

Measurements of the Visual Double Star STF 2079

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Abstract: With an astrometric eyepiece and self-made protractor-pointer mounted on a 12-inch aperture telescope, two first-time observers, during a physics research seminar at Cuesta College, determined the linear scale factor of the eyepiece using the drift-timing method. The separation and position angle of two well-known visual binary stars and one neglected visual binary star, STF 2079, were then measured. Measurement errors were calculated, and the observational results were found to agree with previous measurements with an accuracy consistent with the calculated errors. Both the separation and position angle of STF 2079 seem to be decreasing.

Introduction

Because many double stars can be seen through small telescopes and quantitatively measured with an inexpensive laser-etched eyepiece and self-made protractor-pointer, double star measurements make ideal astronomical research projects for those with modest means. By repeatedly measuring binary star separations and position angles over many decades—even centuries—their orbits and periods can be established. Newton's form of Kepler's third law ($\text{mass}_1 + \text{mass}_2 = \text{semi-major axis}^3 / \text{period}^2$) can then be applied to determine their masses, a key astrophysical parameter. Observing a double star can be a multi-generational effort, with individual observers patiently contributing their meticulous observations until, eventually, enough observations have accumulated to derive the binary's orbital parameters and hence its mass.

This project was a joint Cuesta College student/instructor effort during a physics research seminar. Neither author had previously observed double stars. The purpose of the project was threefold: (1) to learn one set of techniques for measuring double stars, (2) to practice these techniques on two well known stars (Zeta Ursae Majoris and Pi Bootis), and (3) to contribute observations of the neglected double star STF 2079.

The Orion Observatory, where all observations

were made, is located on California's central coast, fifteen miles east of San Luis Obispo. Observations were made with a twelve-inch Meade LX-200 f/10 telescope using a Meade illuminated astrometric eyepiece. To measure the position angle of the double stars, Johnson built a protractor-pointer out of foam board, duct tape, an indicator pin, and a six-inch diameter plastic 360° protractor. The Sky 6.0 was used to locate the stars. All observations were made June 19-26, 2007.

Scale Factor Calibration

To determine the eyepiece's scale factor in arc-seconds per division, we set a bright star with a known declination on the eastern-most division of the eyepiece's horizontal scale. The right-ascension tracking was turned off. Using the drift time method, the time required for the star to drift to the western-most division was recorded. Twenty of these drift timings were obtained. After finding the average, standard deviation, and mean error of these drift times, we applied the following equation (Argyle, 2004, 152).

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

Where z is the scale factor in arc-seconds per

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| Star Name | RA | Dec | Pri Mag | Sec Mag |
|------------------|-----------|----------|---------|---------|
| Zeta UMa (Mizar) | 13h 23.9m | +54° 56m | 2.2 | 3.9 |
| Pi Boo | 14h 40.7m | +16° 25m | 4.9 | 5.8 |

Table 1: The positions and magnitudes of the two well-known visual doubles used to evaluate the precision and accuracy of our measurements.

eyepiece division, 15.0411 is arc-seconds per seconds of time that the Earth rotates, t is the average time for the star to drift across the entire scale in seconds, d is declination in degrees, and D is the number of divisions on the scale (50 for the Meade eyepiece)

We obtained twenty full-scale drift timings of Alpha Bootis (Arcturus), with a declination of +19° 11', and found the average time to be 28.0 seconds with a one-sigma standard deviation of ± 0.4 seconds. The mean error (standard deviation divided by the square root of n) was 0.1 seconds. Using the scale factor equation above, we determined there were 7.9 ± 0.02 arc-seconds per scalar division.

Procedures for Determining Separation and Position Angles

Separation was determined by centering the primary star in the eyepiece and adjusting the eyepiece's rotation so that the scale passed through the center of both stars. The number of divisions between the two stars was estimated and multiplied by the scale factor, z .

Position angle was determined by aligning the eyepiece so that the primary star moved straight along the scale with minimum deviation as the telescope swung east and west. The pin pointer was aligned parallel with the linear scale on the eyepiece. The protractor was then set so the pin pointed to 90.0°. The eyepiece was then rotated until the scale passed through the centers of both stars. The angular reading of the pointer was then estimated as the position angle to the nearest 0.1°. While we did not

apply the protractor correction procedure, we did carefully center the protractor on the eyepiece (Argyle, 2004, 146-147).

Observational Results

We used two known double stars (Table 1) to practice measuring separations and position angles. They were selected from *Double Stars for Small Telescopes* (Haas 2006) based on magnitude, separation, and location in the sky.

These two stars were repeatedly observed. The mean error of the separation for these two stars, $\pm 2.29''$ and $\pm 1.07''$ respectively, were greater than anticipated. We attribute this to poor seeing, less than optimum alignment of telescope optics, and five first-time observers (three observers besides the authors contributed observations). Three observers besides the authors contributed observations. The observational results are displayed in Table 2 below.

The separation and position angle measured by Johnson, as shown in Table 3, provide the calendar and Besselian dates and the observations including mean errors. While the separations recorded on both nights agreed within the mean error, the position angles differed significantly, suggesting a small, systematic calibration difference between the two nights.

Analysis

The separations and position angles from past observations are shown in Table 4 as a comparison to those recorded by the authors.

As illustrated in Figure 1 below, it would appear

| Star Name | Separation | | | Position Angle | | |
|------------------|------------|------------------|-------|----------------|-------------------|------|
| | # Obs | Result | Haas | # Obs | Result | Haas |
| Zeta UMa (Mizar) | 6 | 15.6" \pm 2.29 | 14.3" | 4 | 152.1° \pm 0.61 | 153° |
| Pi Boo | 5 | 7.5" \pm 1.07 | 5.5" | 3 | 109.3° \pm 0.41 | 111° |

Table 2: Results from observing the two well-known stars. The mean errors of the observations were calculated as an estimate of the precision of the measurements.

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| Date | Epoch | # Obs Sep | # Obs PA | Separation | Position Angle |
|---------|-----------|-----------|----------|--------------|----------------|
| 6/25/07 | B2007.482 | 10 | 10 | 17.0" ± 0.12 | 90.5° ± 0.12 |
| 6/26/07 | B2007.485 | 6 | 5 | 16.7" ± 0.25 | 90.1° ± 0.05 |
| Total | | 16 | 15 | 16.9" ± 0.15 | 90.4° ± 0.10 |

Table 3: Observations of the neglected visual double star STF 2079 made by the authors.

| Year | Separation | Position Angle | Source |
|------|------------|----------------|-------------------|
| 1830 | 18.0" | 91.0° | Mason |
| 1997 | 17.2" | 92.0° | Morlet |
| 2000 | 17.2" | 91.0° | Haas |
| 2002 | 16.9" | 91.0° | Mason |
| 2007 | 16.9" | 90.4° | Johnson and Genet |

Table 4: Five measurements of STF 2079

that the separation has decreased by approximately 0.3" and the position angle has decreased by approximately 1.5° in the last ten years.

The latest *Washington Double Star Catalogue* (WDS, Mason 2007) entry for STF 2079 gives a separation of 16.79" and a position angle of 90.5°. The separation measured by the authors differed from the latest WDS records by only 0.11", and the position angle differed by only 0.1°, both within the estimated error.

Conclusions

With this project we learned, practiced, and applied a technique for measuring the separations and position angles of double stars. After calibrating our system's scale factor, we applied this technique to two known stars to practice and refine our methods.

We then used the same technique on STF 2079 to contribute a new measurement of a visual double star to the astronomical community. We concluded that, within our measurement error, there had been a

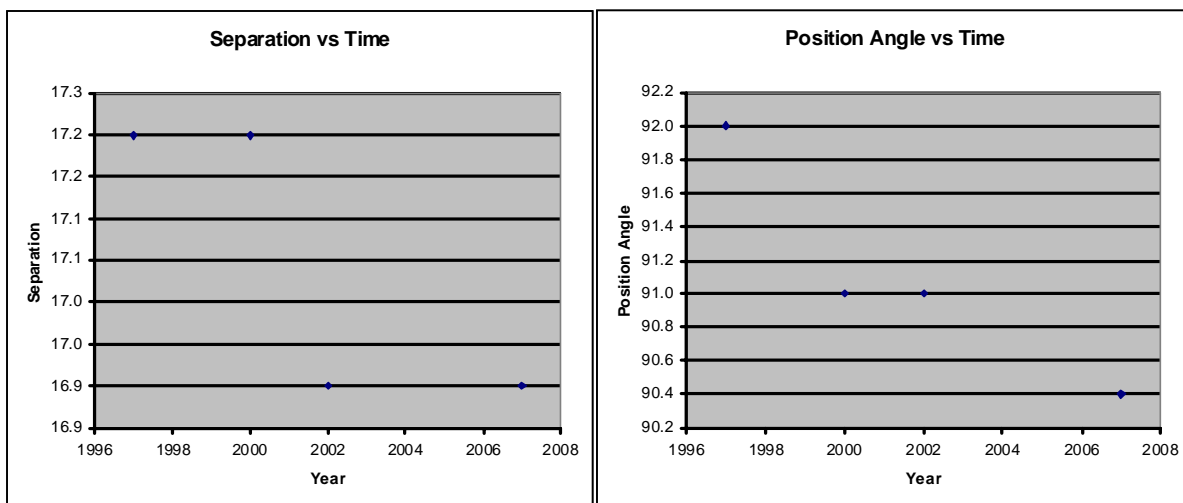


Figure 1: Separation and position angle have decreased since 1997

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significant change in the separation and position angle of STF 2079 since 1997.

To obtain more precise results in the future, we may use the bisecting method for measuring position angle (Argyle, 2004, 154). We recently purchased a Celestron Micro-guide astrometric eyepiece. As compared with the Meade eyepiece, there are more divisions on its scale, a reverse 360° protractor, and the scale has a space down the center so the divisions do not cover the stars, perhaps allowing fainter stars to be observed. Finally, greater precision may be achieved if we employ fewer, more experienced observers.

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Jolyon Johnson is starting his second year as a student at Cuesta College. He has been studying astronomy intensely for over a year, and is enrolled in the physics research seminar at Cuesta College. Russell Genet is a Professor of Astronomy at Cuesta College and instructs the physics research seminar. He is also a Research Scholar in Residence at California Polytechnic State University, and the Director of the Orion Observatory, www.OrionObservatory.org.

