Visual Measurements of the Multiple Star STT 269 AB-C and ARN 8 AB-D

Thomas G. Frey[1], Irina Achildiyev[2], Chandra Alduenda[2], Reid Bridgeman[2], Rebecca Chamberlain[2], and Alex Hendrix[2]

1. California Polytechnic State University, San Luis Obispo
2. Evergreen State College, Olympia, Washington

Abstract: This astrometry project was performed by a member of the faculty and students from The Evergreen State College at the 2010 Pine Mountain Observatory Summer Science Research Workshop. This study involved measuring and analyzing the separation and position angles of the multiple star system STT 269 AB-C and ARN 8 AB-D. The astrometric binary AB was treated as a single star. Separation and position angles of the C and D components relative to AB were made. Percent differences between observed and literature values were all less than 1 percent.

Introduction

A multiple star astrometry investigation was performed by an interdisciplinary team (Figure 1) from The Evergreen State College (TESC) at the Pine Mountain Observatory (PMO) Summer Science Research Workshop near Bend, Oregon. The workshop was conducted August 5-8, 2010. This investigation involved the separation and position angle measurements of the multiple star system, STT 269 AB-C and ARN 8 AB-D, shown in a modified ALADIN image in Figure 2 (ALADIN previewer, RA: 13 32 50.99, Dec: +34 54 25.69).

Equipment

The instrumentation used in this investigation was the same as has been previously reported [Frey 2008], namely, an 18-inch Newtonian telescope by Obsession on an alt-az mount. The tracking unit was StellarCAT's ServoCAT GOTO system guided by an Argo Navis computer. A Celestron 12.5 mm Micro Guide astrometric eyepiece was used to measure the separation and position angles. Calibration of the Celestron eyepiece was unnecessary because the telescope was in the same configuration as in a previous study [Frey, et. al. 2010]. The scale constant for the linear scale, as previously determined, was 10.24 arc seconds per division. The standard deviation for the 11 observations was 0.94 arc seconds/division; the standard error of the mean was 0.29 arc seconds/division.

Figure 1. Clockwise from top right: Thomas Frey, Alex Hendrix, Rebecca Chamberlain, Irina Achildiyev, Reid Brickman, and Chandra Alduenda. The team is gathered around Frey's 18" alt-az Obsession telescope used in this study.

Locale and Observing Conditions

Pine Mountain is located east of Bend, Oregon at +43.79 degrees north latitude and 120.94 degrees

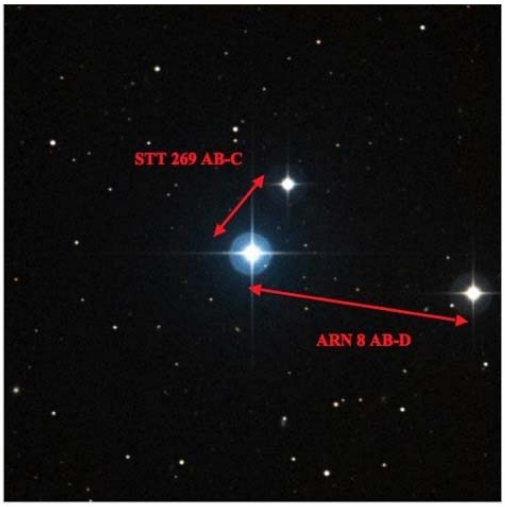

Figure 2: The multiple star system STT 269 AB-C and ARN 8 AB-D

west longitude. The sky was clear and the seeing was excellent with a minimum of scintillation. The temperature during observing hours was 40-45 degrees Fahrenheit. Breezy conditions existed each night with occasional strong gusts that did lead to a few outliers that were recorded, but were deleted from the analysis.

Background

In past workshops and undergraduate research seminars. double star investigations often follow the pattern of (1) calibration of the eyepiece, (2) collecting separation and position angle measurements on a "known " double star (a system that has been extensively studied), and (3) repeating this operation on a "neglected" double star. Neglected double stars are systems that have been rarely studied or have not been restudied for quite a while. For investigators new to double star research, the neglected double stars are chosen to be fairly bright and have separations of 25 arc seconds or greater because only an astronomic eyepiece is being used without a Barlow lens and cannot effectively measure dim stars or ones with small separations. The choice of neglected double stars in the northern hemisphere has diminished in recent years thanks to the Herculean efforts of such visual observers as David Arnold in Flagstaff, Arizona. The ones remaining on the neglected double star list are either too dim or too close together to be easily evaluated by beginners.

So the Pine Mountain Observatory team decided to measure a visual triple star system instead of attempting one of the neglected double stars. Triple stars are common, such as Σ279 in Andromeda (Haas 2006). The three stars are indicated by the letters A, B, and C listed in this order and, usually, in diminishing brightness. In essence, this study is like measuring two double stars in the same field of view, with the same primary star. Since triple star measurements are less often reported, the students decided to take on the challenge.

The multiple star chosen was STT 269 AB-C and ARN 8 AB-D. Frey had originally requested a list of triple stars from Brian Mason, Director of the Washington Double Star Catalog (WDS) at the US Naval Observatory [Mason, 2010]. His request included stars with no RA limits, declinations limited from -15 to +90 degrees, separations greater than 15 arc seconds and magnitudes for each star no greater than 11. Mason graciously sent a list of 26 possible candidates. As an added bonus the 26 were actually quaternary systems. The four-star system selected for observation by the TESC team visually appears as a triple star since the A and B components have a very small separation. The stars are in the constellation Canes Venatici.

Historical Information on STT 269 AB

The investigation of STT 269 AB began in 1843 when it was discovered by Otto Struve, the son of the Russian astronomer Friedrich G. W. von Struve. In 1839 the Russian government called upon Friedrich to build and direct the new Imperial Observatory at Pulkowa. The principle instrument was an equatorial refractor with a 15-inch objective lens. This was the largest refractor in the world at the time just as the 9.5-inch Fraunhofer refractor at Dorpat Observatory had been in 1824. It was thought that this 15-inch instrument might reveal double stars that had escaped detection by the Dorpat refractor due to smaller angular separations or faint components [Aitken 1935]. Otto Struve's observations of STT 269 AB revealed a binary system having magnitudes 7.3 and 8.1 with a position angle of 210 degrees and a separation of 0.3 arc seconds (Mason 2009). This separation was just within the Dawes limit for this instrument.

In 1879 the third star of the system was identified as the "C" component of STT 269 AB-C with a position angle of 333 degrees relative to the AB components, a separation of 116.5 arc seconds, and magnitude of the "C" star of 9.2. Its spectral type is F5.

The Dawes Limit

If two stars of approximately the same magnitude are close enough that their Airy disks overlap, they

will be seen as an elongated single star. If these disks generate a figure-8 shape and the light intensity between the two touching disks drops by 30%, the two stars can still be viewed as separate stars. William Dawes (1799-1868), an English astronomer, discovered that the smallest separation between two stars manifesting this 30% drop in intensity can be determined by the empirically developed formula

Dawes Limit = 4.56 arc seconds/*A*

where *A* is the aperture of the objective lens in inches. The larger the aperture, the smaller the Dawes limit. For a 15-inch refractor, the Dawes limit is 0.304 arc seconds. Dave Arnold (Arnold 2010), a well known double star observer, pointed out that Struve's 15-inch refractor had the theoretical capability to resolve this pair, especially since the difference in magnitudes were minimal (7.3 and 8.1). The combined magnitude of the two stars in STT 269 AB listed in the WDS is 6.8.

Current Separation and Position Angle of STT 269 AB

In 2007, according to the WDS, the position angle of STT 269 AB had changed to 220 degrees while the separation had remained constant at 0.3 arc seconds. This system, also known as ADS 8939, has been used as an astrometric standard to calibrate deformable secondary mirror adaptive optic systems [Close 2003]. Its separation of 0.3 arc seconds in our telescope, using just the Celestron astrometric eyepiece, cannot be detected and thus it appears as a single star.

Separation and Position Angle Measurements of STT 269 AB-C

After performing two star alignment and engaging the servo motors, 21 separation trials were taken and 4 outliers were deleted due to strong wind gusts leaving a total of 17 observations. The separation of the AB-C system in the current study was determined to be 123.4 arc seconds. The most recent WDS separation, determined in 2002, was 122.5 arc seconds. The standard deviation of our observations was 0.53 arc seconds, while the standard error of the mean was 0.13 arc seconds. The percent difference from the most recent literature value was 0.74%. These values are summarized in Table 1. The Besselian epoch for all measurements recorded in this study was B2010.597.

The position angle was then evaluated. Some 15 trials with no outliers were observed. Our observationally determined position angle was 331 degrees, compared to the WDS value of 332 degrees. The standard deviation was 0.66 degrees and the standard error of the mean was 0.18 degrees. The percent difference from the most recent literature value was -0.30%. These values are summarized in Table 2.

Separation and Position Angle Measurements of ARN 8 AB-D

The separation measurements of both STT 269 AB-C and ARN 8 AB-D were taken consecutively while the servo motors were still engaged. After the separation measurements had been completed, the servo motors were disengaged and the position angles evaluated by the drift method. Both operations were easily manipulated because all stars in the system were in the same field of view.

In 1919, the fourth "D" star was incorporated into the system. It was originally observed with position angle of 259 degrees from STT 269 AB, a separation of 357.1 arc seconds, and the magnitude of the "D" component was 8.4. Dave Arnold is the official discoverer of ARN 8 AB-D, dated in 2002. The 1919 data were obtained from other catalogs available to the Naval Observatory (Mason 2010). Arnold's discovery of the AB-D system occurred in 2002 with an 8"

Table 1: Separation Measurements for STT 269 AB-C. *plus 4 Outliers

Star System	Identifiers	Lit. Epoch	# Obs.	SD/ME	Obs. Sep.	Lit. Sep.	% Diff.
STT 269AB-C	13 32 52.1 +34 54 25.8	2002	17*	0.53/0.13	123.4	122.5	0.74

Table 2: Position Angle Measurements for STT 269 AB-C

Star System	Identifiers	Lit Epoch	# Obs.	SD/ME	Obs. PA	Lit. PA	% Diff.
STT 269AB-C	13 32 52.1 +34 54 25.8	2002	15	0.66/0.18	331	332	-0.30

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Table 3: Separation Measurements for ARN 8 AB-D. *plus 1 Outlier

Star System	Identifiers	Lit. Epoch	# Obs.	SD/ME	Obs. Sep.	Lit. Sep.	% Diff.
ARN 8AB-D	13 32 52.1 +34 54 25.8	2002	19*	0.42/0.10	349.7	352.5	-0.79

Table 4:. Position Angle Measurements for ARN 8 AB-D

Star System	Identifiers	Lit Epoch	# Obs.	SD/ME	Obs. PA	Lit. PA	% Diff.
ARN 8AB-D	13 32 52.1 +34 54 25.8	2002	12	1.08/0.31	258	260	-0.77

Schmidt Cassegrain telescope. The results were published in 2003 [Arnold 2003].

In 2002, position angle and separation measurements were taken yielding 260 degrees and 352.5 arc seconds, respectively. In the current study, 20 trials with 1 outlier deleted resulted in a separation of 349.7 arc seconds, with a standard deviation of 0.42 arc seconds and a standard error of the mean of 0.10 arc seconds. The percent difference from the most recent literature value was -0.79%. This information is summarized in Table 3.

The position angle was then observed with 12 trials (no outliers). The experimentally determined position angle was 258 degrees, compared to the most recent WDS value of 260 degrees. The standard deviation was 1.08 degrees and the standard error of the mean was 0.31 degrees. The percent difference from the most recent literature value was -0.77%. These values are summarized in Table 4.

Analysis

Triple star systems, analogous to double stars, can either be bound by gravity or just optically aligned by coincidence. For instance, the Alpha Centauri system is composed of two sun-like stars, Centauri AB, orbiting one another every 80 years, and Proximi Centauri located at a distance of about 15,000 AU, orbiting the AB components about every 100,000 to 150,000 years. All three components are bound by gravity. Beta Cephei, however, is composed of a true binary star and an optical component. In some other triple systems none of the components are bound by gravity due to the great distances between them, i.e. their alignment is just coincidental.

In order to specify the binary or optical nature of the star system it is necessary to examine the proper motion vectors and relative distances between the components. Some of the physical parameters for the star system STT 269 AB-C and ARN 8 AB-D are summarized in Table 5. Proper motion vectors and parallax values are given in milli-arc seconds per year (mas/yr).

Experienced double star observer, Dave Arnold, [Arnold 2010] explains that in order to be considered a true binary star, the proper motion vectors of a pair should have about 90% agreement. Examination of the AB-C and AB-D proper motion vectors in Table 5 shows that these vectors lay outside these restrictions and should be considered optical components. However, the STT 269 AB system has been studied at length [Close 2003] and with a separation of 0.3 arc seconds is considered an astrometric binary.

Examination of the standard deviation and standard error of the mean for separation and position angle for this system shows our measurements to be precise and in good agreement with the Washington Double Star data of 2002.

Figure 3 shows a modified ALADIN applet photo

Table 5: Parameters for SST 269 AB-C and ARN 8 AB-D

Star System	Proper Motion[1] (mas/yr)	Parallax (mas/yr)	Distance (parsecs)	Sep.[1] (arcsec)	Spectral Type	WDS Epoch
STT 269AB	(A)-046-015	5.73[2]	174.5	0.3	(A) A6III[1]	2007
STT 269AB-C	(AB)-046-015 (C) -082+037	4.36[3]	229.5[3]	122.5	(C) F5[3]	2002
STT 269AB-D	(AB)-046-015 (D) +013-027	2.31[3]	432.9[3]	352.9	(D) G0[3]	2002

1-Washington Double Star Catalog, 2-SIMBAD, 3-The Sky6

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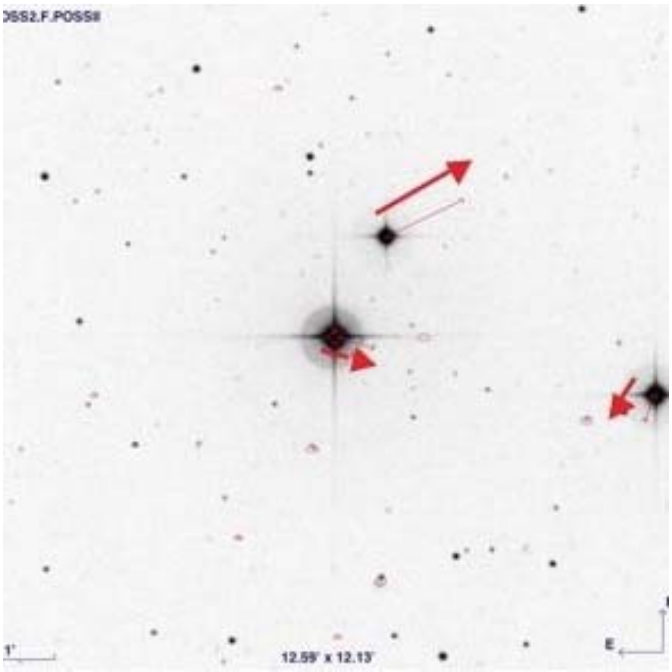

Figure 3: Proper motion vectors for STT 269 AB-C, ARN 8 AB-D.

with enhanced proper motion vectors. Arrows are shown to approximate scale and direction. The vectors show pictorially the divergent proper motion vectors indicating the optical nature of the AB, C, and D stars.

Conclusions

The separation measurements for both components were precise with standard deviation and mean error values all below 1.0 arc seconds. The experimental difference in separation for STT 269 AB-C was less than 1 arc second from the current WDS literature value. However, the experimental value for the separation of ARN 8 AB-D differed from the literature value by 2.8 arc seconds. One possibility for this difference could be due to a persistent breeze that was causing the two stars to jitter around on the linear scale making precise measurements more difficult. The larger separation was an additional factor. With a separation of about 350 arc seconds, and a scale constant of about 10 arc seconds per division, it required the observer to scan about 35 divisions on the linear scale, simultaneously, to get the appropriate separation. Actually, the observer would often cite one value on the scale and the second value several seconds later. During this hiatus, the breeze could easily have moved the telescope so the second value would be inaccurate.

Future studies of multiple stars will concentrate on systems with smaller angular separations when true binary star systems may be investigated.

The position angle measurement for ARN 8 AB-D also suffered from the wide separation. For STT 269 AB-C, the experimental separation of 123.4 arc seconds was small enough to allow easy alignment on the linear scale. The position angle was then precisely measured to within a degree of the literature value and standard deviation and mean error values less than 1.0. But the observed separation of ARN 8 AB-D was over 2.8 times larger than that of STT 269 AB-C. Team members found it more challenging to align the two stars on the linear scale before performing the drift method of position angle determination. The resulting values for the position angle had a wider spread (standard deviation of 1.08 degrees) and an experimental value 2 degrees from the literature value.

Through these experiences, the students gained confidence and the ability to apply these newly crafted skills toward further work on the "push-Dobs" available at The Evergreen State College.

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weren't for Russ Genet's initial efforts, none of the double star projects would have taken place.

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