Visual Measurements of Double Stars with a NexStar 6 SE at the Pine Mountain Observatory Summer Research Workshop 2009

Austin B. Schrader
University of Oregon, Eugene, Oregon

Amanda M. Walker-LaFollette
South Eugene High School, Eugene, Oregon

Jolyon M. Johnson
California State University, Chico, California

Danyal J. Medley
Celestron, LLC

Russell Genet
Cuesta College, San Luis Obispo, California
California Polytechnic State University, San Luis Obispo, California

Abstract: As part of the Pine Mountain Observatory Summer Research Workshop 2009, high school and college students joined with an experienced double star observer and an engineer from Celestron to test a portable observatory utilizing a Celestron NexStar 6 SE with a Celestron Micro Guide eyepiece. This was the first time the students operated a telescope to make quantitative measurements, thus the secondary goal was to make the workshop an educational experience. The observations included a double star with a well known separation and position angle and then a neglected double star.

Introduction

This project was part of a research workshop held at Pine Mountain Observatory (PMO) near Bend, Oregon in July 2009 (B2009.543). The workshop observers, mostly students from various high schools and colleges, met with instructors at PMO for a weekend of learning and observation (Figure 1). Double stars were chosen as the primary research targets because of their suitability for student projects. They also offer students the opportunity to work cooperatively in groups.

The primary goal of this particular project was to evaluate the capabilities of a portable 6-inch telescope that can be used for scientific research primarily by students. The secondary goal was to allow the students to gain experience operating telescopes and to learn the specific techniques used to measure double stars. The final goal was to observe a neglected double star from the Washington Double Star (WDS) Catalog to make a modest contribution to double star research.

Equipment

The telescope used to make the astrometric observations was a Celestron NexStar 6 SE (SE 6). The SE 6 is an altitude-azimuth (alt-az) telescope with a 6-inch (150mm) f/10 Schmidt-Cassegrain optical tube assembly (OTA) with a 1500mm focal length. A standard tripod and integrated wedge were used to configure the SE 6 for equatorial use (Figure 2). A 1.25-inch Star Diagonal was also used.

The eyepiece used was a Celestron 12.5 mm illuminated Micro Guide eyepiece. The reticle contains two scales that were used for making observations. A 6mm scale with 60 divisions across the center and the large circular scale were used (see Figure 3 below). A

Visual Measurements of Double Stars with a NexStar 6 SE at the Pine Mountain Observatory ...

Figure 1: The observational team (left to right) consisted of Austin Schrader, a student at the University of Oregon in Eugene and a former student at St. Mary's School in Medford, Oregon, Russ Genet, the PMO Workshop Director, Dan Medley, Celestron's Principal Engineer, Jo Johnson, a PMO Workshop Instructor and student at California State University, Chico, and Mandy Walker-LaFollette a student at South Eugene High School in Eugene, Oregon.

Figure 2: The Celeston NexStar 6 SE mounted on a light tripod for easy portability with an integrated equatorial wedge.

stopwatch that reads out to the nearest 0.01 seconds was used to calibrate the linear scale.

Some equipment that was replaced on the NexStar 6 SE included the LED reflex finder. An Orion 9x50 right-angle finder was used instead. The 25mm standard plössl eyepiece was replaced with a 40mm eyepiece to make locating objects easier.

At points during the process of locating objects, TheSky 6 planetarium software was used to obtain visual references. A standard bound notebook, pen, and portable table were used for the annotation of the observations. A flashlight with a red filter was used to see at night and preserve night vision. A comfy chair made observations through the eyepiece easier, particularly near the zenith. A spreadsheet was used to calculate the average, standard deviations, and standard errors of the mean of the observations.

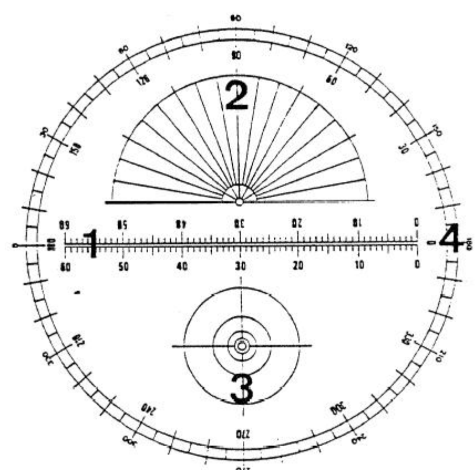

Figure 3: The four scales of the 12.5 mm Celestron Micro Guide eyepiece are (1) the linear scale, (2) the semicircular position angle scale, (3) the concentric guiding circles, and (4) the large circular scale. Only 1 and 4 were used.

Methods

Before any observations or measurements were recorded, the Micro Guide eyepiece was calibrated. 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 to travel across the linear scale. This was achieved by turning off the tracking motors once the star was on the east side of the linear scale, and turning them back on once the star reached the west side of the scale. The mean value of several trials was then taken and entered into the following equation to calculate the scale constant for the eyepiece (Teague 2004):

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

Where

- Z is the scale constant in arc seconds per division,
- 15.0411 is the number of arc seconds per second of the Earth's rotation, also known as the sidereal rate,
- t is the average drift time in seconds (recorded by the stopwatch),
- d is the declination of the star, and
- D is the number of divisions on the linear scale (60).

To determine the double star's angular separation, the observers aligned both of the stars on the linear scale. Using the Micro Guide eyepiece, the team oriented the stars in such a way that the positions of the two stars were clearly visible on the divisions of the linear scale. Each observer moved the telescope to view the stars at different points of the linear scale to reduce observational bias. The distance between the two stars was estimated by counting the number of divisions between the stars on the linear scale to the nearest tenth of a division (Teague 2004). 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 position angle was measured by meticulously placing the primary, or apparently brighter of the two stars, in the center of the eyepiece. It was crucial for the team to attain maximum accuracy with this step or the angle could be as much as five to ten degrees off. Once the primary star was properly aligned with the center of the eyepiece, the tracking motor was turned off. The observers then recorded the degree measurement where the primary star crossed the inner part of the large circular scale of the eyepiece (Teague 2004). The star was then realigned in the middle of the linear scale and the process was repeated until the team had ten trials. The data from the position angle measurements were entered into a spreadsheet and the statistical information calculated.

Results

The observers chose Alpha Cephei to calibrate the linear scale in arc seconds per division because of its optimal declination at 62.58°, not too close to the equator or pole (Teague 2004). The results of the drift and the scale constant calculation are shown in Table 1.

Table 1: Average drift time and calculated scale constant with standard deviations and standard errors of the mean.

	Average	St. Dev.	Mean Error
Drift Time (sec.)	105.96	1.68	0.56
Scale Constant (a.s./div.)	12.23	0.19	0.06

To test the methods of observation and practice making measurements, the team selected the well known double star Iota Boötis. This double star has a separation of 39.0" and a position angle of 32.5°. The team's measurements compared to the literature values are shown in Table 2.

Table 2: Measured values for Iota Boötis with standard deviation and standard error of the mean compared to literature values.

	Measured	Literature
Separation	38.7″	39.0″
St. Dev.	1.1″	
Mean Error	0.4″	
Position Angle	34.1°	32.5°
St. Dev.	1.1°	
Mean Error	0.4°	

The observed separation differs from the established value by 0.7%, while the measured position angle differed by -4.8%. Ronald Tanguay (1998), an experienced visual observer, states that, "Measurements within 5% of catalog values can be considered good..." and both the separation and position angle measurements were within the 5% discrepancy. With these results, the observers felt confident enough to measure a neglected double star from the (WDS) Catalog.

The double star ARY 52 (RA 15h 12.4m Dec 52° 56m) was selected because it was bright for a neglected double star, had a wide separation, and was measured recently (2005), thus giving it a higher probability of being found. Atmospheric conditions were less than optimal on the night of observation, so the stars appeared dimmer than normal. This was compounded by the LED light in the Micro Guide eyepiece that was bright enough that the star could not be seen. A method was created by Medley to compensate, particularly during the position angle measurement where the primary must be in the center of the linear scale. When the primary star was near the center of the eyepiece, the LED light was turned off and the telescope moved slightly to better center the star. The position of the star was remembered and the light turned back on to see if the star was in the center. This process was repeated until the star was in the exact center of the linear scale. Once the observers collected all of the data it was clear that one of the separation trials was a random outlier and was thus rejected. The results of the observations are shown in Table 3 along with catalog values.

Table 3: Measured values for ARY 52 with standard deviation and standard error of the mean compared to WDS Catalog values.

	2009	2005
Separation	149.1″	147.1″
St. Dev.	1.7″	
Mean Error	0.6″	
Position Angle	326.7°	331.0°
St. Dev.	1.1°	
Mean Error	0.3°	

The team's data shows a difference from the WDS Catalog value of the separation of 2.0 arc seconds, and a difference from the recorded value of the position angle of 5.3°. One reason the team's observations could have differed from the literature value is because of the poor seeing conditions. On the night of observation there were many high cirrus clouds drifting through the field of view and seeing was less than optimal. Also, it is possible that there was an imprecise alignment of the stars relative to the linear scale, which could have greatly affected the accuracy of the recorded position angle, even with good precision. Another possible source of discrepancy is the motion of the stars since the last data was taken in 2005.

Conclusions

The primary objective of this project was to test the equipment as a portable observatory. The observers found that setting up and polar aligning the telescope on the tripod was simple and could be done in a few minutes, and most importantly it was easy to move the telescope when needed. However, the equatorial wedge that was used was built into the tripod and was somewhat unstable. This meant that gusts of wind moved the stars enough to make measurements difficult. This has serious implications for CCD research using this set-up. In the future the team will use a more stable wedge that can be fixed on the tripod. Also, there was a significant amount of backlash that made centering the stars difficult. This was overcome by using a feature of the Celestron hand control that allows quick bursts of fast slewing when centering a star at a slower rate. When using a given direction button, pressing the opposite button at the same time activates the faster slewing rate. Using this feature made working through the backlash more tenable when having to change directions for centering.

In the future, the team also plans to try different ways of dimming the reticule. One way to do this is to use a weaker battery or letting the battery drain down before use. This is not desirable as a sub-goal of the portable observatory is to be inexpensive and buying many batteries would undermine this feature. Perhaps a more suitable way to dim the reticule is to put a piece of toilet paper in to cover the LED. This was attempted by Howard Banich, another observer at the PMO workshop, using a 28-inch alt-az telescope. While he succeeded in dimming the light, the numbers on the outermost ring of the large circular scale were obscured and almost illegible. As the observers were using a Schmitt-Cassegrain telescope with a right-angle eyepiece, this would not have been an issue since the inner ring was used for that configuration. However, this can be compensated for by Newtonian observers as well by using the inner ring and making a 180° correction when calculating the position angle. One other option suggested by PMO instructor Richard Berry is to replace the red LED with a weak green LED.

The second objective was to instruct students in the proper use of telescopes as well as the proper techniques used to measure double stars. The students demonstrated the ability to manipulate the telescope during polar alignment and the centering of the stars as well as rotating the eyepiece to take the necessary measurements.

They also learned to deal with the frustrations associated with astronomy, including staying up late, slewing a telescope with notable backlash, and making tedious observations. They participated in data reduction, scale constant calculations, and statistical analysis. The students were particularly surprised by the determination of the separation. It was hard for them to imagine that the number of divisions separating the stars would appear different each time they looked through the telescope.

Perhaps the most crucial piece of the science puzzle is communicating results so that other scientists can use the data gathered and repeat the experiment. The students gained experience writing a scientific paper during the workshop and presented the paper at a symposium before their peers. Each student was assigned a section of the paper and helped to meld the sections together to avoid redundancy. Once the paper was done, the students found the experience of critical reviews particularly beneficial. One lesson they learned was that a reviewer's suggestions are not to be taken as insults. In fact, the more critical and specific reviewers are, the more useful their comments can be.

The final goal was to research a neglected double star. The observations made in this study differ from the 2005 observations by more than the calculated standard deviation. This discrepancy may be due to several factors including weather, experience, and the motions of the stars. Because of the large differences in proper motion vectors and trigonometric parallaxes noted by Frey et al. 2009, the authors were also able to conclude that the double star is optical rather than binary in nature.

Acknowledgments

Our team would like to thank Thomas Frey, Professor Emeritus of Chemistry at California Polytechnic State University (Cal Poly), for suggesting known and neglected double stars for us to observe and record and for reviewing this paper. Thanks go to Gregory Bothun, Director of Pine Mountain Observatory for allowing us to use their facilities. Thanks also go to Vera Wallen and Dave Arnold for reviewing this paper. Special thanks to St. Mary's School in Medford, Oregon and South Eugene High School in Eugene, Oregon for their participation and encouragement.

References

Frey, T. et al., "Visual Measurements of the Neglected Double Star ARY 52 at Pine Mountain Observatory's Summer Science Workshop." (2009).

Mason, Brian, The Washington Double Star Catalog. July 2009, Astrometry Department, U.S. Naval Observatory, http://ad.usno.navy.mil/wds/wds.html.

Tanguay, Ronald, *The Double Star Observer's Handbook*, Saugus, MA: Double Star Observer (1998).

Teague, Tom, "Simple Techniques of Measurement", *Observing and Measuring Visual Double Stars*, Ed. Bob Argyle, London: Springer (2004).

Austin Schrader graduated from St. Mary's School in Eugene, Oregon after having participated in their astronomy program. He now attends the University of Oregon. Amanda Walker-LaFollette attends South Eugene High School and plans to attend a university majoring in Physics or Astronomy. She was a volunteer during summer 2009 at Pine Mountain Observatory. Jolyon Johnson is a transfer student from Cuesta College in San Luis Obispo, California to California State University, Chico, majoring in Geology. He is the Science Advisor for Orion Observatory in Santa Margarita, California and was an instructor for the Pine Mountain Observatory Summer Research Workshop 2009. Danyal Medley is the Principal Engineer for Technology at Celestron, where he has worked for seven years. He has been an avid amateur astronomer for 14 years and is interested in both recreational and scientific astronomy. Russell Genet is the Director of Orion Observatory and Director of the Pine Mountain Observatory Summer Research Workshop 2009. He is also a Research Scholar in Residence at California Polytechnic State University and a Professor of Astronomy at Cuesta College in San Luis Obispo, California.