Measuring Double Stars with A Modified Meade Astrometric Eyepiece

Anthony Tripodi

Astronomical Society of Southern New England, Rehoboth, MA

Abstract

A 150mm refractor and a modified Astrometric eyepiece are used to measure position angle and separation of selected binary stars. Star systems are chosen to complement the equipment and conditions, and to remain within the limitations and experience of the operator. Raw data is accumulated and reduced to provide scientifically useable results.

Equipment

Telescopic equipment consists of a 150mm Sky Watcher Evostar ED refractor with a focal length of 1200mm. The telescope is permanently mounted on a pier carrying a Celestron CGEM German equatorial mount with GOTO capability.

The Meade 12mm Astrometric eyepiece has a laser etched micrometer reticle that is illuminated with a Rigel illuminator. A 1.5x Dakin barlow is fitted to the base of the eyepiece, and the eyepiece is inserted into a 3x Televue barlow, giving the Astrometric eyepiece system a total multiplier of 4.5. Thus equipped, the telescope operates at an effective focal length of 5,400mm, or f/36. The resulting magnification is 450x, with an exit pupil of 0.33 mm.

Further modification to the Meade Astrometric eyepiece is as follows: A 360º external protractor is mounted independent of the Televue barlow, mounted so as to rotate freely about the barlow while the barlow is rigidly clamped to the telescope. The eyepiece is mounted so as to rotate about the optical axis independent of the protractor and the barlow. The eyepiece is also fitted with a pointer to indicate position angle.

Eyepiece calibration was performed via the "drift method"[1] and using

$$k = \frac{15.0411 \cdot cos\delta \cdot t}{50}$$

where:

k is the scale increment graduation value, in arc seconds

15.0411 is the sidereal speed of Earth's rotation adjusted to reflect solar time, in arc seconds per second

cos δ is the cosine of the calibration star's declination

t is the star drift timing, in seconds of solar time

50 is the incremental count of the linear reticle scale

Two stars were used for calibration, 12 timings each. Mean (μ), standard deviation of the sample (s), and standard error of the mean (SE) were determined:

Star Name	Epoch	Declination	μ	k	s
Capella	J2022.3	+46.02114	19.089 sec	3.987"	0.106
Dubhe	J2022.3	+61.63450	28.07 sec	4.012"	0.144

'k' was determined for each star individually, and combining the results of those products yields a value of

k = 3.9995" (for all intents and purposes k = 4.0"), SE = 0.0088.

Method

Star systems are chosen so as to remain within the limitations of the equipment and the operator.[2, 3] The nominal Rayleigh limit for a 150mm aperture is 0.923", and brighter stars and/or star color may adversely affect that limit. Therefore, minimum separations are chosen to be approximately twice the nominal Rayleigh limit, or ≥ 2.0". Magnitudes are limited to ≤ 8.5 so as to avoid using averted vision for reading the scale, and to keep the target from being overwhelmed by eyepiece illumination. Magnitude difference, Δm, is chosen to be ≤ 3.

Position angle in degrees, θ, is measured (read) directly from the protractor scale. The reference star is allowed to drift west along the eyepiece graduation line for several iterations until the star is able to drift *exactly* along the line, indicating true west. The protractor is then rotated so as to align the 270º marking with the eyepiece pointer. With the protractor thus aligned, the eyepiece is rotated about the optical axis so as to align both stars with the graduation line, companion toward the pointer, and θ is read directly under the pointer. Experience has shown that position angle can thus be very accurately determined.

Separation, ρ, is read directly from the graduated scale. Procedure is to position the target on the reference line, take one or two readings, then move the target to a different part of the scale so as to mitigate parallax and eyepiece illumination errors. Ten readings are taken. Mean (μ), standard deviation of the sample (s), and standard error of the mean (SE), are calculated and multiplied by k to determine actual separation and tolerances in arc seconds.

At x450, bright stars can have a diameter easily reaching 1" or greater. Seeing effects will often cause artifact dancing and flaring. Therefore, ρ estimates are read to the nearest 1", or 0.25 graduation mark.

Double Star Measures

Listed in the table below are measurements of selected star systems measured in August of 2022:

Discoverer	WDS[4]	Besselian	θ	SE	ρ	s	SE
STF2308AB	18002+8000	2022.591	232	0	18.9	0.5676	0.1796
STFA44	19332+6010	2022.591	287	0	75.8	0.4216	0.1332
STF2571AB	19482+7016	2022.591	20	0	3.5	0.3688	0.1168
STF2571AB	19295+7816	2022.591	19	0	11.4	0.5164	0.1632
STF2845AB	21523+6306	2022.618	173	0	2.0	0.0000	0.0000
S 800AB	21538+6237	2022.618	145	0	62.8	0.4216	0.1332
ARY43	21572+6609	2022.618	127	0	101.0	0.4376	0.1384
STF2873AB	21582+8252	2022.618	66	0	14.6	0.5164	0.1632
STF2863AB	22038+6438	2022.632	274	0	8.2	0.4216	0.1332
ARY45	22083+6959	2022.632	206	0	67.3	0.6748	0.2136
STF2872A, BC	22086+5917	2022.632	315	0	22.0	0.6668	0.2108

An average of SE taken from the above table shows an overall tolerance in August measures to be ± 0.1441".

Conclusion

A well calibrated eyepiece and patience at the telescope will produce accurate and meaningful results. Atmospheric conditions, patience, and experience affect the outcome of each measure.[3] In poor seeing, where artifact bloating and dancing cause readings to vary by maybe 3" during data collection, tolerances are understandably higher, but still produce reasonable results. In those rare occasions of excellent seeing, results can be very accurate indeed.

References

1. “Observing and Measuring Visual Double Stars”, Bob Argyle, et al., 2004, page 152

2. “Stelle Doppie” website, Gianluca Sordiglioni

3. “Observing Visual Double Stars”, Paul Couteau, 1978, Chapter 4, “Some Practical Advice”

4. “Washington Double Star Catalog”, Mason, Wycoff, Hartkopf, maintained by the U.S. Naval Observatory