Comparison of Two Methods of Determining the Position Angle of the Visual Double Star 61 Cygni

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Abstract: As part of a research workshop at Pine Mountain Observatory, we observed a visual double star with a Celestron Micro Guide eyepiece to contribute to the Washington Double Star (WDS) Catalog and to compare two methods of observing its position angle. The visual double star, 61 Cygni (STF 2758 AB), was selected because it has a well established position angle. The two methods used to find the position angle were drift and slew. The slew method's advantages are that one can stop the drift on the eyepiece's protractor to get a better reading and does not have to turn the tracking motors on and off. However, the slew method is dependent on the accuracy of the polar alignment. The difference between the standard deviations of the two methods was found to be insignificant, so both were equally precise. The average position angles measured with the two methods was found to be 4.25 mean errors (σ) apart. The WDS Catalog value for position angle is 152°. The drift method had an average position angle of 151.1° and the slew method had an average position angle of 149.4°. This indicates that the drift method was more accurate.

Introduction

This project was part of the 2010 Pine Mountain Observatory Summer Research Workshop. We chose to study double stars because their concepts are straight forward enough to understand over a three day workshop, their observation promotes team efforts, and their study incorporates statistical analysis. Also there is a dedicated journal that allows for swift publication (Johnson 2008). Our goals for this research workshop were to contribute observations of a double star to the Washington Double Star (WDS) Catalog, to learn the technique for measuring double stars, and to compare two methods of obtaining position angles.

There are many methods of measuring the position angles of visual double stars, and we wanted to determine which of two methods using an astrometric eyepiece would be most precise and which would be most accurate: drift or slew. The drift method has the advantage that its accuracy doesn't depend on polar alignment so it can be done on any telescope.

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Figure 1: Jo Johnson (left) and Alex Baxter (right) stand next to the Celestron NexStar 6 SE telescope and prepare for the night's observations.

However, it may take longer to perform this method and the point where the primary star crosses the protractor has to be read on the fly as the primary star drifts by. The slew method is faster and easier to perform. The telescope can be stopped when the star reaches the protractor, which may allow for more precise readings. The disadvantage is that any polar misalignment during the telescope setup could lead to inaccurate position angles.

We hypothesized that the drift method would produce a more accurate position angle when compared to literature values, but might produce a less precise one. To make a fair comparison of the two methods, we made the measurements with the same telescope, on the same double star, at the same time, and with the same observers.

We chose the double star 61 Cygni (STF 2758 AB) because the AB stars in this system are physically bound by gravity which makes adding a data point more useful to future observers (Arnold 2010). Additionally, it is fairly bright, well separated, and its position angle is well established. It is also famous because in 1838 Friedrich Bessel, a German astronomer, was the first to accurately measure stellar parallax. He reported that 61 Cygni had a parallax of 0.314", and that the star was about 3 parsecs (9.8 light years) away (Hirshfeld 2001).

Table 1: Wedge alignment results.

	Azimuth	Altitude
Trial 1	+ 1º 18m	-0º 28m
Trial 2	+ 1º 22m	-0º 21m
Trial 3	+ 1º 11m	-0º 11m

Methods

We used an f/10 six inch Celestron NexStar 6 SE (SE 6) Schmidt-Cassegrain telescope. A Celestron tripod and wedge were used to configure the SE 6 for equatorial use (Figure 1). We used a Celestron 12.5 mm illuminated Micro Guide eyepiece. The reticle contains two closely spaced linear scales with 60 divisions across the center and a large circular protractor around the periphery. A stopwatch that read out to the nearest 0.01 seconds was used to calibrate the linear scale.

To polar align the telescope, we used the equatorial auto-align procedure as specified in the Celestron Instructional Manual. Medley then used the wedge alignment procedure which provides a check on the alignment accuracy. Readings close to zero more accurately point to celestial north. We repeated this alignment three times with the results shown in Table 1. It became clear that the azimuth alignment accuracy was not improving so we stopped after the third attempt.

The team used the drift method to calculate the scale constant in arc seconds per division. The observers used a stopwatch to measure the time it took for a relatively bright star, Navi (Declination 60.717º), in the constellation Cassiopeia, to travel across the linear scale. This was achieved by turning off the tracking motor once the star was on the east side of the linear scale, and turning it back on once the star reached the west side of the scale (Teague 2004). The mean value of several trials was then taken and entered into the following equation to calculate the scale constant in arc seconds per division for the eyepiece.

Table 2: Average, standard deviation, and mean error for the drift time and scale constant

	Drift Time	Arc seconds/ Division
Average	99.45	12.19
Stan. Dev.	0.71	0.09
Mean Err.	0.22	0.03

$$\text{scale constant} = \frac{\text{rotation of the Earth} * \cos(Dec) * \text{drift time}}{\text{number of divisions}}$$

$$\text{scale constant} = \frac{15.0411 * 0.4891 * 99.45}{60}$$

Table 2 shows the results of the drift time and scale constant.

To determine the double star's angular separation, the observers aligned both stars along the linear scale. The team rotated the eyepiece in such a way that the positions of the two stars were clearly visible along the linear scale. Each observer moved the telescope to view the stars at different points along the linear scale to reduce observational bias. The distance between the two stars was estimated by estimating the number of divisions between the stars on the linear scale to the nearest tenth of a division (Frey 2010). In total, ten trials were taken. The data was then entered into a spreadsheet from which the average, standard deviation, and mean error were obtained and recorded.

The team first used the drift method to determine the position angle of the double star. This was achieved by turning off the tracking motors once the primary star was centered in the center of the eyepiece and both stars aligned on the linear scale. We then watched the primary star pass through the outer protractor. The point where it crossed was noted and recorded (Teague 2004). The team then used the slew method. This was achieved by centering the primary star in the eyepiece. Once the star was centered, we slewed the telescope east until it intercepted the protractor. The point where it crossed was noted and recorded. Ten trials for each method were obtained, and the average, standard deviation, and standard error of the mean of the trials were separately calculated for the two methods.

Results and Analysis

We made our observations at University of Oregon's Pine Mountain Observatory east of Bend, Oregon on the nights of August 3 and 4, 2010 (B2010.59) at roughly 23:00 PST (UT) each night. There was a very slight wind and clear skies. Baxter and Johnson performed the observations. Estrada was the recorder.

Table 3: Average, standard deviation, and mean error for position angle using the drift method and slew method.

	Drift Method	Slew Method
Average	151.1°	149.4°
Standard Deviation	1.0°	1.5°
Mean Error	0.3°	0.5°

The observed separation was 30.9" with a standard deviation of 1.1" and a mean error of 0.4". The WDS Catalog value for the separation of STF 2758 AB is 30.7 arc seconds. As the observed separation is 30.9", the percent error was 0.1%.

Table 3 shows the results for both methods of determining position angle. The method with the lowest standard deviation was considered the most precise. The drift method yielded a standard deviation of 1.0° while the slew method yielded a standard deviation of 1.5°. The difference between the two standard deviations was not statistically significant, indicating that neither method was significantly more precise than the other.

To test the accuracy of the two methods we first determined if the difference in the measured position angle between the two methods was significant. To quantify the comparison, we used the following calculation:

$$\text{significance of the difference } (\sigma) = \frac{\text{(drift average) - (slew average)}}{\text{mean error average}}$$

$$\sigma = \frac{(151.1) - (149.4)}{0.4}$$

The result of 4.25σ suggest the difference in measured position angle between the two methods was not due to chance. Whichever method was closest to the WDS Catalog value was considered most accurate. If the catalog value was between them, they were considered equally accurate. The observed drift method position angle was 151.1° while the observed slew position angle was 149.4°. The WDS Catalog value for position angle is 152º. Since the catalog value is closer to the drift method value, that method was determined to be more accurate than the slew method.

Conclusion

During the workshop, the team observed the separation and position angle of a known double star. They then incorporated their measurements into a scientific paper that also describes the method of observation.

Two position angle measurement methods were compared to determine which had the best precision and the best accuracy. It was suspected that the drift method would be more precise, which it was, albeit not significantly. However, as suspected the drift method was more accurate than the slew method. The difference in accuracy between the two methods was statistically significant. Therefore, unless the telescope could be polar aligned more accurately in the future, the drift method would be preferred.

We assume that the difference between the measured position angle using the slew method differed from the catalog value in a geometric relationship to the inaccurate orientation of the telescope in azimuth. Future studies may examine this difference and establish an analytic correction for such offsets.

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