Exploring the Binary Nature of STF 2128 Using Separation and Position Angle Measurements

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Abstract: A team of nine students from Cuesta College studied double star STF 2128 (WDS 17033+5935) using ten CCD images obtained at the Sierra Remote Observatories. Calculations of these ten observations yielded an average separation of 12.203″ and an average position angle of 42.957°. By comparing these values with past observations from the Washington Double Star Catalogue, we concluded that STF 2128 is likely a true binary system.

Introduction

In the spring semester of 2017, nine Cuesta College students studied past observations and gathered new data on the double star listed as STF 2128 (WDS 17033+5935) in the Washington Double Star Catalogue (WDS). STF 2128 is a suspected binary star system with a seemingly curved orbit. However, the latest observation, published in 2010, suggests that it strays slightly from the ellipsoidal trail traced by previous data points (shown in Figure 1). This suggests that the primary and secondary stars may not be orbiting each other, but appear to be close together as optical doubles. STF 2128 was discovered by Friedrich Georg Wilhelm von Struve (shown in Figure 2) in 1830. It is just one among the hundreds of thousands of known doubles today.

Double star astrometry has its origin deep in ancient Greek and Egyptian culture. Centuries later in 1803, astronomer William Herschel and his sister Caroline (shown above in Figure 2) had already observed 269 double stars when they made an unexpected discovery. Some of these pairs were in fact gravitationally bound "binary" stars with one star moving in an arc relative to the other. Their remaining subjects were "optical doubles" – any two stars that appear close together from a viewer on Earth. It takes decades, even centuries to determine the orbit of a binary system. Some doubles may simply have a linear relationship to each other in space, rather than a curved orbit. Still, observations and analysis of both optical doubles and binaries contribute to our overall knowledge of stars. For instance, binary stars can reveal highly desired information about stellar masses. Herein lies the motivation for the team's research.

The team selected STF 2128 with the goal of collecting a new accurate measurement for the separation and position angle of this star using modern, advanced equipment and, in turn, contributing the first CCD observation of STF 2128 to the Washington Double Star Catalog. We aimed to compare our data with previous findings, identify any trends, and help others refine the path of motion shown in Figure 1 by adding data to our understanding of the star's path. The final goal was to make a conservative conclusion on whether or not STF 2128 could be classified as a binary system with elliptical relative motion. Furthermore, we hoped to offer a modest, yet authentic and professional contribution to the astronomy research community that will increase the aforementioned collective understanding of celestial phenomena.

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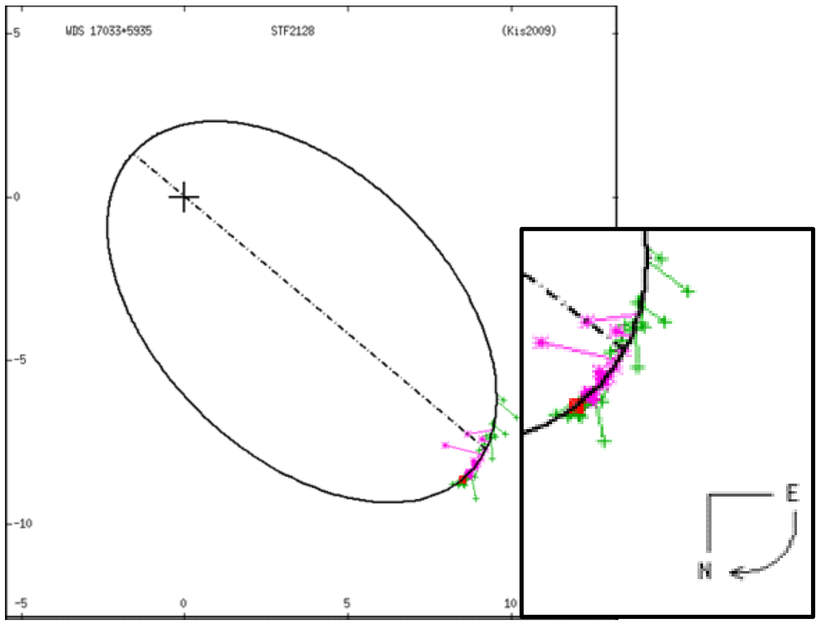

Figure 1: Orbital plot of past 69 observations made on STF 2128 provided by Brian Mason of the United States Naval Observatory (USNO).

Equipment and Procedures

Measurements of STF 2128 were obtained using the charge-coupled device camera (CCD) astrometry method. CCD astrometry of double stars typically involves 1 second or longer exposures and a field of view (FOV) of several arcminutes to produce high-resolution images of the target star and surrounding stars. Ten images of STF 2128 were captured on April 9th, 2017 at the Sierra Remote Observatories (SRO) (shown in Figure 3). SRO is located 4,610 feet above sea level in California's Sierra Nevada Mountains, providing prime atmospheric conditions and preventing the interference of fog and the thermal inversion layer.

A PlaneWave Instruments CDK17 Astrograph telescope was utilized to obtain these measurements (shown in Figure 4). The CDK17 is a 17 inch (0.43 meter), f/6.8 corrected Dall-Kirkham model. It encompasses a 70 millimeter field view without any field cur-

Figure 2: (left) Friedrich Georg Wilhelm von Struve and (right) William Herschel and his sister, Caroline.

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Figure 3: The Sierra Remote Observatories are devoted to modern remote/robotic imaging and data acquisition.

vature, off-axis coma, or astigmatism. The camera used to obtain the ten images was an Apogee Alta F16M front illuminated KAF-16803 monochrome CCD camera. This camera has a 16.8 Megapixel sensor with 9 mm pixels. There were no filters used when capturing the ten images.

Astrometric plate-solving was done on Astrometry.net, in order to transform the pixel (X, Y) coordinates into celestial (RA, Dec) coordinates for each image. The aperture size was reduced, then the team obtained calculated values for the separation and position angle of STF 2128

Then, the ten images were uploaded onto AstroImageJ, a downloadable imaging program. We obtained calculated values for the separation and position angle of STF 2128. These measurements from all ten images were averaged using the statistical software, Minitab. We constructed a position angle versus time graph, as well as a separation versus time graph from our new data and data from past observations.

Results

Table 1 displays the separation and position angle measurements calculated for the ten CCD images of STF 2128. The average separation was 12.20 arcseconds with a standard deviation of 0.18 and a standard error of 0.05. The average position angle was 42.95 degrees with a standard deviation of 0.46 and a standard error of 0.14.

Discussion

The graph (shown in Figure 5) presents a best-fit linear trend line for all 70 position angle measurements of STF 2128, including the team's observation, over time. This is indicated by the descending trend line at the top of the graph. The coefficient of determination (R^2) value is 0.9529. The best-fit trend line for all 70

Figure 4: The PlaneWave Instruments CDK17 astrograph telescope similar to the telescope used for observations at SRO.

Table 1: Separation and position angle measurements from the ten CCD images, as well as their average values, standard deviation (SD), and standard error (SE Mean).

Observation	Separation (arcseconds)	Position Angle (degrees)
1	12.40	42.26
2	12.45	42.51
3	12.02	42.72
4	12.32	43.37
5	12.16	42.96
6	12.16	43.84
7	11.95	42.92
8	12.48	42.59
9	12.10	43.29
10	12.26	43.09
Mean	**12.20**	**42.96**
SD	**0.18**	**0.47**
SE Mean	**0.058**	**0.15**

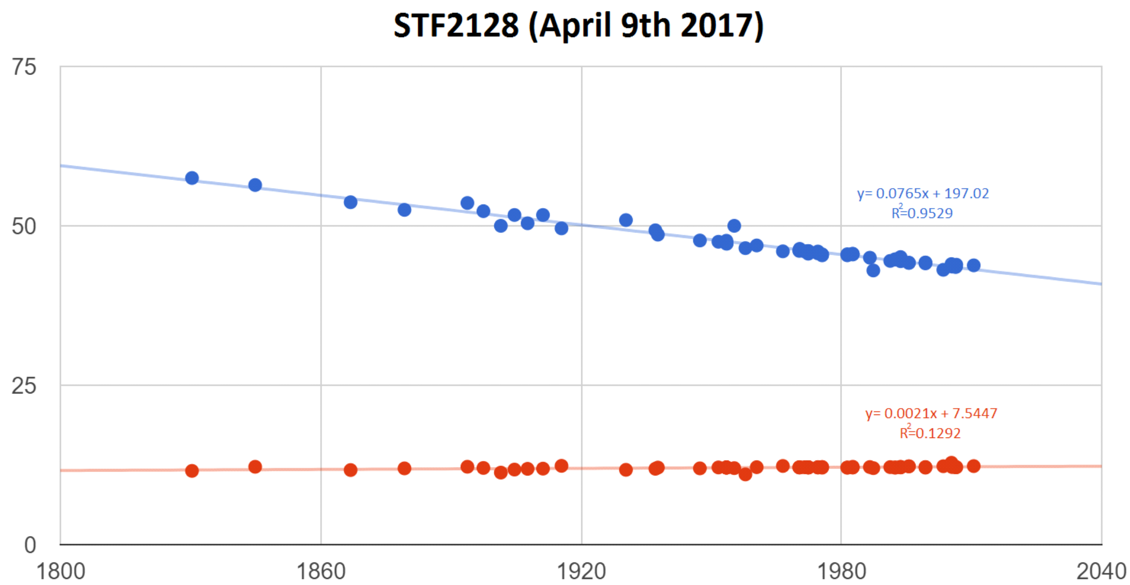

Figure 5: Position angle (degrees) v. time (years) is indicated by blue and separation (arc seconds) v. time (years) is indicated by orange.

separation measurements, including the team's, over time is shown on the lower portion of the graph. This has an R^2 value of 0.1292.

The graph reveals that while the separation has hardly changed since 1830, the position angle has decreased with some variation - the last several data points slightly deviate from the linear trend. The team acknowledged that the most recent measurements are likely more accurate than previous ones due to sophisticated modern technology used for data acquisition. This could account for inconsistencies in measurements for STF 21218.

According to the WDS Catalog, the primary star has proper motion vectors of -356 milliarcseconds right ascension and +236 milliarcseconds declination. The secondary star has proper motion vectors of -345 milliarcseconds right ascension and +237 milliarcseconds declination. These numbers are very similar, suggesting that the two stars were born from the same cloud of dust, and are traveling together. With the addition of our observation we inferred that this double star is indeed following the theoretical curved path (shown in Figure 1). Therefore, STF 2128 is likely a binary system or a common proper motion pair, rather than an optical double.

Conclusion

We successfully calculated the separation and position angle of STF 2128 from our ten images, simultaneously providing the first CCD observation for this binary. We graphically compared their results to past measurements, identifying both trends and inconsistencies. Finally, we concluded that STF 2128 is actually a binary following the proposed orbital path displayed in Figure 1. Observations of this system should be continuously made every several years to validate its binary nature and perfect its computed orbit.

Acknowledgments

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