Student Measurements of the Double Star STFA 28AB Compared with 18th - 21st Century Observations

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Abstract: Five students participated in a summer double star workshop at the Lewis Center for Educational Research in Apple Valley, California. An 8-inch Schmidt-Cassegrain telescope with a 12.5mm Celestron Micro Guide eyepiece was used to measure the position angle and separation of the double star STFA 28AB which was found, respectively, to be 170° and 108 arc seconds. The results were compared to late 18th and early 19th century observations as well as the most recent ten observations listed in the Washington Double Star Catalog. The measured separation changed by 20 arc seconds between 1781 and 1800 and then did not change significantly for the subsequent 212 years. The authors suggest either a procedural error by Herschel or, if binary, the orbital inclination of the system may explain the change.

Introduction

A two-day Summer Double Star Workshop was held by the High Desert Astronomical Society (HiDAS) and the Central Coast Astronomical Society (CCAS) to measure and report on the double star system μ Boötis (STFA 28AB). The observations were made at the Lewis Center for Educational Research in Apple Valley, California by a team of students from Victor Valley College.

The star system STFA 28AB is identified in the Washington Double Star Catalog (WDS) as WDS 15245+3723, located at right ascension 15hr 24' 05" and declination +37° 23'. The magnitudes of the primary and secondary stars are listed as 4.3 and 7.1, respectively. We compared our observations to late 18th and early 19th century observations, as well as the most recent ten observations listed in the WDS.

Figure 1: The observers from left to right: Gary Ridge, Mark Brewer, William Buehlman, Deanna Zapata, and Hannah Jarrett.

The WDS and the Set of Identifications, Measurements, and Bibliography for Astronomical Data (SIMBAD) were used to find different identifiers, including 51 Boo A, ADS 9626, BDS 7258, CHR 181A, H 6_17, IDS 15207+3742, mu 1 Boo, STFA 28Aa-BC, STFA 28AB, SAO 64686, STTA 139, and TYCO-2 2570-01521-1.

Figure 2: An illustration of the star system STFA 28Aa-BC. The figure shows stars A, B, and C. The primary is a double star that cannot be visually separated.

Figure 3: William Herschel 1738 – 1822

Background

STFA 28AB was discovered by William Herschel over two hundred years ago and has been observed by many astronomers, each with a unique identifier. STFA is the identifier for Friedrich Georg Wilhelm von Struve. The letters "AB" refer to the brightest components of the system. STFA 28AB also has "a" and "C" components which means the system is composed of at least four stars. Figure 2 shows the three brightest stars in the system STFA 28Aa-BC.

William Herschel (1738 – 1822), Figure 3, a German-born astronomer, is listed in the WDS under the reference code "H." From October 1779 to 1792, he discovered and measured double stars from his home in Bath, England. Herschel presented his observations to the Royal Society of London in 1782 of 269 double or multiple systems (Herschel 1782) and in 1784 of 434 systems (Herschel 1784).

Herschel designed and built a 6.2-inch aperture, 7-foot focal length Newtonian telescope with two small keys in the stand that allowed the observer to follow the sky in altitude and azimuth. Herschel made over 200 telescopes with apertures between 6 and 9 inches

Figure 4: This is the telescope William Herschel used to discover the double star STFA 28AB. The photograph of astronomer Brian Manning was taken by Richard Berry at the Herschel Museum in Bath, England.

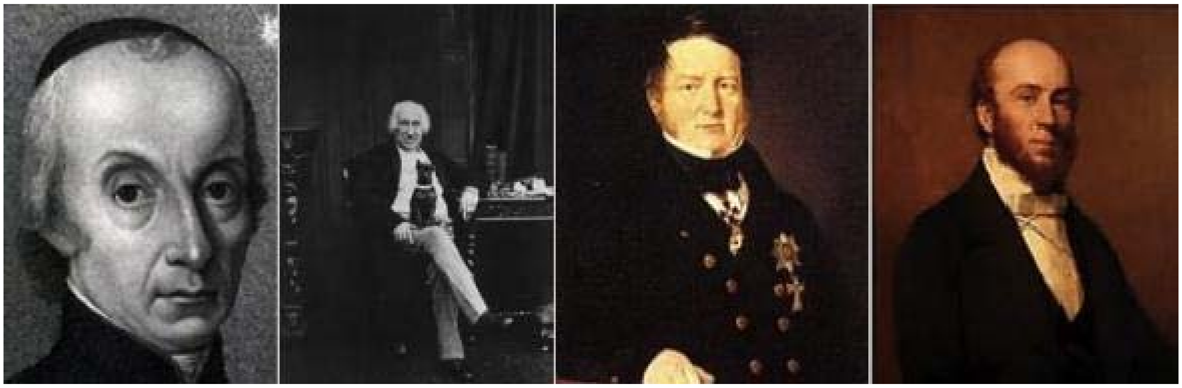

Figure 5: Pre-1900 astronomers who observed STFA 28AB. Left to right: Giuseppe Piazzi 1746 – 1826, Sir James South 1785 – 1867, Friedrich Georg Wilhelm von Struve 1793 – 1864, and William Henry Smyth 1788 – 1865.

on alt-azimuth stands similar to the one shown in Figure 4.

Several other pre-1900 observers measured STFA 28AB (Figure 5). Giuseppe Piazzi (1746 – 1826), listed in the WDS under the reference code "Pz," is most famously known as the discoverer of the dwarf planet Ceres. He supervised the compilation of the *Palermo Catalogue* of stars published in 1802 and revised in 1814 (Darling 2012), containing 7,646 star entries, including his measurements of STFA 28AB in 1800. Sir James South (1785 – 1867), listed in the WDS under the reference code "SHJ," was a member of the Royal Astronomical Society. He observed and cataloged 380 double stars prior to 1824, including STFA 28AB in 1821.

Friedrich Georg Wilhelm von Struve (1793-1864), listed in the WDS under the reference code "StF," is most famous for his *Catalogus novus stellarum duplicium*, published in 1827 (Batten 1977). He observed STFA 28AB in 1837. Admiral William Henry Smyth (1788 – 1865), listed in the WDS under the reference code "Smy," reported his observation of STFA 28AB in 1832. Smyth built his own observatory in Bedford, England, where he published his now famous *Cycle of Celestial Objects* and *The Bedford Catalog* containing 1,604 double stars and nebulae.

Figure 6: Anthony Roger's 8-inch Meade Schmidt-Cassegrain Telescope

Methods

An 8-inch Meade Schmidt-Cassegrain go-to equatorial telescope (Figure 6) equipped with a 12.5mm Celestron Micro Guide eyepiece was used for our observations. A stopwatch which reads to the nearest 0.01 seconds was used for timing.

The observers used the the drift method to determine the scale constant. A star was positioned on the linear scale of the Micro Guide eyepiece and the eyepiece was rotated such that the star would drift precisely along the linear scale when the the clock-drive was turned off. The time it took, in seconds, for the primary star to move across the linear scale's 60 division marks was estimated with the stopwatch. The average of 10 drift times was used to determine the scale constant using the equation

$$Z = \frac{15.0411\, t \cos(d)}{D}$$

where

Z is the scale constant in arc seconds per division,

15.0411 is the Earth's rotational rate in arc seconds per second,

t is the average drift time in seconds,

d is the declination of the calibration star in degrees,

D is the number of division marks on the linear scale (60).

The separation was determined by aligning both the primary and secondary stars along the linear scale, and the number of divisions between the stars was estimated to the nearest 0.1 divisions. The stars were repositioned at different points along the linear scale after each observation to avoid measurement bias. After 10 trials, the average, standard deviation and standard error of the mean were calculated and multiplied by the scale constant to determine the separation in arc seconds.

The position angle was determined by again aligning both stars on the linear scale, with the primary star on the 30th division, which marks the precise center of the eyepiece. The observers then disengaged the clock-drive, allowing both stars to drift to the inner protractor ring of the Micro Guide eyepiece. When the primary star reached the protractor, the clock-drive was reengaged and the primary star's position was estimated to the nearest degree. The eyepiece was rotated 180° between each observation to reduce bias (Frey, 2009). A 90° correction was applied to all position angle estimates as required with the Micro Guide eyepiece, and a 180° correction was applied to half of the observations to account for the rotation after each observation. The average, standard deviation, and standard error of the mean were calculated for 7 trials.

Observations

Observations were made on June 15, 2012 (B2012.45) in the parking lot of the Lewis Center for Educational Research in Apple Valley, California. Figure 7 shows a student making a measurement. Observations took place during a new moon, with average sky conditions and a temperature of 80°F. Table 1 lists the averages (mean), standard deviations, and standard errors of the mean for the drift time, separation, and position angle measurements. Toward the end of the workshop, the star system approached the zenith and observations ended. The average drift time yielded a scale constant of 9.73 arc seconds per division.

Figure 7: William Buehlman taking a measurement.

Comparisons and Conclusion

Table 2 lists the measurements from the late 18th and early 19th century observations. Table 2 also compares the separation and position angle differences and percentage differences to our measurements in Table 1. Table 3 lists the last ten years of separation and position angle measurements as well as their average, standard deviation, and standard error of the mean. Figure 8 shows the students doing a statistical analysis of their data.

We found the 20.0 arc second difference from the 1781 Herschel measurement significant by 9.5 standard deviations. The 4.0 arc second difference from the 1800 measurement by Piazzi was a statistically

Table 1: Student Measurements

	Units	# Obs.	Std. Dev.	Mean	Std. Mean Err.
Drift Time	Seconds	10	0.21	48.85	0.06
Separation	arc seconds	10	2.1	108	0.7
Position angle	degrees	7	1.2	171	0.4

Table 2: Student's observations compared to late 18th early 19th century observations provided by Brian Mason.

Historical Observations			Comparison to Present Study			
Epoch	Position angle (degrees)	Separation (arc seconds)	Position angle difference (degrees)	Separation difference (arc seconds)	Position angle percentage difference	Separation percentage difference
1781	170.4	128.0	0.6	20.0	0.4	15.0
1800	171.5	112.0	0.3	4.0	0.3	3.5
1821	171.9	108.5	0.9	0.5	0.5	0.5

Table 3: The last 10 observations provided by Brian Mason.

Date	Position angle (degrees)	Separation (arc second)	Observer Code	Telescope Aperture
2006.402	170.0	109.0	UPR2008b	31-inch
2006.571	170.9	107.94	Vim2008b	5-inch
2008.276	169.9	107.4	Ant2010b	10-inch
2008.311	170.0	108.7	Ant2010b	10-inch
2009.15	172.0	108.6	Bin2010a	4-inch
2009.266	170.9	108.63	Arn2009d	8-inch
2009.299	170.8	107.4	Abt2010b	10-inch
2009.514	170.8	108.91	Bvd2010c	11-inch
2010.419	170.7	107.7	Ant2011b	10-inch
2010.52	171.0	108.61	StJ2011	6-inch
Average	171.0	108.0		
St. Dev.	0.6	0.6		
St. Err. Mean	0.2	0.2		

Figure 8: The authors having fun while preparing a scientific paper.

insignificant 1.9 standard deviations. The 0.5 arc second difference from the 1821 measurement by Sir James South was only 0.24 standard deviations away from our measurement and for the past ten years the separation and position angle has not changed by any statistical amount. Therefore, the separation of STFA 28AB has been essentially constant for 212 years since Piazzi's measurement.

We offer three possible causes for the large reported change in separation between the 1781 and 1800 observations: 1) technology of the late 18th century may not have allowed the same accuracy as more modern equipment (it has been suggested that this is common in early observations); 2) there may have been a transcription error when the measurement was initially recorded; 3) if the double star is binary and the orbit is nearly on-edge as seen from Earth, the secondary may have approached greatest elongation in the late 18th century. With a separation over 100 arc seconds, the secondary could remain there for centuries as seen from Earth. Causes 1 and 2 were not tested by the present study due to a lack of access to period technology or original data sheets. Cause 3 is the most unlikely, though it is supported by the lack of change in position angle. If the orbit is nearly edge-on, we would not expect to see a change in position angle until inferior conjunction.

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