Comparing Two Calibration Methods of a Micro Guide Eyepiece using STF 1744AB

Eric Weise[1], Jolyon Johnson[2], Russ Genet[3,4], Ryan Gelston[3],
Brian Reinhardt[3], Tess Downs[3], Tori Gibson[3], and Austin Ross[3]

1. University of California, San Diego, CA
2. California State University, Chico, CA
3. Cuesta College, San Luis Obispo, CA
4. California Polytechnic State University, San Luis Obispo, CA

Abstract: Students at Cuesta College measured the double star STF 1744 AB and used two methods to calibrate the linear scale of the eyepiece. The drift method yielded a separation of 14.9 ± 0.6 arc seconds, which was 0.2 arc seconds different from the average of ten recent observations. Calibrating the scale by measuring the scale with a caliper gave a separation of 14.6 ± 0.5 arc seconds which was 0.1 arc seconds different from the average of ten recent observations. We concluded that the physical measurement of the linear scale is an appropriate method for the calibration of an eyepiece.

Introduction

This project began as an astrometric inquiry into a double star, but pursuing our scientific curiosity we decided to compare two methods of calibrating the linear scale in the Celestron Micro Guide eyepiece. We observed the double star STF 1744 AB (Mizar) at Orion Observatory on June 28, 2012 (B2012.489). Ultimately there were two goals that this research group completed: 1) to learn how to locate and measure the astrometric parameters of double stars and 2) to compare two methods of calibrating the linear scale in a Micro Guide eyepiece.

Figure 1: The STF 1744 AB team. From left to right: Eric Weise, Ryan Gelston, Bryan Reinhardt, Austin Ross, Tori Gibson, and Tess Downs.

Methods

Measurements of STF 1744 AB were made with an eleven inch Celestron telescope on a German equatorial mount. A Celestron Micro Guide eyepiece was used for the measurements. Two calibration methods were used to determine the number of arc seconds per division in the eyepiece.

In the first method, the eyepiece was aligned such that when the clock drive was turned off and the primary of STF 1744 AB star drifted down the entirety of the linear scale with minimal deviation. The time it took the star to drift along the scale was measured using a stopwatch that reads to the nearest 0.01 second. The scale constant in arc seconds per division was calculated using the following equation:

$$Z_1 = \frac{t\ 15.4011\cos(\delta)}{60}$$

where Z_1 is the scale constant using the drift method, t is the drift time, δ is the declination of the primary star (54.91°), 15.4011 is the rate of rotation of the Earth in arc seconds/second, and 60 is the number of divisions on the linear scale. The average of twelve drift times was used in our calculation.

The second calibration constant was found by disassembling the eyepiece and measuring the length of the linear scale using a caliper. (See Figure 2.) The scale constant was then determined with the following equation:

$$Z_2 = \frac{205625\ s}{60\ Fl}$$

where Z_2 is the scale constant using the calipers, 205,625 is the number of arc seconds per radian, s is the length of the linear scale in millimeters, 60 is the number of divisions on the linear scale, and Fl is the focal length of the telescope (2800 mm) as specified by the manufacturer. The average of five measurements of s was used in our calculation.

To determine the separation we lined up the stars on the linear scale in the eyepiece and twelve measurements were taken of the separation to the nearest 0.1 division. After each measurement the stars were repositioned on the scale to reduce bias. The average separation in divisions was multiplied by each of the scale constants, Z_1 and Z_2, to compare the accuracy of the two methods described above.

We measured the position angle of STF 1744 AB by the drift method. We began by placing the primary star on the midpoint of the linear scale and rotating the eyepiece such that the secondary star was also on the linear scale. The clock drive was then deactivated and the star began to drift with the Earth's rotation. The angle that the primary star passed through on the inner protractor was estimated. The telescope was reset and the process repeated eleven more times. It was necessary to apply a 90° correction to our data because of the nature of the Micro Guide eyepiece (Teague 2004). The average, standard deviation, and standard error of the mean were calculated for all separation, position angle, and calibration constant measurements.

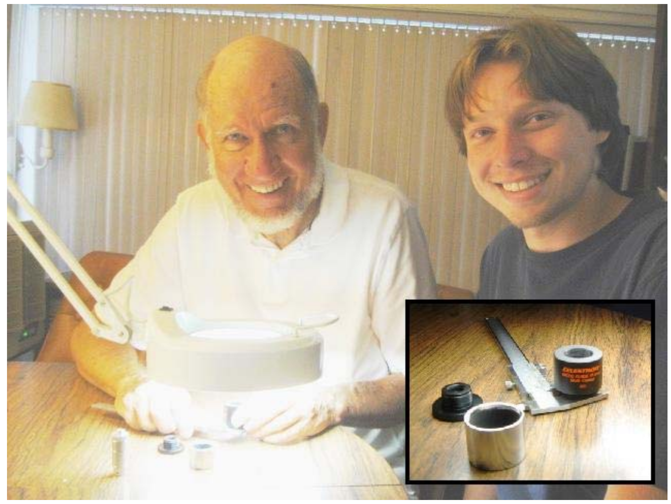

Figure 2: Genet (left) and Johnson (right) measure the length of the linear scale. Inset: calipers and disassembled eyepiece.

Results and Analysis

Our results are compared to the average of the ten most recent observations sent by Brian Mason in Table 1. The first of the ten observations was made on B2007.474 and the last observation was made on B2011.359. The calibration constants that were used to convert separation from divisions to arc seconds were found to be 7.38 ± 0.18 arc seconds/division using the average drift time and 7.26 ± 0.29 arc seconds/division using the calipers. The uncertainties are found by propagation of the standard error of the mean of the number of divisions and the measurements of the drift time and length of the linear scale (Taylor 1997).

From the drift time calibration we found the separation of STF 1744 AB to be 14.9 ± 0.6 arc seconds, which is 0.2 arc seconds different from 14.7, the average of the last ten observations (Mason 2012). This is a difference of 0.16 standard deviations of our separation value. From the caliper calibration we found the separation of STF 1744 AB to be 14.6 ± 0.6 arc seconds. The difference from the average of the the past observations is 0.1 arc seconds and is 0.06 standard deviations of our separation away from our average of past observations (Mason 2012). Furthermore, the precisions of the calibration constants are calculated by the formula:

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Table 1: The average, standard deviation and standard error of the mean of our data as well as the last ten observations provided by Brian Mason. The standard deviation and the standard error of the mean for our separation were found by addition in quadrature (Taylor 1997)

	Our Data					Last 10 Observations (Mason 2012)	
	Drift Time, t (sec)	Separation from Drift Time (arc seconds)	Length of Linear Scale, s (mm)	Separation from Caliper (arc seconds)	Position Angle (degrees)	Separation (arc seconds)	Position Angle (degrees)
No. Obs.	12	12	5	12	12	10	10
Average	50.09	14.9	5.93	14.6	156.0	14.7	152.7
Standard Deviation	0.46	1.2	0.42	1.6	1.3	0.7	0.4
Standard Error of the Mean	0.13	0.4	0.19	0.6	0.4	0.2	0.13

$$p = \frac{x}{\sigma x}$$

where p is the precision, x is the calibration constant, and σx is the uncertainty of the calibration constant. The precision of the drift method scale constant is 0.024 and the precision of the caliper scale constant is 0.040. The position angle was found to be 156.0° ± 0.4° which is 3.3° and 2.5 standard deviations different from the average of past observations.

Conclusion

After comparing the differences of two methods of calibrating the linear scale in a Micro Guide eyepiece we have determined that both methods are accurate because the uncertainties of the scale constants overlap. Our calculated precision for drift time method was ultimately greater than the caliper method. Interestingly enough, our data shows that the method of physically measuring the linear scale and using the manufacturer-provided focal length appeared slightly more accurate than measuring the drift time. Therefore, even though the caliper method is less precise method, it is still useable. Although using a caliper and a magnifying glass can be a more tedious task, it is a less time consuming operation and can be done in the daytime. Our measured position angle is greater than the accepted value by 2.5 standard deviations which is statistically significant. We attribute this large error to our failure to rotate the eyepiece by 180° after each observation, which may have introduced a systematic error to our measurements (Frey 2008). This extreme oversight will be corrected in future research.

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