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

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Abstract: Separation and position angle measurements were made on seven different double star systems with a six-inch equatorial mounted refractor and an eighteen-inch alt-az reflector. The accuracies of the observations made with the two instruments were compared to each other and the corresponding literature values. The results indicated both telescopes can be used to accurately measure the separation and position angles of double stars for separations greater than 25 arc seconds.

Background

The eventual goal of binary star astrometry is to determine the masses of the two stars. Once the separation and position angle of the binary stars has been recorded over many years, the period and semi-major axis of the binary system can be determined. From this data, and by application of Newton's version of Kepler's Third Law, the masses of the stars can be calculated.

Binary star measurements have been recorded for over 200 years. Most visual measurements have been taken using telescopes on equatorial mounts and measuring devices such as filar micrometers or astrometric eyepieces (Argyle, 2004). Recently it has been demonstrated that telescopes on altitude-azimuth (alt-az) mounts can also be used to make separation and position angle measurements (Frey, 2008).

Yet there is still disagreement on whether the use of equatorial and alt-az mounts in making double star measurements are equally efficient. Equatorial mounted telescopes were initially used because the polar aligned system allows tracking along the right ascension axis. Both separation and position angle can be effectively measured in the stationary field of view. Alt-az mounted telescopes, due to alignment on the zenith, suffer from field rotation, making the measurement of position angle more challenging. Yet there are many large Dobsonian mounted telescopes being used by amateurs that could be making valuable scientific contributions and inspiring young minds. So is the 18-inch "light bucket" up to the challenge of the exquisite 6" refractor?

Goal

This initial study was conducted to compare the

Figure 1: Lee Coombs with his 6-inch refreactor and Thomas Frey.

Figure 2. Thomas Frey with his 18-inch reflector at Pine Mountain Observatory in Oregon.

Figure 3. Lee Coombs at his observatory in Atascadero, California.

accuracy between refracting and reflecting telescope measurements for a series of binary stars. A series of separation and position angle measurements on the same binary stars were made. The binary systems chosen were bright, having magnitude ranges between 4.1-8.2. This initial study avoided binaries of separations less than 25 arc seconds, thus avoiding the requirement of a Barlow lens. Measurements were made concurrently at the same observatory so atmospheric conditions were identical. Observation values were compared with literature values obtained from the Washington Double Star (WDS) Catalog.

Instrumentation and Sky Conditions

A 6-inch f/12 Astro-Physics refractor equipped with a 12.5 mm Celestron MicroGuide eyepiece was mounted on a German equatorial mount. The focal length of the instrument was 71 inches giving 144x using the Celestron eyepiece. 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) 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 using the Celestron eyepiece. It 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 eyepiece. Due to field rotation, the alt-az mounted telescope cannot use the external protractor setup as was done with the refractor. The drift method (Frey, 2008) was used to obtain position angles.

Observations were made at the Coombs Observatory in Atascadero, CA. This site was used for previous double star studies (Johnson, 2008). There was a small amount of turbulence that may have hindered accurate separation values to a certain extent. There were some high cirrus clouds but this did not affect the study since the chosen binary systems were quite bright. There was essentially no wind and little atmospheric moisture detected during observations.

Data

All observations were done on March 19, 2010 (Besselian 2010.214). Due to the trial nature of the study, only 2-4 observations were performed on each binary system; just enough to see if there were significant differences in the measurements. This small number of observations also allowed time to compare results between each binary system. Table 1 shows the comparison between the separation and position angles recorded for the equatorial mounted refractor and alt-az reflector along with the corresponding WDS literature values.

Standard deviation and standard error of the mean statistics were not determined due to the low number of observations (2-4 on average). However the percent error was calculated for each set.

% Error = ((experimental - accepted)/(accepted)) x 100

The experimental values were the observed values. The accepted values were taken as the literature values. A positive percent error indicated an observa-

Table 1: Comparison of separation and position angles of binary 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.	
15 Gem	06278+2047	25.2	25.5	25.2	201.9	203	203	2008
39-40 Cnc	08401+2000	150.9	148.2	150.1	151.9	153	153	2002
i Cnc	08467+2846	32.0	30.6	30.6	307.0	310	309	2009
41 UMa	09287+4536	72.1	71.4	70.1	161.1	159	162	2005
42 LeoMi	10459+3041	197.4	195.5	196.5	173.2	174	174	2002
67 UMa	12021+4303	277.8	275.4	278.5	62.4	62	62	2002
t Leo	11279+0251	90.9	88.0	88.9	181.8	183	181	2004

tion value greater than the literature value; a negative percent error indicated an observation value less than the literature value. Table 2 lists the percent error for separation measurements for both instruments. Table 3 lists the percent errors for position angle measurements for both instruments.

Discussions and Conclusions

Both telescopes used the 60 division linear scale of the Celestron reticle eyepiece to measure separation. Because the focal lengths of the refractor and reflector were 71 and 79.7 inches, respectively, the scale constants used to determine the arc seconds per division were also close (11.43 and 10.20, respectively), so the accuracy for separation measurements showed similar values with one outlier.

The equatorially mounted refractor was able to utilize the external protractor to measure position angles. This enabled measurement to the nearest 0.1 degree. But the reflector just used the protractor scale on the reticle eyepiece so the position angles were only estimated to the nearest degree. A Dobsonian mounted telescope cannot use the external protractor since these mounts orient the telescope to the zenith, not the pole star as with the equatorial mount. Therefore both altitude and azimuth axes must move to keep the object in the field of view. This factor results in field rotation, requiring the use of the protractor scale of the reticle eyepiece. Note that the literature values for the position angles were only available to the nearest degree so that extra 0.1 degree obtained by the refractor didn't affect the accuracy of the observed value compared with the literature value.

Only two of the systems studied were actually binary stars: 39-40 Cancri and ι Cancri. The other systems are optical double stars where the two stars appear to be close by chance line of sight but are actually very distant from one another. One way these two types of systems can be differentiated from one another is by examining the proper motion vectors of each star in the pair. Proper motion values are indicated in right ascension (RA) and declination in units of arc seconds per 1000 years. For example, iota-Cancri, a true binary, shows the primary star moving -024-043 (24 arc seconds/1000 yr westward in RA; 43 arc seconds/1000 yr southward in declination) and the secondary star moving -022-046. Since the RA and declination of both stars are moving in the same direction and have the same approximate values, it suggests the stars are bound by gravity and orbit one another. Compare this to the proper motion vectors for τ Leonis. The primary star has vectors of +017-010 and the secondary -090+017. Such divergent motions indicate the two stars are not bound by gravity and are optical double stars.

Though common proper motion is a necessity, it is not the only factor in determining if a double star is a true binary. Similar distance from the sun is also a crucial parameter. This is because a pair of stars can share a common proper motion yet be parsecs apart. This can happen when two stars are ejected from the same protostellar cloud in roughly the same direction, but are not bound by gravity. This is not the case with ι Cancri where the mean distance between the stars is only 2800 AU (0.014 parsecs) and the system is about 57 parsecs from the sun. The stars also have not changed their separation for about a century. These additional factors strengthen the perception that ι Cancri is a true binary.

Most of the percent errors between the two instru-

Table 2: Comparison of percent errors between separation measurements for the refracting and reflecting telescopes.

	Separation (arc seconds)				
Double Star	**Lit. Value**	**Refractor**	**% Error**	**Reflector**	**% Error**
15 Gem	25.2	25.2	0.0	25.5	1.2
39-40 Cnc	150.1	150.9	0.5	148.2	-1.3
i Cnc	30.6	32.0	4.6	30.6	0.0
41 UMa	70.1	72.1	2.9	71.4	1.9
42 LeoMi	196.5	197.4	0.5	195.5	-0.5
67 UMa	278.5	277.8	-0.3	275.4	-1.1
t Leo	88.9	90.9	2.2	88.0	-1.0

Table 3: Comparison of percent errors between position angle measurements for the refracting and reflecting telescopes.

	Position Angles (degrees)				
Double Star	**Lit. Value**	**Refractor**	**%Error**	**Reflector**	**%Error**
15 Gem	203	201.9	-0.5	203	0.0
39-40 Cnc	153	151.9	-0.7	153	0.0
i Cnc	309	307.0	-0.7	310	0.3
41 UMa	162	161.1	-0.6	159	-1.9
42 LeoMi	174	173.2	-0.5	174	0.0
67 UMa	62	62.4	0.6	62	0.0
t Leo	181	181.8	0.4	183	1.1

ments are less than ±3% in separation compared to literature values. The one outlier is the 4.6% for the ι Cancri for the refractor. This difference between the observed and literature values was due solely to the ability in estimating the scale divisions. Scale readings can only be estimated to ±0.1 divisions. This translates to an error in the separation of 1 arc second. The estimated scale reading for iota-Cancri was 2.8 divisions. This would give a separation of 32.0 arc seconds for a scale constant of 11.43 arc seconds per division. The reading could just as easily have been 2.7 divisions that would give a separation of 30.9 arc seconds. This is an excellent example why a higher magnification is preferable. By using 400x (Barlow lens in conjunction with the Celestron MicroGuide eyepiece), the scale constant is changed to 4.12 arc seconds per division. This would correspond to a separation error of about 0.4 arc seconds for a scale error of 0.1 divisions. This would be the preferable way of recording separations as long as the turbulence was low.

The values for both separation and position angle on 41 UMa were outliers for the reflector. The observed separation value (71.4) differed from the literature (70.1) yielding a percent error of +1.9%. Referring to the previous paragraph, if the number of divisions on the reticle had been only 0.1 divisions less (6.9 rather than 7.0 divisions), the 6.9 value, when multiplied by the scale constant, would have given a separation of 70.4 arc seconds and a percent error of +0.4%. Only three observations were recorded in this trial. This is an excellent example why multiple readings must be recorded to avoid random error. A similar argument can be given for the errant position angle for 41 UMa.

The percent errors for the position angle for the refractor ranged from -0.7 to +0.6, an interval of 0.9% . The percent errors for 6 of the 7 position angles for the reflector ranged from +0.3 to +1.1, an interval of 0.8 %. This small range for both instruments indicates that they were less than the 5% error required by Tanguay for "good measurements" (Tanguay, 1998).

From this study it is evident that both equatorial and alt-az mounted telescopes can both be effectively used to determine separation and position angle values of double stars that closely agree with the literature values. And, if more observations had been taken, closer values to the literature may have been obtained for both instruments for both separation and position angles. In general, a significant difference was not observed in this study, indicating that either refractors or reflectors of approximately the same focal length and similar power at the eyepiece can be used to make effective double star measurements. Both instruments required about the same time to make the measurements and were equally easy to use.

Future Directions

Future comparison studies could focus on binary stars with smaller separations or ones where the secondary stars are fainter. The superior resolving power of the refractor would really test the ability of the large reflector when separations were less than 10 arc seconds. But the greater light gathering power of the large reflector would be able to detect much fainter binary pairs than the refractor. A series of binary stars with ever increasing magnitude differences could be measured to see the limit of detection by the two instruments.

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References

Observing and Measuring Visual Double Stars, R. Argyle, Springer, London 2004.

Frey, Thomas G., Spring 2008, *Journal of Double Star Observations*, **3(2),** p.59-65.

Johnson, J., et.al., Spring 2008, *Journal of Double Star Observations,* **4(2),** p. 52-55.

Tanguay, Ronald C., 1999, *Sky and Telescope*, February, 116-120.

The Double Star Observer's Handbook, Editions 1 and 2, R. Tanguay, R. Tanguay Publisher, Saugus, MA, 1998 and 2003.

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