Astrometric Measurements of WDS 17033+5935

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Abstract: We report astrometric results for the essential data belonging to the components of the STF-2128 (WDS 08359 + 0955) double star system using the iTelescope network. When combined with existing historical observational measurements, our data contributes to the confirmation of the system as a true physically-bound binary based on its orbital motion.

Introduction

This research project was part of an Astronomy Research Seminar offered by Mesa College, supported by the Institute for Student Astronomical Research (InStAR), and conducted by Boyce Research Initiatives and Education Foundation (BRIEF).

As a proof of concept of our data analysis process, we decided to observe a double star system listed in the Washington Double Star Catalog (WDS) as having a "known" orbital solution. The double star system we selected was best observable from the Northern hemisphere in the summer, with an angular separation greater than six arc seconds, and with a listed difference of apparent magnitude of 2.5 between the stars. WDS 08359 + 0955 (hereafter referred to as STF 2128) satisfied these criteria. Motivations for these criteria are discussed in the telescope selection section below.

After review of the WDS catalog, we selected WDS 17033+5935 as our binary system. It was last measured in 2006, with position angle (theta) 45.6° and separation (rho) 12.12". In addition, WDS 17033+5935 had ample observations, 55, along with a particularly useful orbital plot that integrates many data points over the total observation period of the system. This plot was provided on the Stelle Doppie Internet Database, which collates hypothetical double star observation data from various sources (See Figure 1). Figure 1 suggests a possible path for the secondary star to travel, if it were a binary star. It also suggests that the secondary star is near the aphelion (apogee) position.

The double star system WDS 17033+5935 was first discovered in 1830 by German astronomer Friedrich Georg Wilhelm von Struve and cataloged as STF 2128. Struve founded modern study of binary star systems and was the first to measure the parallax of Vega, placing him in the front line of astrometric research. Between 1824 and 1837, Struve made a measurement for 2714 double star systems. The first measurements for STF 2128 reported position angle (theta) of 58° and separation (rho) of 11.6". Selection on historic measurements of the WDS 17033+5935 is presented in the Table 2. In 1986, the information for STF 2128 was updated by a European Agency space mission that had first launched a satellite called Hipparcos, which resulted in updates of 2373 binary stars, reporting a position

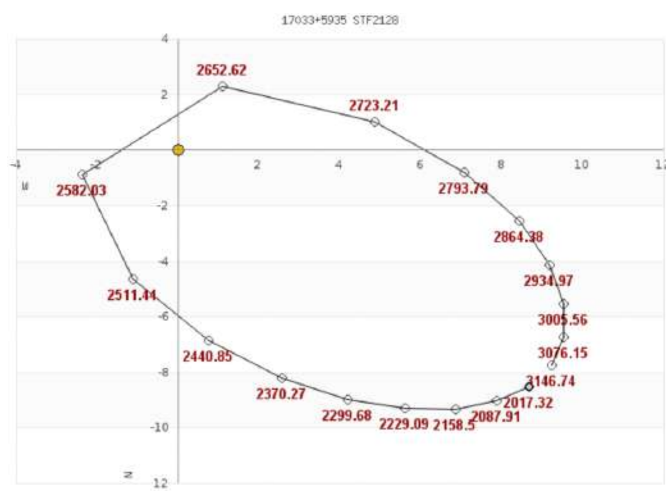

Figure 1. Orbital plot that points out possible future locations of the WDS 17033+ 5935.

***Table 1:** A summarization of the data collected from 1830 to the most recent observation of 2017. The selected data suggests that there could be a possibility that it may be a binary star system, but at the moment, the previous observations data is too sporadic to make such daring accusations.*

Year	Theta	Rho
1830.4	57.5	11.57
1866.89	53.7	11.70
1893.81	53.58	12.21
1915.50	49.6	12.36
1930.35	50.9	11.73
1937.13	49.3	11.90
1951.66	47.5	12.11
1953.494	47.35	12.09
1970.294	46.07	12.14
1986.56	45.	12.17
1993.653	44.572	12.15
2003.489	43.1	12.30
2006.486	43.9	12.15
2017.930	42.845	12.185

Figure 2. T18 Telescope based out of Nerpio, Spain. From the iTelescope Network. Telescope Specs: TEL 0.32-m f/8.0 reflector + CCD, Resolution: 0.73 arc-seconds/pixel, UTC +1:00 Madrid Daylight Savings Time is Observed, Minimum Target Elevation: Approximately 30°-40° Degrees, North: 38° 09'- West: 002° 19', Elevation: 1650m

angle of 45° and separation of 12.17". In 2016, 359 pairs of stars were collected from plates obtained from 1960 to 2007. Out of those plates, information on STF 2128 was collected in 1993, using a 26-inch Zeiss Refractor with a Canon Camera with a 21M Jupiter lens, giving STF 2128 an angle of 44.572° and a separation of 12.15"

According to Stelle Dopie, WDS 17033+5935 is found to have a spectral class of K4V, yellow-orange, leaving it relatively cooler than other double star systems. A K spectral class is measured to have temperatures between 3,900K and 5,200K meaning that it is significantly cooler than Earth's Sun, which measures at 5778K. However, like Sun, WDS 17033+5935 is the main sequence star.

Equipment, Observations, and Data Reduction Procedures

CCD images were taken using the T18 Telescope (Figure 2), which is based in Nerpio, Spain, and is part of the iTelescope Network. The T18 Telescope uses a 0.32-m f/8.0 reflector equipped with the CCD (SBIG-STXL6303E) that yields a resolution of 0.73 arc-sec/pixel and has varying filters available for observations. The filters used for WDS 17033+5935 were red(2) 30/60 second increments of exposure, hydrogen alpha (3) 30/60/90 second increments of exposure, and visible light(2) 30/45 second increments of exposure. Seven images were collected on March 27, 2017. One of the images that used the hydrogen alpha filter can be seen in Figure 3. These images were preprocessed (dark and flat subtraction) by the iTelescope data reduction pipeline.

Each image was received as a FITS file. We performed image analysis using MaximDL v6 software. In its astrometric measurements, MaximDL finds all the stars in the image and matches them against catalog positions for stars in that vicinity (by referencing the UCAC4 catalogue). The calculated mapping is stored

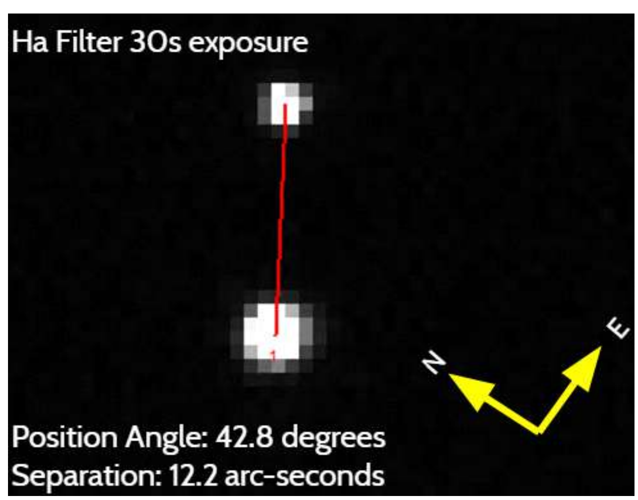

***Figure 3:** Hydrogen alpha filter data, with an exposure of 30s.*

as standardized World Coordinate System (WCS) values in the FITS header of each image file.

To analyze the separation and position angle of the components in our double star system we have used Mira64 (Mira, 2016). Mira64 was also used to reduce the contrast for the double star system. The images provided by the iTelescope network had decent resolution.

DS9 was used to estimate a Signal-to-Noise ratio of approximately 700, indicating a high data quality. A circle was made on the primary star to find the signal, and then it was compared to nine other similar sized circles to collect data from the empty space surrounding the primary star. By making a circle around the primary star, we were able to determine how much space in the circle was being preoccupied by some type of illumination from nearby stars. The nine other circles were placed around the primary star to determine if any nearby star's illumination was interfering with the primary star's illumination, which would allow for error in the data. The data collected can be found in Table 2.

***Table 2**: Data collected from DS9, using the BARC.*

STF 2128 T18	
Main Sum	79640
Sum1	1369
Sum 2	1395
Sum 3	1379
Sum 4	1244
Sum 5	1581
Sum 6	1359
Sum 7	1178
Sum 8	1347
Sum 9	1268
Deviation	114
Noise	114
SNR	698

Results

Table 3 shows the angular separation and position angle (θ) for STF 2128, that we calculated, and the uncertainty in each. The average of all the data collected was found to be 42.8° for the position angle (θ), and 12.18" the separation (ρ). The standard deviation is less than 1%.

Discussion

Based on the data collected from the images taken of WDS 17033+5935, further observations over the next decade can reveal whether STF 2128's angular separation will continue to increase or reach a maximum. Figure 4 is the provided (WDS - USNO) orbital plot of STF 2128, with the median data point from our images added (red color). In Figure 5 a plot of position angle as a function of time can be found, showing how historic points and the current point fall nearly along the trendline that indicates decreasing position angle. Figure 6 is the plot for separation as function of time for STF 2128 and it is somewhat scattered around the separation of 12", indicating that this parameter is more or less constant over the last two hundred years. If we were to base our data on the previous observations, as well as the proposed orbital plot in Figure 1, it is expected that the secondary star should be closed to its aphelion (apogee) position. There could be a possibility that the data can be skewed, since the points seen in Figure 4 were hand picked, suggesting that the secondary star could continue moving in a straight line, until further data can be collected in the future to suggest that the secondary star is actually curving.

Conclusion

Using, the moderately-sized robotic telescope, T18 from the iTelescope network we measured the position and separation angle of the stars in WDS 17033+5935 system. If we were to base our measurements, from the double star system, to the calculated orbital path (Figure 1), there is a possibility that the star system could be curving, but there isn't enough data to actually prove this correct, since previous data can be seen as sporadic. Combined with existing historical data our

***Table 3**: Results of Mira Pro astrometric measurements of WDS 17033+5935.*

STF2128 (WDS 17033+5935 Astrometry			
Telescope: (number of images used in each filter)	**Epoch 2017.0328**	**Position Angle (degress)**	**Separation (arcsecond)**
T18: (2R), (2 Luminance), (3 Hα) 7 images total	Mean	42.8	12.2
	Standard Deviation	0.050	0.016
	Std. Error of Mean	0.019	0.0061
2006 measurement (most recent prior to this investigation)		45.6	12.13

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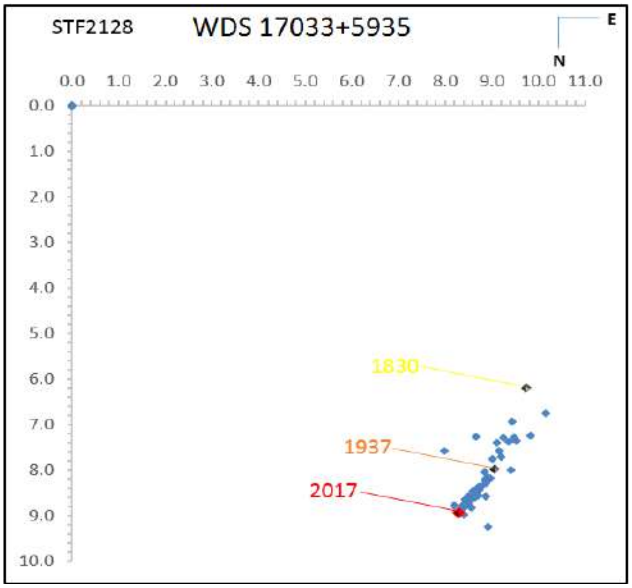

Figure 4. XY Orbital plot of historic data with the new found 2017 point.

astrometric measurements suggests that WDS 17033-5935 is double star system with secondary star being at the apogee or turning point of its orbit. Future observations over time will be key in further confirming the system as being a true physical binary.

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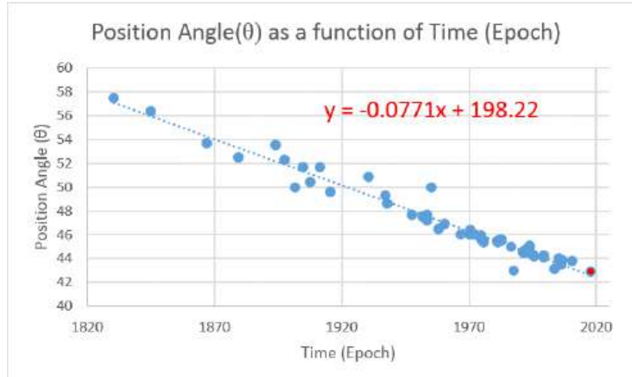

Figure 5. STF2128 Position Angle versus Epoch. XY plot of the historical observations of STF2128's A & B component stars' relative positions. The blue dots are the historic points, and the red dot represents the current position we have. A linear trendline and a function of the line was added to represent the pattern of the data.

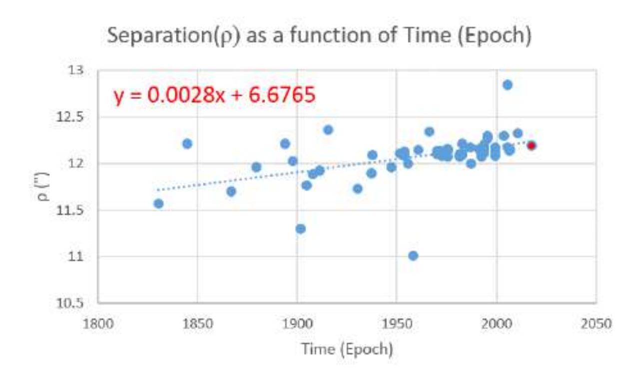

Figure 6. STF 2128 Separation versus Epoch. XY plot of the historical observations of STF 2128's A & B component stars' relative positions. The blue dots are the historic points, and the red dot represents the current position we have. A trendline and a function of the line was added to represent the pattern of the data.

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