A Comparison of the Astrometric Precision and Accuracy of Double Star Observations with Two Telescopes

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Abstract: Using a manual Meade 6” Newtonian telescope and a computerized Meade 10” Schmidt-Cassegrain telescope, students from Arroyo Grande High School measured the well-known separation and position angle of the bright visual double star Albireo. The precision and accuracy of the observations from the two telescopes were compared to each other and to published values of Albireo taken as the standard. It was hypothesized that the larger, computerized telescope would be both more precise and more accurate.

Introduction

The objective of this project was to compare the precision and accuracy of visual astrometric observations of a double star made with two different telescopes. Precision is the repeatability (reliability) of the observations, i.e. how well the observers agree among themselves. Accuracy, on the other hand, is agreement with some already well-established value. Highly precise and accurate astrometric measurements are desired because they will be more strongly weighted in later analyses of a binary system. Since our objective was to evaluate both the precision and accuracy of our astrometric observations, as opposed to obtaining new values on a neglected or rapidly changing double star, we chose the double star Albireo because it has a well established separation and position angle that change only slowly over time.

This project was part of the Fall 2008 Physics Research Seminar at Cuesta College's South Campus in Arroyo Grande, California. As suggested by Johnson (2007), visual observations of double stars are well suited to one semester research seminars. Ten student first time observers attending Arroyo Grande High School met with experienced observers Genet, Johnson, and White on September 19th, 2008 (B2008.718) at the Marble residence in Arroyo Grande to observe Albireo (Marble et al, 2008).

The observers were divided into two teams: Alvarez, Kight, Navarro, Schachter, Summers, Weise, Mires and Genet used a manual 6”, f/6 Newtonian telescope with a clock drive; Fishbein, Hyland, Lopez, Rosas, Johnson, and White used a computer controlled 10”, f/10 Meade LX200 Schmidt-Cassegrain telescope. A 12 mm Meade astrometric eyepiece was used with the 6” telescope while a 12.5 mm Celestron Micro Guide eyepiece was used with the 10” telescope. Stopwatches that read out to the nearest 0.01 second were used in the calibration of the linear scales of both eyepieces.

Prior to the observations, the authors hypothesized that with a longer focal length (100” versus 36”) and larger aperture (10” versus 6”), the separations

Figure 1: Aubrey Schachter (right) watches Vega drift across the field of view of the 6" Newtonian telescope, while Molly Summers (center) times the drift with a stopwatch, and Cheyne Kight (left) records the time.

and position angles would be easier to see through the larger 10" telescope and hence would be more precisely and accurately recorded. Furthermore, the 10" telescope was on a much sturdier mount, computer controlled, and operated by an experienced operator, all factors which could lead to greater precision and accuracy. Specifically, we hypothesized that the variance of both the separation and position angle measurements would be significantly greater for the 6" than for the 10" telescope while the accuracy would be significantly higher on the 10" than the 6".

Mathematically, our hypothesis for precision was H_1: $\varsigma_{10}^2 < \varsigma_6^2$ (statistically significant at 95%), while the null hypothesis was H_o: $\varsigma_{10}^2 = \varsigma_6^2$ (not statistically significant at 95%); where H_1 was our hypothesis, H_o was the null hypothesis, ς was the standard deviation, and ς_x^2 was the variance of the data set. Our hypothesis for accuracy was H_1: $\delta_{10} < \delta_6$, while the null hypothesis was H_o: $\delta_{10} = \delta_6$; where H_1 was our hypothesis, H_o was the null hypothesis, and δ was the accuracy of the data set.

Calibrations

To calculate the scale constants for the two telescopes in arc seconds per division, the observers determined the time it took for stars with a known declination to drift across the linear scale of each eyepiece (Teague, 2004). Each star was aligned so the linear scale passed through the center of the calibration star. The eyepiece was then rotated until the star followed the ruler with minimal deviation as the telescope was slewed east and west. The star was then placed on the outer protractor and the right ascension motor turned off. When the star passed over the beginning of the ruler, the stopwatch was started, and then stopped as the star crossed the other end of the ruler. The displayed time was recorded to the nearest 0.01 second. This procedure was repeated five times on the 6" and nine times on the 10". The observers on the 6" telescope did not make as many observations because their telescope was not computerized, so re-aligning the star before each drift was more time consuming. One random outlier from the 10" observations was not included in the final analysis.

The mean drift time for each telescope was used to calculate the scale constant for each eyepiece using the following equation (Teague, 2004):

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

where Z is the scale constant in arc seconds per division; 15.0411 is the number of arc seconds per second that the Earth rotates; t is the average drift time; d is the declination of the star; and D is the number of divisions on the linear scale (50 for the Meade eyepiece and 60 for the Celestron eyepiece).

Each team observed a different star for calibration, Vega for the 6" and Beta Andromeda for the 10". Using the calibration equation above, the 6" team determined their scale constant to be 32.0 ± 0.06"/division. The 10" team calculated a scale constant of 7.07 ± 0.01"/division. Table 1 shows the declinations of both stars (Epoch 2000), the number of observations, mean drift times, standard deviations, and standard errors of the mean.

	6" Telescope	10" Telescope
Star Observed	Vega	Beta And
Star Declination	+38° 47' 01"	+35° 47' 14"
Number of Observation	5	8
Mean Drift Time	136.47s	34.74s
Standard Deviation	0.55s	0.41s
Standard Error of the Mean	0.25s	0.14s

Table 1: Comparison of Calibration Drift Times

Separation and Position Angle Observations

The distance between the two stars was estimated by each observer to the nearest 0.1 division. The double star was moved between each observation to different parts of the linear scale to avoid observational bias. The angular separation in arc seconds for each telescope was then determined by multiplying the average number of divisions separating the two stars on the linear scale by the appropriate scale constant.

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The position angle was determined by placing the brighter star at the center of the eyepiece and rotating the eyepiece so that the linear scale bisected both stars. The right ascension motor was then turned off. The position angle was determined by estimating which degree marking the star crossed the outer protractor of the eyepiece (Teague, 2004). This step was repeated three times on the 6" and four times on the 10". Atmospheric conditions and the rising moon did not allow for further observations. For each measurement, team members privately recorded their results to avoid influencing the other observers.

To compare the astrometric precision of the two telescopes, the students aimed both telescopes at the well documented, slowly revolving double star, Albireo. Each team measured its separation and position angle. Table 2 shows the means, standard deviations, and standard errors of the mean for both telescopes' measurements of separation and position angle. The students used *Microsoft Excel* for the calculations.

	Separation		Position Angle	
	6″ Telescope	10″ Telescope	6″ Telescope	10″ Telescope
Mean	37.12″	32.45″	56.3°	54.0°
St. Dev.	6.08″	1.2″	0.6°	0.8°
St. Err.	0.64″	0.14″	0.1°	0.2°

Table 2: Comparison of Separation and Position Angle of Albireo

Analysis

Were the 10" separation and position angle observations more precise than the 6" observations as the authors hypothesized? Table 3 shows the separation variance for both telescopes.

	# of Obs.	St. Dev.	Variance
6″ Telescope	5	6.8″	46.2
10″ Telescope	8	1.2″	1.4

Table 3: Separation Variance for two telescopes

The critical f-ratio (95%) was 4.12 from tables for 4 degrees of freedom for the numerator (5-1 = 4) and 7 degrees of freedom for the denominator (8-1 = 7). The observed variance ratio of 33 (46.2/1.4) was 8 times the critical F ratio value from the table, so the null hypothesis was rejected while the hypothesis that the 10" observations of the separation would be more precise was accepted.

Table 4 shows the position angle variance comparison for the precision of both telescopes.

	# of Obs.	St. Dev.	Variance
6″ Telescope	3	0.6°	0.36
10″ Telescope	5	0.8°	0.64

Table 4: Data for Position Angle Variance Comparison

The critical f-ratio (95%) was 19.2 from tables for 4 degrees of freedom for the numerator (5 -1 = 4) and 2 degrees of freedom for the denominator (3-1 = 2). The variance ratio of 1.8 (0.64/0.36) was more than 10.7 times less than the critical F ratio from the table, so the null hypothesis could not be rejected and the hypothesis that the 10" position angle observations would be more precise was not accepted.

Were observations made on the 10" more accurate than those on the 6"? Table 5 compares the observed separations and position angles for both telescopes to literature values of Albireo (STFA 43Aa-B) from the Washington Double Star (WDS) Catalog (Mason, 2006).

While the separation measured on the 6" was approximately 3% more accurate than on the 10", the position angle measured on the 10" was identical to the literature value. According to Ron Tanguay (1998), who is highly experienced in astrometry with eyepiece reticle micrometers, "With a well calibrated reticle micrometer, we may expect measurements to average about +/- 1 degree in the position angle and +/- 2% in separation from the data listed in the WDS Catalog."

Based on Tanguay's criteria, observations on both telescopes were reasonably accurate in their separation and position angle measurements. However, neither set of observations were definitively more accurate than the other. Therefore, the hypothesis that the larger telescope would make more accurate measurements could not be accepted.

Discussions and Conclusions

The students concluded that the larger telescope was more precise than the smaller one when measuring the angular separation of a double star because the separation measurements made with the 10" telescope were about five times more precise than those made with the 6" telescope. A likely cause is that the stars were separated by about one division in the 6" while they were separated by several divisions

	Separation				Position Angle			
	Obs.	Lit.	Diff.	% Diff.	Obs.	Lit.	Diff.	% Diff.
6″ telescope	37.12″	35.3″	1.82″	5%	56.3°	54.0°	2.3°	4%
10″ telescope	32.45″	35.3″	2.85″	8%	54.0°	54.0°	0.0°	0%

Table 5: Comparison of Observed Values for Albireo on the 6" and 10" Telescopes to Literature Values

in the larger telescope. Thus the stars didn't appear to blur together.

It was suggested by a reviewer that the apparent difference in precision could also have been due to the different eyepieces used in each telescope. The Celestron Micro Guide eyepiece has 60 divisions on its linear scale while the Meade Astrometric eyepiece has only 50. With more divisions on the linear scale, one might expect a more precise result from the Celestron eyepiece regardless of the telescope used. However, our difference in precision was probably not primarily due to the different eyepieces alone since the observed variance ratio was 8 times the critical f-ratio. Perhaps it was a combination of a larger telescope and an eyepiece with more linear scale divisions that produced the more precise result on the 10" telescope. Future evaluations, however, might consider controlling this variable by using the same eyepiece in both telescopes.

It was suggested by another reviewer that the observers who used the 10" telescope might have made more precise measurements because they were either more organized or more careful and meticulous than those who used the 6" telescope. This reviewer suggested that this possibility could be evaluated in any future assessments by having teams exchange telescopes and make a second set of observations.

The most surprising result from the comparison, however, was that the position angle measurements were no more precise on the 10" than on the 6". In fact, the 10" observations were slightly less precise (although the difference was not statistically signifi-

Figure 2: Several of the students analyzed the data with Russ Genet and Jo Johnson at the Marbles' home in Arroyo Grande, California. Left to right: Hairold Lopez, Jolyon Johnson, Mike Hyland, Carlos Rosas, Amos Fishbein, Aubrey Schachter, Molly Summers, and Russ Genet.

cant). This lack of difference may be because it does not matter how magnified an object was in the eyepiece when making position angle measurements. The authors suggest that since the protractor itself was not magnified, it could not be viewed more precisely. Furthermore, with the longer focal length of the 10" telescope and correspondingly smaller field of view, the star drifted faster across its field of view, including the protractor, and thus may actually have been more difficult to observe. On the other hand, with twice the magnification and brighter stars on the 10", one would have expected that the ruler could have been set to more accurately bisect the two stars prior to commencing the positional angle drift.

It might be noted that Darrell Grisham (2008), an experienced astronomer in California Valley, made very accurate measurements of bright visual double stars during the fall 2007 research seminar with a three inch Tasco telescope. His separation measurements were approximately 0.8% different from the literature values (ours were 5% for the 6" and 8% for the 10") and his position angle measurements were approximately 3% different (ours were 4% for the 6" and 0% for the 10"). For smaller telescopes, accuracy might be more dependent upon the experience of the observer than telescope aperture or focal length.

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