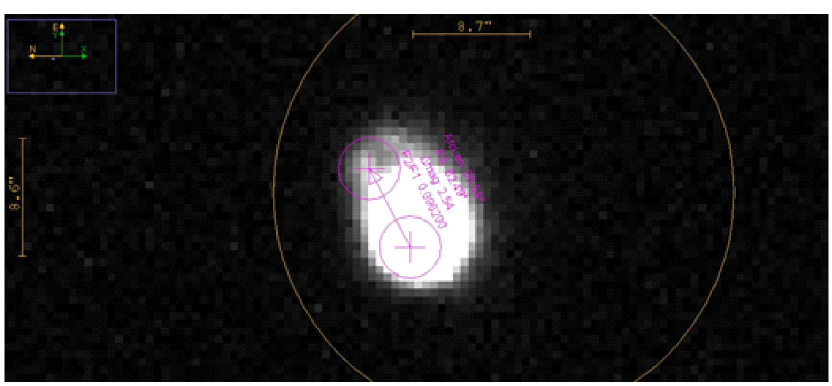


***Figure 3.*** *WDS 16579+4722AB as viewed and measured in AstroImageJ. Note the lack of distinction of components A and B and the skew of the centroid apertures.*

*Table 1. Exposure (seconds), position angle (degrees) and separation (arcseconds) measurements of WDS 16579+4722AB from LCO images acquired on JD 2458425 (1 November 2018).*

| Time | Exposure | SEP | PA | | Time | Exposure | SEP | PA |
|---|---|---|---|---|---|---|---|---|
| 19:13:43 | 0.85 | 5.81 | 63.71 | | 19:17:28.513 | 1.34 | 5.2 | 64.13 |
| 19:13:57 | 0.84 | 6.84 | 63.29 | | 19:17:42.771 | 1.35 | 5.45 | 64.13 |
| 19:14:11 | 0.85 | 5.76 | 64.66 | | 19:17:59.059 | 1.34 | 5.8 | 63.73 |
| 19:14:26 | 0.85 | 5.8 | 62.23 | | 19:18:13.914 | 1.35 | 5.68 | 63.3 |
| 19:14:39.856 | 0.85 | 6.62 | 62.22 | | 19:18:28.036 | 1.35 | 5.74 | 65.32 |
| 19:14:55 | 0.84 | 5.12 | 63.25 | | 19:19:02.711 | 1.1 | 5.32 | 63.99 |
| 19:15:08.512 | 0.84 | 5.62 | 64.4 | | 19:19:16.780 | 1.09 | 5.33 | 63.51 |
| 19:15:22 | 0.85 | 5.46 | 63.78 | | 19:19:30.959 | 1.1 | 5.55 | 62.92 |
| 19:15:35.934 | 0.85 | 5.54 | 63.58 | | 19:19:45.160 | 1.1 | 5.53 | 63.08 |
| 19:15:50.564 | 0.84 | 5.76 | 64.6 | | 19:19:59.072 | 1.1 | 5.62 | 65.33 |
| 19:16:15.201 | 1.35 | 5.64 | 63.78 | | 19:20:13.885 | 1.1 | 5.42 | 64.82 |
| 19:16:29.191 | 1.34 | 5.73 | 64.51 | | 19:20:28 | 1.1 | 5.75 | 62.48 |
| 19:16:44.228 | 1.35 | 5.82 | 63.56 | | 19:20:41.939 | 1.1 | 5.47 | 64.57 |
| 19:16:58.733 | 1.34 | 5.55 | 64.14 | | 19:20:58.620 | 1.09 | 5.47 | 64.94 |
| 19:17:13.362 | 1.34 | 5.74 | 64.04 | | 19:21:12.530 | 1.09 | 5.49 | 64.1 |
| **Avg. SEP** | 5.65 | | | | **Av. PA** | 63.87 | | |
| **SEP Std. Dev.** | 0.37 | | | | **PA Std. Dev.** | 1.28 | | |
| **SEP SEM** | 0.063 | | | | **PA SEM** | 0.15 | | |

*Table 2. Exposure (seconds), position angle (degrees) and separation (arcseconds) measurements of the AC components of WDS 16579+4722 from LCO images acquired on 1 November 2018.*

| Time | Exposure | SEP | PA | | Time | Exposure | SEP | PA |
|---|---|---|---|---|---|---|---|---|
| 19:13:43 | 0.85 | 112.47 | 261.47 | | 19:17:28.513 | 1.34 | 112.43 | 261.54 |
| 19:13:57 | 0.84 | 112.23 | 261.62 | | 19:17:42.771 | 1.35 | 112.32 | 261.49 |
| 19:14:11 | 0.85 | 112.38 | 261.6 | | 19:17:59.059 | 1.34 | 112.44 | 261.57 |
| 19:14:26 | 0.85 | 112.59 | 261.52 | | 19:18:13.914 | 1.35 | 112.23 | 261.56 |
| 19:14:39.856 | 0.85 | 112.37 | 261.55 | | 19:18:28.036 | 1.35 | 112.3 | 261.49 |
| 19:14:55 | 0.84 | 112.43 | 261.56 | | 19:19:02.711 | 1.1 | 111.97 | 261.57 |
| 19:15:08.512 | 0.84 | 112.39 | 261.64 | | 19:19:16.780 | 1.09 | 112.36 | 261.53 |
| 19:15:22 | 0.85 | 112.38 | 261.47 | | 19:19:30.959 | 1.1 | 112.46 | 261.52 |
| 19:15:35.934 | 0.85 | 112.41 | 261.56 | | 19:19:45.160 | 1.1 | 112.26 | 261.44 |
| 19:15:50.564 | 0.84 | 112.26 | 261.57 | | 19:19:59.072 | 1.1 | 112.36 | 261.52 |
| 19:16:15.201 | 1.35 | 112.21 | 261.56 | | 19:20:13.885 | 1.1 | 112.55 | 261.54 |
| 19:16:29.191 | 1.34 | 112.31 | 261.52 | | 19:20:28 | 1.1 | 112.52 | 261.55 |
| 19:16:44.228 | 1.35 | 112.28 | 261.59 | | 19:20:41.939 | 1.1 | 112.38 | 261.46 |
| 19:16:58.733 | 1.34 | 112.66 | 261.6 | | 19:20:58.620 | 1.09 | 112.33 | 261.57 |
| 19:17:13.362 | 1.34 | 112.49 | 261.44 | | 19:21:12.530 | 1.09 | 112.35 | 261.53 |
| **Avg. SEP** | 112.37 | | | | **Av. PA** | 261.54 | | |
| **SEP Std. Dev.** | 0.13 | | | | **PA Std. Dev.** | 0.05 | | |
| **SEP SEM** | 0.024 | | | | **PA SEM** | 0.009 | | |

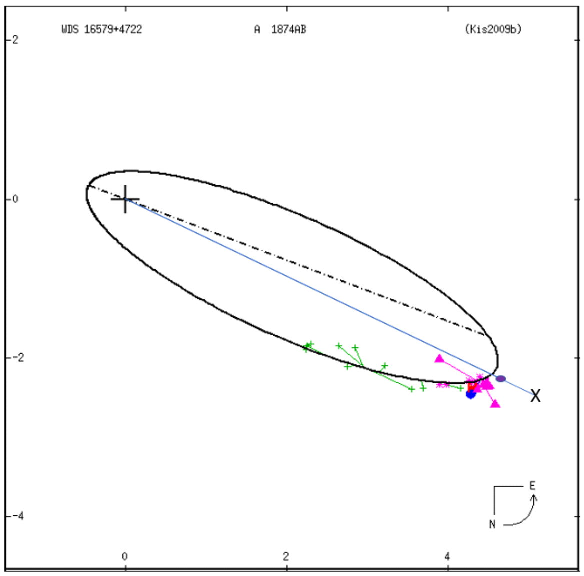


*Figure 4. Orbital Diagram of WDS 16579+4722AB with newly recorded data. Data from this observation is represented by the black X; data from last recorded observation (Sérot 2018) is represented by the purple oval.*

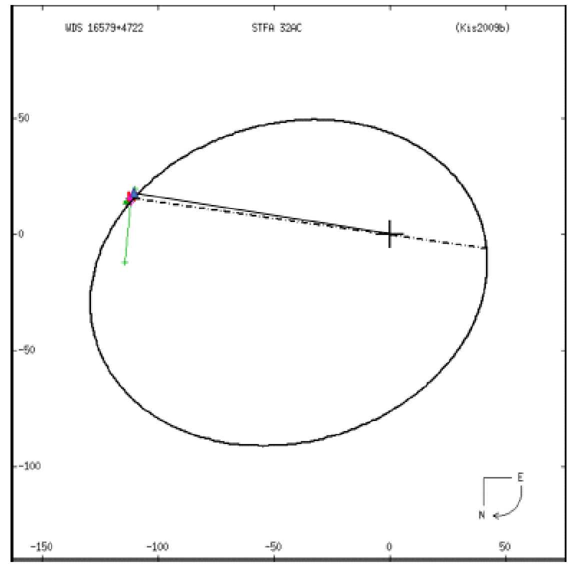


*Figure 5. Orbital Diagram of WDS 16579+4722AC with newly recorded data. Data from this observation is represented by the blue triangle.*

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blurred distinction of the AB components and the consistent skew of the centroid apertures to the bottom left. Figure 4 shows the orbital diagram of the AB components of WDS 16579+4722A, while Figure 5 shows the orbital diagram of the AC components.

In Figures 7, 8, 9, and 10 the newly gathered SEP and PA of the AB and AC components are shown in comparison with data from past observations provided by the USNO. The orange points correspond to the data collected in this observation.

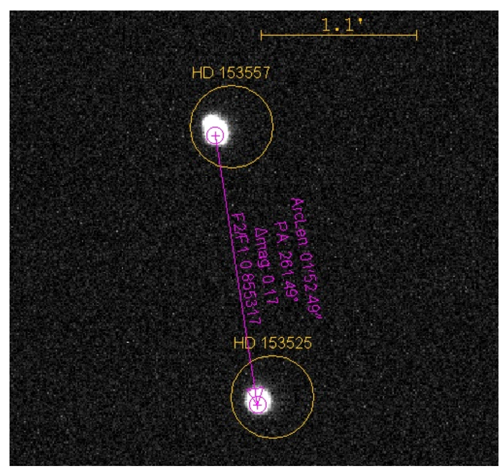


*Figure 6. WDS 16579+4722Ac as viewed and measured in AstroImageJ. Note the skew of both centroid apertures to the bottom left of the image.*

## Discussion

Issues arose when gathering PA and SEP data from the primary component (A) and secondary component (B). The first was due to the proximity and difference in magnitudes of A and B and the second was due to a slight distortion in the images. When two stars with differing magnitudes are near one another the brighter star's light appears to saturate the area around it which makes seeing the secondary star difficult. Additionally, our images showed a consistent skewing of light to the top-right direction for all stars assessed; we concluded that the images may have been slightly out of focus. Both of these factors contributed to the inability of the AstroImageJ program to automatically find the center of B (there was no difficulty locating the center of A or C). This centroid feature is key to producing consistent results in CCD double star astrometry. As such, the center of B had to be estimated by hand for each measurement, yielding data with a large standard error. The standard error of the mean of the PA and SEP of the AB components (without use of the centroid feature) were 0.063 degrees and 0.149 arcseconds respectively, compared to the AC PA and SEP measurements' standard errors of 0.024 degrees and 0.009 arcseconds.

## Conclusion

The new data seems reasonable when referenced to past data. The SEP measurement of WDS 16579+4722A was greater than projected; this may be due to the inability of AstroImageJ to centroid on the B

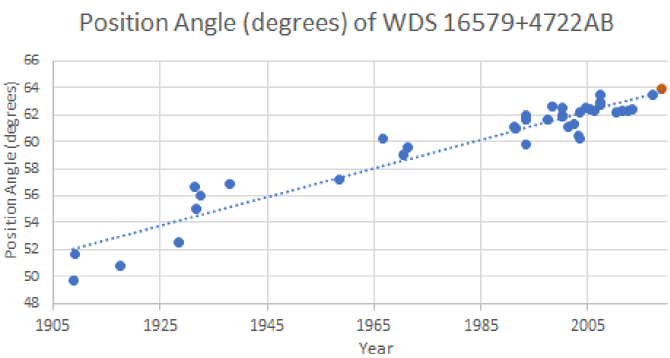


*Figure 7. Position Angle of WDS 15679+4722AB over time. New data represented by orange point.*

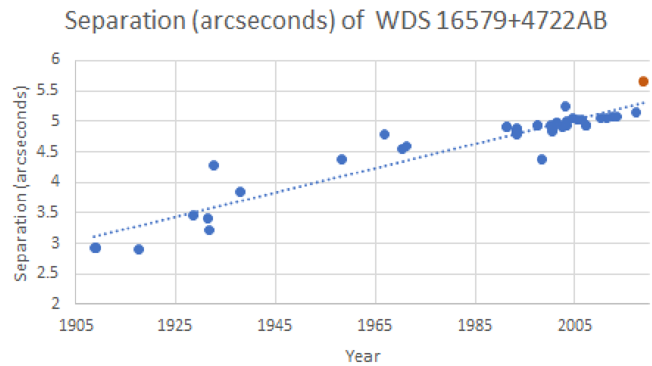


*Figure 8. Separation of WDS 16579+4722AB over time. New data represented by orange point.*

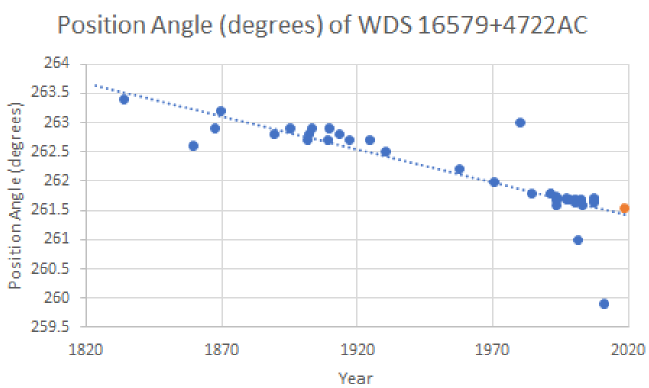


*Figure 9. Position Angle of WDS 16579+4722AC over time. Two far outlying points have been omitted to remove bias. New data represented by orange point.*

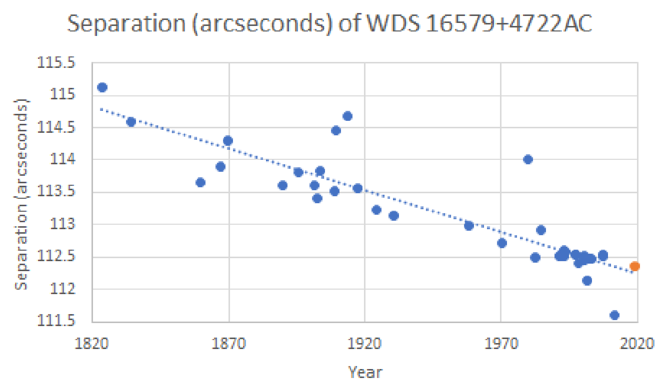


*Figure 10. of WDS 16579+4722AC over time. New data represented by orange point.*

component given its closeness and dimness in regard to star A and or the skewed focus of the images. The PA of WDS 16579+4722AC was exactly as projected and the SEP nearly was as well. Further observation is needed to confirm AB's relative position more accurately.

Based solely on past PA and SEP data, these new measurements of the AB components may suggest the stars are not binary and in an elliptical orbit but, conversely, are an optical double with linear relation to each other. However, the classification as a binary star is not based solely on PA and SEP measurements, but using radial velocity measurements and the apparent motion technique collected and calculated by Kiselev, A. A., et al. at the Main Astronomical Observatory of the Institute of Astronomy at the Russian Academy of Sciences. This method also enabled their team to derive the stars' masses and takes into account more factors than just observed coordinates (Kiselev, et al. 2009).

## Acknowledgements

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## References

Aitken, Robert G. “Early Work on Double Stars at the Lick Observatory.” *Publications of the Astronomical Society of the Pacific*, vol. 57, 1945, p. 138., doi:10.1086/125705.

Genet, R., Johnson, J., Buchheim, R., & Harshaw, R. (2016). *Small Telescope Astronomical Research Handbook*. Santa Margarita, CA: Collins Foundation Press.

Herschel, John Frederick William, and James South. “Observations of the Apparent Distances and Positions of 380 Double and Triple Stars.” *Philosophical Transactions of the Royal Society of London*, vol. 114, 1824, pp. 1–412., doi:10.1098/rstl.1824.0001.

Kiselev, A. A., et al. “A Dynamical Study of the Wide Hierarchic Triple Star ADS 10288.” *Astronomy Reports*, vol. 53, no. 12, 25 June 2009, pp. 1136–1145., doi:10.1134/s1063772909120063. “16579+4722 A 1874AB (STFA 32AC).”

Sérot, Jocelyn. “Measurements of Aitken Visual Binary Stars: 2017 Report.” *Journal of Double Star Observations*, vol. 14, no. 3, 1 July 2018, pp. 527–537.