Comparison Study II: Double Star Measurements Made Using an Equatorial Mounted Refractor and an Alt-Az Mounted Reflector

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Abstract: Eight double stars with separations between 13 and 48 arc seconds were studied. Their separations and position angles were measured using an equatorial mounted refractor and and alt-az mounted reflector. A 2x Barlow lens was used along with a Celestron Micro Guide eyepiece to magnify the separation. Comparison of the possible effect of magnitude difference on the separation and position angle measurements was investigated.

Background

This is the second article that compares the precision and accuracy of double star measurements made with an equatorial mounted refractor and an alt-az mounted reflector. In the first paper (Frey and Coombs, 2010[1]) the same seven double stars with separations ranging from about 25 to 278 arc seconds were studied concurrently with both instruments. Most of the separation percent errors between the two instruments were less than ±3% compared with Washington Double Star (WDS[2]) literature values. Using just the Celestron Micro Guide eyepiece (CMGe), the scale constants for the linear scale for both instruments was approximately 10 arc seconds per division. So if double stars with separations less than 20-25 arc seconds are to be studied, the scale constant would have to be reduced substantially in order to gain more accurate results. The present study, therefore, utilizes a 2x Barlow lens in conjunction with the CMGe to increase the magnification. The percent errors in the first study for the position angle for the refractor and reflector ranged from 0.9% and 0.8%, respectively.

The net results of the initial study showed that either reflector or refractor telescopes of approximately the same focal length and using similar magnification can be used to make effective double star measurements for separations greater than 25 arc seconds.

Figure 1. Lee Coombs and Tom Frey at Coombs Observatory

Goal

In the present investigation, a series of double stars were selected to test the effect of magnitude difference on the measurement of separation and position angle. One might expect that as the difference in magnitude increases, the error in the determination of the separation would also increase due to the more difficult estimations of the star's centroids on the linear scale. The difference in determining the position angle, however, might be due more to the method used than to the magnitude difference. The Newtonian reflector used the dynamic drift method (Frey, 2008[3]) to make these measurements whereas the refractor used a static method. One might also expect that as the magnitude difference increased, the difficulty of determining the position angle may be influenced. The data obtained will be compared to the most recent (WDS[2]) catalog findings.

Many studies have been carried out involving the resolution of double stars based on factors such as magnitude difference of the pair. Napier-Munn (2008 [4]) has an excellent review of these studies in his article on a mathematical model for predicting the resolution of double stars by amateurs. Besides a review of resolution based on the Rayleigh and Dawes Limits, he states that stars of differing magnitudes are difficult to split due to the glare of the primary obscuring the secondary, so seeing (i.e. the steadiness of the atmosphere due to the presence or lack of turbulence) can have a dramatic effect on resolution. There is also evidence that different types of telescopes have different resolving limits based on observing conditions.

The above review also mentions the work of Peterson (1954[5]) who developed a predictive tool defining a range that could be divided for a particular telescope based on separation and magnitude of the secondary star. For his three-inch refractor, a constant resolution of 3 arc seconds was observed until the secondary magnitude reached 9, after which resolution declined. Fisher's observations (2006[6]) were also cited where larger apertures become seeing-limited rather than diffraction-limited and that leads to different resolution limits based on different ranges of apertures; smaller instruments sometimes have the advantage.

Since this study involves double star measurements with an 18" reflector and a 6" refractor, some of the above effects may influence the results. Will the magnitude differences ranging from 0.2 to 3.0 and a secondary magnitude maximum of 8.7 affect the separation and position angle measurements for either instrument?

In order to effectively study double stars with separations less than that of the initial study, the magnification was increased using a 2x Barlow lens on both instruments. Separations between the double stars were chosen with at least three divisions on the linear scale to avoid a large error in measurement due to alignment issues. But with increased magnification comes the possible specter of poor seeing. We will check if these changes alter the accuracy of the refractor compared to the reflector. Again, will the range of magnitude differences affect the position angle measurements significantly for the two instruments?

Instrumentation and Sky Conditions

A 6-inch f/12 Astro-Physics refractor equipped with a 12.5 mm Celestron Micro Guide eyepiece was mounted on a German equatorial mount. The focal length of the instrument was 71 inches giving 144x power using the Celestron eyepiece. An Astro Physics 2x Barlow lens was used in conjunction with the CMGe; the Barlow was inserted between the telescope and the diagonal mirror. This effectively increased the focal length so the final magnification was 400x power. Separations were measured using the 60 division linear scale on the Celestron eyepiece. Position angles were measured using an external 360° protractor with a fine wire pointer attached to the reticle eyepiece (see Figure 1). This augmented feature described by Tanguay (1999[7]) allowed the position angle to be recorded to the nearest 0.1 degree.

An 18-inch f/4.5 Obsession reflector equipped with the same Celestron eyepiece as above used a Dobsonian mount. The focal length of the instrument was 79.7 inches giving 162x power using the Celestron eyepiece. An Orion "Shorty" 2x Barlow was also used inserted between the CMGe and the telescope. This resulted in a magnification of 324x power. The telescope was also equipped with a ServoCAT tracking and GOTO system made by StellarCAT and was controlled by a Wildcat Argo Navis computer. Both separations and position angles were determined by using the Celestron/Barlow eyepiece combination. Due to field rotation, the alt-az mounted telescope cannot use the external protractor setup as was done with the refractor. The drift method was used to obtain position angles.

Observations were made at the Coombs Observatory in Atascadero, CA. The observations were carried out on two consecutive nights, B=2011.3965 and B=2011.3992. The first night was very humid, and scintillation was high which made detection of faint secondary stars challenging. The second night was much drier with only moderate scintillation. A few

Table 1: Comparison of separation and position angles of eight double stars measured with refracting and reflecting telescopes

Double Star	WDS Identifier	Separation (arc-sec)			Position Angle (degs)			Lit. Epoch
		Refractor	Reflector	Lit.	Refractor	Reflector	Lit.	
S 1964AC#	15382+3615	15.6	15.2	15.5	83.1	85	85	2009
S 1627*	12182-0357	20.1	20.2	20.0	195.4	196	195	2010
S 2079#	16396+2300	17.3	16.8	16.7	90.6	92	90	2007
S 1931AB*	15187+1026	13.7	14.7	13.1	167.5	169	166	2007
SHJ 195AB#	15145-1826	46.4	47.8	45.6	139.6	138	140	2009
κ Boo	14135+5147	14.1*	13.4#	13.3	234.6*	233#	235	2009
33 Lib#	14575-2125	25.6	25.5	25.3	305.1	304	306	2009
S 2063#	16318+4536	16.3	16.7	16.4	196.1	194	197	2008

*First night observations #Second night observations

cirrus were also present on the second night but cleared by 11:00 PM local time. There was virtually no wind on either night.

Data

Five to nine observations were made on each binary system. Table 1 shows the comparison between the averaged observed separation and position angles recorded for each instrument along with the WDS literature values.

Reading Error

Due to the low number of observations in some trials, standard deviation and standard error of the mean statistics were not determined. Instead the accuracy and precision of the data was determined by examining the “reading error” of each instrument and comparing it to the range of observed separation and position angle measurements. If, for instance, the seeing is bad, the observed range would be larger due to scintillation effects.

The refractor was equipped with a 2x Barlow lens, a diagonal mirror, and the 12.5 mm CMGe. Attached to the latter was the external protractor with a fine wire cursor that enabled the refractor to read position angles to the nearest 0.1 degrees. So the reading error here would be ±0.1 degrees (or a range of 0.2 degrees) under ideal conditions. The scale constant for the linear scale was about 4 arc seconds/division. Since separations could be estimated to about ±0.1 divisions (or a range of 0.2 divisions), the refractor had an ideal separation reading error of about 4 x 0.2 = 0.8 arc seconds.

The reflector was equipped with a 2x Barlow lens and the 12.5 mm CMGe. Due to the field rotation inherent with the alt-az mount, the external protractor used above was not possible with the reflector, so the protractor scale on the CMGe was used to measure position angles. So the reading error here would be ±1 degree (or a range of 2 degrees) under ideal conditions. The scale constant for the linear scale was about 5 arc-seconds/division. Since the separations could again be estimated to the nearest ±0.1 divisions (or a range of 0.2 divisions), the reflector had a separation reading error of about 5 x 0.2 = 1.0 arc-seconds.

Table 2 shows the ranges of the recorded data obtained for the separations and position angles for both refractor and reflector. The difference between the high and low observed values may be a better indication of precision for a small number of measurements than the standard deviation and mean error usually quoted. If the range of observed values for separation and position angles are within the “reading error” (RE) of the instrument scale under excellent seeing and transparency conditions, the values can be considered precise. If the range of observed values is outside the RE range, the readings are being affected by other factors, such as poor seeing or transparency,

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Table 2: Separation and position angle value ranges compared to the reading error for the DS measurements taken 5/25-26/2011.

		Refractor			Reflector		
Double Star	Mag. Differ.	# Obs	Separ. Range (as)	PA Range (degs)	# Obs	Separ. Range (arc secs)	PA Range (degs)
S 1964AC	0.2	6	4	3.9	8	1.0	2
S 1627	0.3	5	0.4	0.8	5	0	2
S 2079	0.5	5	0.8	0.7	9	2.0	1.5
S 1931AB	0.9	5	1	0.6	5	0.5	2.5
κ Boo	1.1	5	1.6	3.4	6	3.1	1
SHJ 195AB	1.5	5	0.8	1.5	9	4.1	3
33 Lib	2.3	6	0.8	1.6	8	1.0	3
S 2063	3.0	5	0.8	1.2	7	1.5	3
RE=Reading Error			RE=0.8″	RE=0.2 deg		RE=1.0″	RE=2degs

breezy conditions, or field rotation.

Refractor

The REs for the refractor are 0.8 arc seconds and 0.2 degrees for the separation and position angle measurements, respectively. Five of the eight separation ranges are less than or equal to the RE of 0.8 arc seconds, whereas none of the position angle ranges are less than the RE of 0.2 degrees.

Then, if the average of observed separations is compared to the most recent literature separation, ALL of the differences between the observed averages and the literature separations are equal to or less than the RE for the refractor (0.8”). See Table 3.

If the average of observed position angles is compared to the most recent literature position angle, ALL of the differences between the observed averages and the literature position angles are greater than the RE for the refractor (0.2°). See Table 3.

Reflector

The REs for the reflector are 1.0 arc seconds and 2 degrees for the separation and position angle measurements, respectively. Four of the eight separation ranges are less than or equal to the RE of 1.0 arc seconds, whereas four of the eight position angle ranges are less than or equal to the RE of 2 degrees. See Table 2.

Then, if the average of observed separations is compared to the most recent literature separation, six of the eight differences between the observed averages and the literature separations are less than the RE for the reflector (1.0”). See Table 4.

If the average of observed position angles is compared to the most recent literature position angle, six of the eight differences between the observed averages and the literature position angles are less than or equal to the RE for the reflector (2°). See Table 4.

Discussion

The purpose of this study was to see if the separation and position angle measurements are influenced significantly as the difference in magnitude of the pair is increased. In this study, the magnitude difference ranged from 0.2 to 3.0. The separations chosen were such that at least three divisions on the linear scale of the CMGe were spanned.

Reading Error (RE) statistics were used to evaluate the accuracy and precision of the data obtained due to the limited number of observations made for each measurement. If the observed data ranges were ≤ to RE ranges, the observed data was considered precise. The refractor had RE ranges for separation and position angle of 0.8 arc seconds and 0.2 degrees, respectively. The reflector had RE ranges for separation and position angle of 1.0 arc seconds and 2 degrees, respectively.

It should be noted that the observed data was compared to WDS data on the date indicated in Table

Table 3: Observed, literature, and difference values for separations and position angles for the refractor.

Double Star	Refractor Separation (arc-secs)			Refractor Position Angle (degs)		
	Obs Sep Av	Lit.Sep.	DSep.	Obs PA Av	Lit. PA	D PA
S 1964AC	15.6	15.5	0.1	83.1	85	-1.9
S 1627	20.1	20.0	0.1	195.4	195	0.4
S 2079	17.3	16.7	0.6	90.6	90	0.6
S 1931AB	13.7	13.1	0.6	167.5	166	1.5
SHJ 195AB	46.4	45.6	0.8	139.6	140	-0.4
κ Boo	14.1	13.3	0.8	234.6	235	-0.4
33 Lib	25.6	25.3	0.3	305.1	306	-0.9
S 2063	16.3	16.4	-0.1	196.1	197	-0.9

Table 4: Observed, literature, and difference values for separations and position angles for the reflector.

Double Star	Reflector Separation (arc-secs)			Reflector Position Angle (degs)		
	Obs Sep Av	Lit.Sep.	DSep.	Obs PA Av	Lit. PA	D PA
S 1964AC	15.2	15.5	-0.3	85	85	0
S 1627	20.2	20.0	0.2	196	195	1
S 2079	16.8	16.7	0.1	92	90	2
S 1931AB	14.7	13.1	1.6	169	166	3
SHJ 195AB	47.8	45.6	2.2	138	140	-2
κ Boo	13.4	13.3	0.1	233	235	-2
33 Lib	25.5	25.3	0.2	304	306	-2
S 2063	16.7	16.4	0.3	194	197	-3

1. No attempt was made to precess the position angle or separation values from the WDS to the current epoch based on proper motions.

Separation Data:

In Table 2, the data show that five out of eight observed separation ranges were less than or equal to the corresponding RE for the refractor, indicating that slightly more than half could be considered precise by this method. For the reflector, only four out of eight were less than or equal to the RE, indicating that only half of the separation measurements could be considered precise by this method.

Then the difference between the average of the observed separation and the literature values was compared to the RE for each specific instrument. For the refractor, all differences were less than or equal to the RE of 0.8 arc seconds. For the reflector, six out of eight differences were less than the RE of 1.0 arc seconds. See Tables 3 and 4.

A majority of the observed separations minus the literature separations were positive (observed separation > literature separation) for both instruments. The random motion of the star due to scintillation would tend to make the star image larger leading to a larger separation compared to literature. See Figure

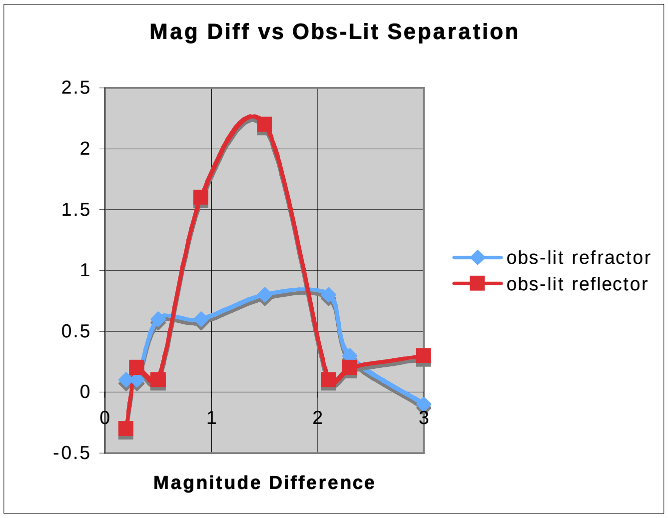

Figure 2. Magnitude Difference vs (Observed-Literature) Separation

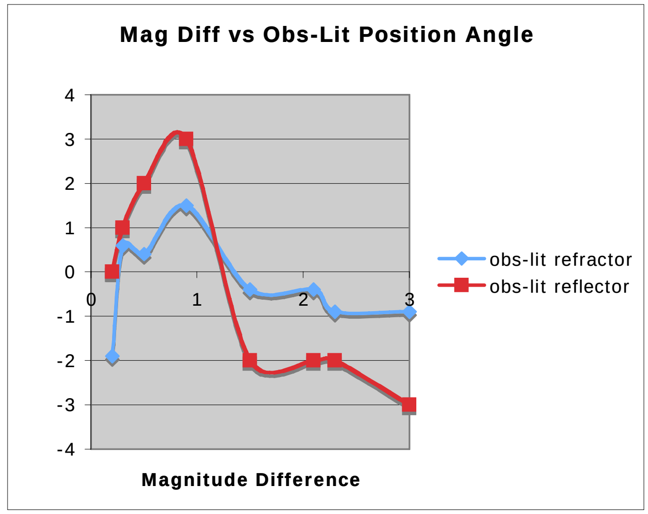

Figure 3. Magnitude Difference vs (Observed-Literature) Position Angle

2. And notice how the range in the difference between the observed and literature separations in arc seconds (Y axis) is greater for the 18" reflector than for the 6" refractor compared with the change in magnitude. This is in keeping with prediction for larger apertures.

Position Angle Data:

In Table 2, the data show that five out of eight observed separation ranges were less than or equal to the corresponding RE for the refractor, indicating that slightly more than half could be considered precise by this method. For the reflector, only four out of eight were less than or equal to the RE indicating that only half of the separation measurements could be considered precise by this method.

Then the difference between the average of the observed separation and the literature values was compared to the RE for each specific instrument. For the refractor, all differences were less than or equal to the RE of 0.8 arc seconds. For the reflector, six out of eight differences were less than the RE of 1.0 arc seconds. See Tables 3 and 4.

The observed position angle minus literature position angle values were approximately equally distributed above and below the zero point line for both instruments. See Figure 3. This indicates there is no definite trend in observed position angle change with increasing magnitude difference. Yet as with the separation measurements, the range of observed position angle values with respect to literature values is greater for the reflector than the refractor. This may be due to the drift method used with the reflector rather than magnitude differences.

The use of the external protractor with the refractor did not enhance the observed data, mainly because the compared literature position angle is only listed to the nearest degree and not to the nearest tenth degree. Yet examining the distribution of observed position angles with respect to literature values, both instruments obtained approximately a 50/50 split of values above and below the literature values, indicating no systematic error in the measurements.

So the data indicates that there was no apparent effect of the magnitude difference on the separation and position angle measurements with either the refractor or reflector for the magnitude ranges for these target data. The small differences could be attributed in part to the poor seeing conditions on the observing nights.

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