

Astrometric Measurements of the Visual Double Star Epsilon Lyrae

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Abstract: Two very different telescopes were used to measure the separation and position angle of the two major components of Epsilon Lyrae, STF 37 AB,CD. One telescope was a 22 inch non-tracking, alt-azimuth “push” Dobsonian, while the other was an 8 inch Celestron on an equatorial mount. Both telescopes were equipped with a 12.5 mm Celestron Micro Guide eyepiece, although two different observational techniques were utilized. Separation measurements were within 2% of the mean of recently reported observations by others. The position angles obtained by the equatorial telescope corresponded very well with other recent observations, while the Dobsonian telescope observations departed from these observations by about 3 degrees. We attributed this departure to systematic errors introduced by the Dobsonian position angle observational procedure. We suggest that such systematic errors could be avoided in future alt-az telescope observations by following suggestions made by Thomas Frey.

Introduction

This research was a portion of the fall 2010 Astronomy Research Seminar held at the Cuesta College South Campus at Arroyo Grande High School in California. The seminar consisted of both Cuesta College and Arroyo Grande High School students (Figure 1) taking this college course in the evening. Two entirely independent separate sets of observations were made and subsequently compared. The first set of observations was made on November 3, 2010, at Star Hill, located near Santa Margarita Lake, California. Estrada brought his Nimbus II 22 inch Dobsonian telescope, which was used by six of us to make these observations. The second set of observations was made by Brewer on November 6,

2010, at Phelan, California, with an 8 inch Celestron Schmidt-Cassegrain telescope.

The purpose of the seminar was to introduce students to scientific research. The students were the seminar’s decision-makers, establishing—with guidance from the instructor—what to observe and analyze. The seminar participants decided to make astrometric measurements (separation and position angle) of the wide AB, CD pairs of stars in STF 37 (Epsilon Lyrae), a double-double. Each of the two very close pairs was treated as a single star, hence we observed the separation and position angle of one close pair with respect to the other.

William Herschel, the famous musician turned astronomer, first observed Epsilon Lyrae in 1779. He noted in his observing log: “A very curious double-

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Figure 1: The seminar participants clockwise from left front: Akash Salam, Chris Estrada, Joseph Carro, John Baxter, Abby Van Artsdalen, Sienna Magana, Miranda Graf, Drew Herman, and Russ Genet. The telescope is Joseph Carro's Celestron C-11. This college seminar was held in the physics classroom at Arroyo Grande High School. Not present was seminar participant Mark Brewer, who was preparing for observations with an 8-inch telescope.

double star. At first sight it appears double at some considerable distance, and by attending a little we see that each of the stars is a very delicate double star." See Figure 2.

The first measurements of Epsilon Lyrae were reported by Admiral William Henry Smyth. Smyth was born in Westminster, England, and joined the Royal Navy during the Napoleonic wars where he served in the Mediterranean. In 1817 he met the Italian astronomer Giuseppe Piazzi in Palermo, Sicily. A visit to Piazzi's observatory ignited his curiosity in astronomy and upon his retirement from the Royal Navy he established a private observatory in 1825 in Bedford, England, that he equipped with a 5.9 inch refractor. In 1830 Smyth was the first to record position angle and separation measurements of Epsilon Lyrae. In his 1844 book, *Cycle of Celestial Objects*, he reported his 1830 observation of Epsilon Lyrae as having a position angle of 172.5 degrees and a separation of 207.3 arc seconds.

Equipment

Our first set of observations was made using the Nimbus II Dobsonian (alt-azimuth) style telescope. This telescope was constructed by Reed and Chris Estrada using methods outlined by Kriege and Berry (1997). Its primary mirror is 22 inches in diameter with an $f/4.5$ focal length. The mirror was configured by Swayze Optical. The telescope was specifically designed to operate as a manual "push" Dob, and is



Figure 2: Shown above is the type of telescope that Herschel probably used for his double star measurements. If you look at the telescope stand carefully, you'll see two small keys that the observer turns to follow the sky in altitude and azimuth. It probably wasn't a bad system. Herschel made over 200 telescopes with apertures between 6 and 9 inches on alt-azimuth stands similar to the one shown above. He sold them to support himself. The photograph above was taken by Richard Berry of his friend Brian Manning, a very accomplished amateur astronomer, at the Herschel Museum in Bath, England.

similar to Herschel's telescope in that it is non-tracking. The second set of observations was made using an 8 inch Celestron Schmidt-Cassegrain telescope on an equatorial, clock-driven mount.

Celestron Micro Guide astrometric eyepieces were used to make all measurements on both telescopes. The edge illumination of the laser etched reticle was too bright, so a neutral density filter (a wad of tissue paper) was placed in the optical path of the red LED in each eyepiece.

Observations

Calibration

Both teams determined the scale constant on their astrometric eyepiece by observing Epsilon Lyrae itself, timing its drift across the 60 divisions of the linear scale. Eighteen drift times were obtained by the Nimbus II team, but one was discarded because the recorded value was way too small (the recorder noted in the observing log that the stop watch beep came before the observer stop command). The average of the remaining observations was 38.18 seconds with a standard deviation of 0.33 seconds and a standard error of the mean of 0.08 seconds. We used the Argyle formula (2004) to calculate the scale constant. We found it was 7.40 arc seconds/division with a standard deviation of 0.06 arc seconds/division and a standard error of the mean of 0.02 arc seconds/division.

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The Celestron 8 team used a scale constant obtained in observations of STF A 43AB.

Separation

Because Nimbus II is a “push” Dobsonian telescope without tracking, the stars drifted across the field fairly rapidly. As a result, separations needed to be estimated on the fly. We first attempted to provide left and right scale readings from a central major division, but making two simultaneous estimates was very difficult using this method. Estrada and Genet both suggested that the telescope be initially positioned in such a way that one star would drift through the zero end of the scale. This allowed a single reading to be made of the scale crossing of the second star, while simultaneously only needing to confirm that the first star actually did pass through the zero tick on the end of the scale.

Eighteen observations were made by the six observers (Figure 3) and all 18 were used in the analysis. The average separation was found to be 28.6 divisions with a standard deviation of 0.7 divisions and a standard error of the mean of 0.2 divisions. When we applied the scale factor, Z , of 7.40 arc seconds/division to these values we obtained a separation of 211 arc seconds with a standard deviation of 5.0 arc seconds and a standard error of the mean of 1.2 arc seconds.

Ten separation measurements were made with the Celestron 8. Since it was a tracking telescope, the measurements did not need to be made on the fly. To reduce any systematic errors, the double star was repositioned on the linear scale between each measurement. The average separation was found to be 28.6 divisions with a standard deviation of 0.7 and a standard error of the mean of 0.2 divisions. When we applied the scale factor to these values we obtained a separation of 206.8 arc seconds with a standard deviation of 0.4 arc seconds and a standard error of the mean of 0.1 arc seconds.

Position Angle

Before making the position angle measurements with Nimbus II, the linear scale was aligned to go through the two double stars. The position angle was measured by positioning the telescope such that the primary star drifted through the middle of the linear scale (30 mark), and reading the inner protractor crossing value. Eighteen position angle drifts were obtained with an average inner protractor value of 281.2 degrees, which translates to an outer protractor value of 258.9 degrees with a standard deviation of 2.1 degrees and a standard error of the mean of 0.5 degrees. However the outer value of the protractor was not the final value but had to be translated as



Figure 3: Observers (left to right) Abby Van Artsdalen, Chris Estrada, John Baxter, Miranda Graf and Sienna Magana all standing in front of the Nimbus II 22 inch Dobsonian telescope. Photo taken by the seminar’s instructor, Russ Genet.

described by Frey and Frey (2010). The translation yielded a final value of 168.9 degrees.

Position angles were measured in a similar manner with the Celestron 8 telescope except that the eyepiece was rotated 180 degrees between measurements. Also, the outer rather than the inner protractor was used for the measurements. Ten position angle drifts were obtained with an average outer protractor value of 172.1 degrees with a standard deviation of 0.5 degrees and a standard error of the mean of 0.2 degrees. However the outer value of the protractor was not the final value but had to be translated as described by Frey and Frey (2010). The translation yielded a final value of 172.1 degrees.

Discussion

Our observations (rounded to the nearest tenth) are summarized in Table 1, below. Besides our own observations, we included in the last row of the table, the mean, standard deviation, and standard error of the 18 most recent separation and position angles of STF A 37 AB,CD reported in the Washington Double Star Catalog.

As can be seen from the table, the separations we found using the two telescopes compared favorably with observations reported in the WDS Catalog—one about 2% higher and the other about 2% lower. With respect to position angle, the Celestron 8 was in

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Table 1: Observations made on two telescopes and those reported in the Washington Double Star Catalog

Source of Observations	Separation			Position Angle		
	Mean	Std Dev	S.E.M.	Mean	Std Dev	S.E.M.
Nimbus II	210.7	0.7	0.2	168.9	2.1	0.5
Celestron 8	206.7	0.4	0.1	172.1	0.5	0.2
WDS Catalog	208.7	0.8	0.2	172.0	1.1	0.3

agreement with 0.1 degrees of the mean of other recent observations. However, the Nimbus II observations were 3.1 degrees less than the mean of other recent observations. We suspect that a systematic error may have been introduced.

With the Celestron 8 position angle readings, the eyepiece was rotated 180 degrees between each observation. This required, by definition, that the eyepiece be repositioned each time, making a new and independent best estimate of the placement of the stars along the linear scale.

As can be seen from the table, the variance of the Nimbus II position angle observations was four times as high as the Celestron 8 observations. Also, the mean value of the Nimbus II position angle observations differed substantially from those of both the Celestron 8 and the WDS catalog. We attribute the significantly greater variance of the Nimbus II observations to possible confusion on reading the protractor values in our inexperienced observers. It seems likely that the significant difference in the mean value of the Nimbus II position angle may have been due to not repositioning the eyepiece between each observation. Thus any error in the initial positioning of the eyepiece showed up as a constant and continuing bias. Had we repositioned the eyepiece between each observation, positioning errors would have tended to average out. Furthermore, as Nimbus II is an alt-az telescope, field rotation during the considerable time it took to make the 18 position angle drift measurements could have been substantial.

Conclusions

Given the difficulties we encountered with our Nimbus II observations, we decided to adopt, as our sole final separation and position values for Epsilon Lyrae, those obtained with the Celestron 8 telescope. Thus we report as our final values for our measurements of the double star Epsilon Lyrae a separation of 206.7 arc seconds and a position angle of 172.1 degrees. For observers using alt-az telescopes, which can have significant field rotation during the time

taken to make a series of position angle measurements, we recommend that the eyepiece be repositioned between each measurement. This could be done by rotating the eyepiece 180 degrees (i.e. reversing the linear scale) as recommended by Frey and Frey (2010).

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