Separation and Position Angle Measurements of Double Star STFA 46 and Triple Star STF 1843

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Abstract: Various students and faculty all participated in the 2011 4th annual summer astronomy workshop at Pine Mountain Observatory. Our group was trained in the proper techniques and skills required for measuring the separation and position angle of the binary star STFA 46 and trinary star STF 1843. We learned how to calibrate an astrometric eyepiece, make appropriate measurements, do a statistical analysis, and analyze data. The separation measurements our group made were comparable to current literature values. However, the observed position angles differed significantly from the literature. This discrepancy from literature values could be due to weather conditions or equipment limitations.

Introduction

A group of students, three new and two experienced observers, and an instructor from The Evergreen State College (TESC) participated in the fourth annual astronomy research workshop at the Pine Mountain Observatory (PMO) near Bend, Oregon. This year's topics were visual double star measurements and photometry. The workshop ran from July 24-28, 2011.

All visual double star teams adopted team names; ours was "Dubhe or Not Dubhe". The alt-az telescope used was an 18" Newtonian made by Obsession. The Celestron Micro Guide 12.5 mm illuminated astrometric eyepiece was calibrated and then separation and position angle measurements were taken. On night two, group members Hernandez-Frey, Key, and King, along with experienced observers Hendrix and Alduenda, joined their instructor Chamberlain and team leader Frey in observing double stars (DS). Since there were three members without DS observation experience, we decided to first

Figure 1: Members of "Dubhe or Not Dubhe". From left to right: Chandra Alduenda, Navarre Hernandez-Frey, Thomas Frey, Patrick King, Gabriela Key, Alex Hendrix, Rebecca Chamberlain

Table 1: Data for STFA 46 AB

		Proper Motion (mas/year)		
Star System	Parallax (mas)	Right Ascension	Declination	Spectral Type
STFA 46A	47.44	-147.82	-159.01	G1.5Vb
STFA 46B	47.14	-135.11	-163.78	G3V

Table 2: Data for STF 1843 AB

		Proper Motion (mas/year)		
Star System	Parallax (mas)	Right Ascension	Declination	Spectral Type
STF1843A	9.03	-46.84	-32.58	F5
STF1843B	13.87	-50.39	-35.71	F5

study the bright DS STFA 46 that had good separation so they could understand the technique. Directly after this, we observed the triple or trinary star (TS) STF 1843 in the constellation Bootes. The data was analyzed and each student was assigned a topic to write up for the published paper. Alduenda and Hendrix were assigned to write a more extensive part of the paper.

Background

The double star STFA 46 (also known as 16 Cygni) is actually a triple star system composed of an AC-B combination. STFA 46 A (HD186408) has a close binary (16 Cygni C) first resolved by Turner (2001). The AC binary has a separation and position angle of 3.4 arc seconds and 209 degrees, respectively, with a projected separation of 73 AU. The C component may be a red dwarf (Raghavan, 2006). STFA 46 B has a Jupiter-mass planet orbiting the star with a period of 2.2 years and an eccentricity of 0.69 (Mazeh, 1996). Due to the close agreement of parallax, proper motion, and spectral types shown in Table 1, STFA 46 AB is considered to be a binary pair (Hipparcos and Tycho, 1997), (Simbad database).

The triple star STF 1843 is in the constellation Bootes. The parallax, proper motion and spectral type for the A and B components are given in Table 2 (Hipparcos Catalog, The SkyX).

The values for proper motion and spectral type indicate a very close association for both A and B so they likely both originated in the same collapsing gas cloud, indicating a possible binary relationship. The parallax difference between A and B is converted to a distance of 38.2 parsecs (124.3 light years). The C component is a G5 star with a right ascension and declination proper motion of -43. 20 and +37.20, respectively (The SkyX). This indicates the star is an optical component of the AB system.

Locale and Observing Conditions

The study was carried out at Pine Mountain Observatory near Bend, Oregon. The Observatory is located at 43.79 degrees north latitude and 120.94 degrees west longitude. Due to high winds, humidity, and dew, the first night of observation was cancelled. The second night was more favorable with some breeziness at times that could have affected some measurements. The seeing was good with only moderate scintillation. At times, the transparency was not favorable.

Calibration of the Celestron Astrometric Eyepiece

The linear scale on the Celestron 12.5 mm astrometric eyepiece, divided into 60 equal divisions, must be calibrated for each telescope-eyepiece assembly to determine the scale constant in arc seconds per division. This has been described at length previously (Frey, 2008). The reference star Navi (Gamma Cassiopeia) was used for this calibration because its declination lies within the recommended 60-75 degree range for calibration (Argyle, 2004). The results are given in Table 3. SD and ME are the standard deviation and the standard error of the mean.

Double Star STFA 46 Literature Values

Once the scale constant had been determined, the 18-inch Obsession was two-star aligned and the tracking motors engaged. Because several of the observers on the team were inexperienced in using an alt-az telescope, a well-studied double star was chosen for initial study; STFA 46 in the constellation

Table 3: Scale Constant Determination

Reference Star	Besselian Epoch	Declination (degs)	# Observ.	Ave.Drift Time(secs)	SD/ME (secs)	Scale Constant (asec/div)
Navi	2011.561	60.717	10	83.28	0.22/0.07	10.21

Table 4: Separation Measurements of STFA 46 and STF 1843.

Star System	Identifier	Bessel. Epoch	Literature Epoch	# Observ.	SD/ME (as)	ObvSep (as)	LitSep (as)
STFA 46AB	19418+5032	2011.56	2010	15	0.51/0.13	42.9	39.7
STF1843AB	14246+4750	2011.56	2007	10	0.54/0.17	20.9	19.8
STF1843AC	14246+4750	2011.56	2007	10	0.30/0.10	98.9	98.8

Table 5: Position Angle Measurements for STFA 46 and STF 1843.

Star System	Identifier	Bessel. Epoch	Literature Epoch	# Observ.	SD/ME (degs)	ObvPA (degs)	LitPA (degs)
STFA 46AB	19418+5032	2011.56	2010	15	3.35/0.87	130	133
STF 1843AB	14246+4750	2011.56	2007	10	4.64/1.47	180	187
STF 1843AC	14246+4750	2011.56	2007	10	3.36/1.01	59	64

Cygnus, first studied in 1800 and most recently in 2010 (Mason, 2009). The most recent Washington Double Star (WDS) Catalog 2010 position angle and separation values were 133 degrees and 39.7 arc seconds, respectively. The primary and secondary magnitudes were 6.0 and 6.2. The right ascension and declination of the primary star are 19h 41m 49.1s and +50° 31m 31.6s. Table 1 gives additional data for STFA 46 AB.

Triple Star STF 1843

The most recent study published in the WDS Catalog of the triple star STF 1843 ABC in the constellation Bootes was done in 2007, where the position angle for the AB component was 187° and a separation of 19.8 arc seconds. The primary and secondary stars had magnitudes of 7.68 and 9.23, respectively. The STF 1843 AC position angle was 64° with a separation of 98.8 arc seconds. The C component had a magnitude of 9.72. Table 2 gives additional data for STF 1834 ABC.

Separation Measurements of STFA 46 and STF 1843

The telescope was two-star aligned and the servo-motors engaged. The Celestron Micro Guide eyepiece was rotated until the central linear scale was parallel with the axis joining the two stars. The distances between the centers of the two stars was estimated to the nearest 0.1 divisions and recorded. Then, using the slow motion controls, the stars were shifted to a new location along the linear scale, and a new measurement was made. We repeated this process 10-15 times, taking turns among all members of the group. This method of moving stars to new locations along the linear scale for each measurement was made to negate bias errors that might exist if the stars were continually kept and measured at the same division marks.

Due to possible field rotation, the eyepiece was continually adjusted so that the two stars remained aligned with the linear scale. The SD/ME are standard deviation and standard error of the mean. The observed and literature separations are given in arc seconds. The separation measurements for STFA 46 and STF 1843 are shown in Table 4.

Position Angle Measurements of STFA 46 and STF 1843

The determination of the position angle using the drift method with the alt-az telescope has been described at length in a previous paper (Frey, 2008). Briefly, it involves disengaging the servo-motors so that the telescope becomes a “push Dob”. The double star is aligned with the linear scale and adjusted manually so, when the telescope is released, the primary star drifts through the 30th division mark on the linear scale. This proper drift is difficult to do and usually takes several attempts to accomplish. Second, a parallax error can occur as the primary star crosses the outer protractor scale that can lead to an erroneous position angle. Third, aligning the two stars on the linear scale becomes more challenging as the separation becomes smaller. If not properly aligned, the position angle will be radically altered. To circumvent these potential problems, 10-15 drift cycles were carried out, and the cycles averaged to obtain the best mean value.

Due to possible field rotation, the eyepiece was continually adjusted so that the two stars remained aligned as much as possible with the linear scale. Special effort was made to realign the stars parallel to the scale and the eyepiece tightened in the draw tube. Position angles (PA) are given in degrees. The SD/ME are standard deviation and standard error of the mean. The position angle measurements for STFA 46 and STF 1843 are shown in Table 5.

Discussion

Separation measurements on the two multi-star systems were carried out using only the Celestron Micro Guide eyepiece. Table 4 shows the observed and most recent WDS literature separation values. If the observed separation values are compared in the order conducted, we see for STFA 46 AB, STF 1843 AB, and STF 1843 AC that the percent differences based on the literature values were 8.1%, 5.5%, and 0.1%, respectively. Because three of the five students taking measurements had never done this before, this decreasing trend in percent error shows that the observers were learning observation techniques very rapidly. This is why it is wise to initiate beginning observers with very bright and well-separated double stars.

The observed position angle measurements did not correlate well with the literature values. There are many possible reasons for these errors. The observed and literature values for the position angles are shown in Table 5. The observed position angles for STFA 46 AB, STF 1843 AB, and STF 1843 AC differed from literature values by 4, 7, and 5 degrees, respectively. Let's account for some of these discrepancies.

First, weather may have contributed to these errors. Occasional breezes would occur during a PA drift cycle enough to nudge the "push Dob" away from a proper drift. Yet, Grubbs Critical Value outlier formula (Burke, 1998) for a 99% confidence level determined that none of the collected data qualified as outliers but errant breezes could have moved the telescope enough to alter the observed position angle.

Second, to cancel out possible field rotation and bias readings, the eyepiece was rotated and realigned after several drift cycles. In the realignment process, the eyepiece was rotated so the linear scale was co-aligned with the axis passing through the two stars and the eyepiece was tightened with a set-screw on the draw tube. During the securing of the set-screw, the eyepiece had a tendency to rotate. So unless the eyepiece was tightly held in place while being secured, it could have rotated and thus be misaligned with the axis of the two stars.

The third and most likely explanation deals with the separation between the two stars. This is especially true of STF 1843 AB with a literature separation of 19.8 arc seconds. Because only the Celestron Micro Guide eyepiece was used to make the measurements, the scale constant was 10.2 arc seconds per division. So a 19.8 arc second separation spans less than 2 divisions on the linear scale. This is a very small distance to accurately align for the PA drift. Whereas a slight misalignment of this span in measuring separations *would not* affect the results significantly, a small tilt in the alignment *would* make a significant error in the position angle value. See Figure 2.

There are other possible reasons for position angle errors observed for STFA 46 AB, some of which can be traced to the recorded values themselves. Eight of the fifteen values ranged between 130-133° and seven ranged from 122-129°. Seven different observers recorded the 15 position angles in the course of the study. In some instances, one observer would begin the drift cycle (because adjusting the telescope to the proper drift position is very difficult for some) and then switch off in mid-drift to another observer, who would watch the pair cross the protractor scale and announce the value. We now know this is an ineffective procedure. There is the possibility that the observer could be watching the wrong star, that is, the secondary instead of the primary. This is complicated by the fact that the two stars have almost identical magnitudes; 6.0 and 6.2. This would change the observed position angle to a whole new data set. If only the eight observations ranging from 130-133° were considered, the mean position angle would have been 131° with a standard deviation and mean error of 1.30 and 0.46, respectively.

The most severe difference between observed and literature values of position angles occurred with STF 1843 AB. As indicated in Figure 2, the 19.8 arc second separation makes alignment for the drift procedure especially challenging. There were ten recorded position angles ranging from 175-186° and the literature value was 187°. Because all of the observed values were less than the literature value, the latter was rechecked. WDS values indicated the position angle in 1830 and 2007 both having 187°. TheSkyX value was 186° 37 minutes, showing close agreement. The recorded position angles were reviewed again to make

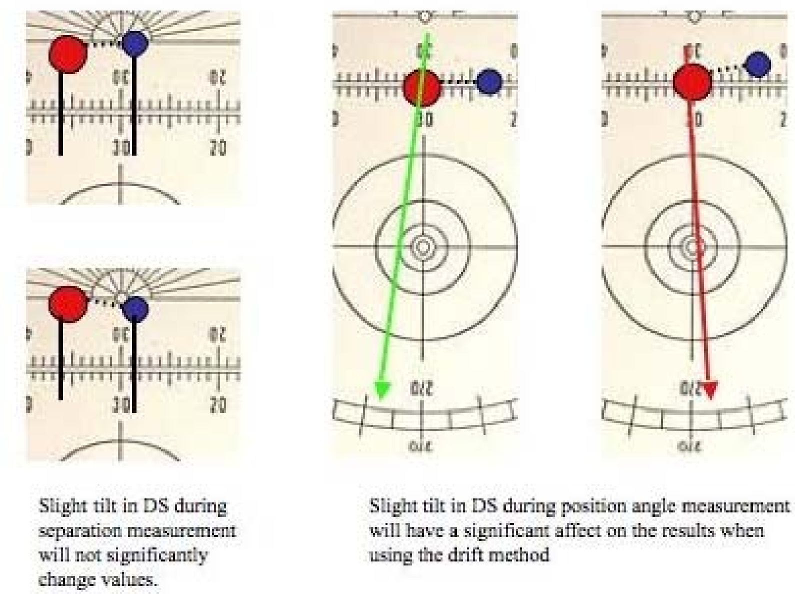

Figure 2: Possible Position Angle Errors Due to Misalignment on Linear Scale

sure that the data was correct. Six of the ten values ranged from 181-186° while the other four values ranged from 175-176°. The range of observed values between separate observers in our group does not appear to be random. This outcome could have been caused by ineffective tightening of the astrometric eyepiece in the draw tube. The eyepiece would have been skewed in the same direction each time leading to consistently incorrect position angles. The four values between 175-176° were taken concurrently so all of the observers could have been looking at the secondary star.

A similar pattern of observed position angles with respect to literature values is noted for STF 1843 AC. The ten recorded position angles ranged from 53-63° with a mean of 58°. The literature value was 64°. The literature values were again rechecked: WDS at 64° (2007) and TheSkyX at 63° 6 minutes. All but one of the observed values were less than the literature value, indicating some source of systematic error. The misaligned astrometric eyepiece is the most probable source of error.

In order to alleviate this problem in future studies, several operations are considered essential. First, for separation values less than 30 arc seconds, it is recommended that a 2x-3x Barlow lens be used in conjunction with the astrometric eyepiece so the increased magnification will allow a more accurate alignment of the pair of stars on the linear scale. This should only be done, however, when the atmospheric conditions are conducive. In the case of this study, the breeze factor was too great to allow use of the Barlow. Also, since moderate scintillation was present it would make alignment and reading of both separation and position angle difficult. Second, limit the number of people doing a particular measurement to one observer. For this workshop the exercises and measurements carried out were for education and training. However, allowing more than one person to take a particular reading could have resulted in faulty results.

Student Reflections

Three of the five students making double star observations had never attempted this kind of science research before. Their efforts included instrument setup, orientation, instruction, making observations, analysis, presentation of data to their peers, and documentation of their experiences. The following is a paraphrased summary of their reflections.

The double star STFA 46 AB were two stars with magnitudes of 6.0 and 6.2. This made it easy at times to see the stars separation and drift as they were clearly visible. Being able to work together as a group, having a positive attitude, helping explain to the next person where to look in the eyepiece and how to control the alt-az hand pad seemed to be extremely helpful. Other things that made data collection smoother were the handouts the lead professor gave us. These were handouts on how to calibrate the eyepiece, using databases for double star research, and data collection. Also, working with college professors offered a rare experience for high school students, and having college students with astronomical experience as team captains deepened the experience further. The two college students in the group taught us how to make observations and calmed fears of not getting the data correct or done in time. One way they did this was by drawing a diagram of the astrometric eyepiece and explaining how to read measurements on it. This really helped us because we were not familiar with this equipment.

We had a night of unfavorable weather which required us to do the double star and triple star meas-

urements back to back the following night without checking our double star data for errors. The triple star STF 1843 ABC gave us additional challenges. Both stars were higher in magnitude making it more of a challenge to see them. Also, Bootes was setting behind the Observatory very quickly, it was still a bit breezy, and the sky had moderate transparency due to haze. The team knew they had to be attentive and alert to finish getting the data. We could have chosen another star system that was higher in the sky and possibly easier to see given the conditions we had been working with, but we did choose this system to study and came up with some interesting results under pressure by a team of novice and experienced observers that required in depth analysis.

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