

## Accuracy and Precision of Multicolor Observations of Four Double Stars

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**Abstract** We observed four neglected, faint, high proper motion double star pairs using the 1.0 meter Las Cumbres Observatory Global Telescope (LCOGT) network in four bands: B, V, R, and I. We measured the right ascensions and declinations using Astrometrica and computed position angles and separations. The band-dependent measurements of the four double stars, LDS 595, LDS 4825, LDS 4907, and LDS 769, were compared to the most recent value in the WDS catalog to determine their accuracy. We also determined the standard deviation in each band to compare their precision. The measurements made in band I were the most accurate and the most precise. This may be due to greater scattering of light in the atmosphere at shorter wavelengths.

### Introduction

No measurements are exact. Accuracy is how close a measurement is to the true value of the quantity being measured (that is, the accepted value in scientific literature). Precision is the measure of variance in that data, or how close repeatable measurements are to each other. It is desirable for a researcher to employ methods which result in the highest degree of both accuracy and precision. The quality astronomical images are color dependent due to an increase in the scattering of light at shorter wavelengths. We observed four double star pairs in four bands—blue (B), visible (V), red (R), and infrared (I)—to determine if one band is preferable to other bands in short exposures. The question that we addressed was, “Given a limited amount of time, which filter will result in the highest accuracy and precision measurements?”

To increase the scientific value of the present study's measurements, we selected four nearly neglected (not observed in last 15 years) southern hemisphere double stars from the Washington Double Star Catalog (WDS). In addition, since the masses of small red stars are poorly known, the selection criteria favored red dwarves. We also preferred to select stars with some ambiguity concerning their gravitational relation. This was accomplished by mostly selecting secondary stars with high proper motions (100 mas/year or greater) and high magnitudes (13 or fainter). We believed that the high proper motion (meaning the stars are likely close to Earth) and faintness would help restrict the selected stars to being “late class.”

Abbreviated entries from the WDS Catalog and SIMBAD, including historic measurements, magnitudes, proper motions of the secondary stars, and precise coordinates can be found in Table 1 (below). We acknowledge that implementing a selection bias which favors dwarf stars which are red may impact the validity of the chromatic study, however, we note that there was no such selection bias for the primary star. SIMBAD also confirmed that the secondary star of LDS 769 has a spectral type of M 2.5.

### Methods

The observations were obtained with the Las Cumbres Observatory Global Telescope (LCOGT) network of 1.0 meter telescopes (Brown et al. 2013). The observations were performed by the dome b telescope at the South Africa Observatory (Latitude  $-32^{\circ}.3473417$ , Longitude  $20^{\circ}.8100389$  East, Altitude 1760.0 m). Between 8 and 16 images were obtained for each of 4 bands, B, V, R and I, for each of the four targets. The targets were observed on June 16, 2013 between 20:30 and 04:30 UT. Integration time for all filters was kept constant for each pair. We found that the primary star in LDS 769 was saturated in the red and

infrared images. This target was re-observed on July 10, 2013 in all bands with the same telescope with a significantly shorter integration time and the original observations were not used in the final analysis.

WDS Identifier	Epoch		P.A		Sep		V Magnitudes		Proper Motion		Precise Coordinates	
	First	Last	First	Last	First	Last	Primary	Secondary	RA	Dec	RA	Dec
LDS 769	1920	2000	135	136	13	14.3	11.1	13.8	627	-079	220405.8	-695530
LDS 4907	1960	1999	300	294	5.0	5.1	14.3	14.3	399	203	214729.0	-262932
LDS 595	1920	1999	225	277	27	25.8	13.3	13.2	unk	unk	172456.2	-352837
LDS 4825	1960	2000	328	329	56	58.1	14.3	16.5	141	-253	195854.0	-252124

*Table 1: Abbreviated entries from the Washington Double Star Catalog for the four targets selected for this study.*

## Results

The images were corrected for bias, dark, and flat fielding prior to analysis as part of standard LCOGT processing. For each image, the right ascension and declination were obtained for the primary and secondary stars using Astrometrica (Caballero et al. 2014). Their separations and position angles were calculated using Pythagorean Theorem. The results along with their errors and standard deviations are presented in Table 2 (below). Table 2 also gives the number of images and exposure times for each filter.

As previously mentioned, two attempts were made to observe 22040-6955LDS 769. In the first attempt the primary star was saturated in the V, R, and I band images. In the second set of observations the secondary star was barely detectable in the B band images. For this target we used observations from the first observing run on June 16, 2013 for the B band, and from the second run on July 10, 2013 for V, R, and I band.

## Discussion

We used the standard deviation of the separation and position angle as our measure of the precision of the individual measurements. The standard deviation instead measures the typical scatter or error of a single measurement. The standard deviation was consistently smaller in separation for observations in R and I than in B and V. For LDS 595, the separation standard deviation was slightly higher in V than in R. Similarly, the standard deviation was consistently smaller in position angle for observations in R and I than in B and V. In the case of LDS 769, V had a slightly lower standard deviation for position angle than R. The standard error of the mean was not used for this purpose because it decreases as the number of measurements increases.

Nearly all color bands for each star were within one standard deviation of the literature values for separation. The only exception is LDS 595 when measured in I, which has a maximum separation of 25.742" and therefore does not round up to the literature value of 25.8". In addition, nearly all color bands for each star were within one standard deviation of the literature values for position angle. The exceptions were LDS 4907 in V, R, and I which all have minimum values that round up to 295° compared to the literature value of 294°.

Target/Filter	# Images	Exp. Time	Sep.	Sep. Err.	Sep. SD	PA	PA Err.	PA SD
LDS 769								
B	7	3	14.43	0.117	0.309	136.72	1.309	3.462
V	8	3	14.34	0.087	0.245	136.23	0.288	0.815
R	8	3	14.44	0.039	0.112	135.27	0.301	0.852
I	8	3	14.30	0.066	0.187	135.83	0.228	0.646
Average			14.38			136.01		
LDS 4907								
B	8	50	5.16	0.050	0.141	294.26	0.368	1.041
V	8	50	5.12	0.005	0.015	294.91	0.116	0.328
R	8	50	5.13	0.003	0.010	295.04	0.030	0.086
I	4	50	5.14	0.002	0.005	295.02	0.048	0.095
Average			5.14			294.81		
LDS 595								
B	8	60	25.79	0.025	0.071	276.65	0.020	0.056
V	8	60	25.80	0.022	0.062	276.66	0.059	0.167
R	8	60	25.83	0.025	0.071	276.67	0.010	0.028
I	5	60	25.73	0.005	0.012	276.70	0.014	0.032
Average			25.79			276.67		
LDS 4825								
B	16	60	58.13	0.067	0.268	328.80	0.057	0.228
V	16	60	58.08	0.022	0.088	328.81	0.038	0.154
R	16	60	58.09	0.010	0.041	328.84	0.021	0.085
I	16	60	58.10	0.005	0.022	328.81	0.017	0.068
Average			58.10			328.81		

Table 2: Summary of results. The discoverer code is given along with the filters B, V, R, and I. # Images indicates the number of images used for the calculations. Exp. Time is the integration time in seconds. Sep. is the separation angle in arc seconds. PA is the position angle in degrees. Err. is the computed error of the mean. SD is the standard deviation of the observations.

It should be noted that the telescopes used for this study have a resolution limit of about 0.1" for the wavelengths which are used (with red having a larger seeing limit). The seeing at the site was generally around 1.2" full width at half max. Thus the resolution limit of the telescope is generally smaller than the sky seeing at the site. If we assume a more typical seeing of 2" and an aperture of 0.25 meters for a typical amateur telescope, then this situation will still hold. Therefore, the minimal superiority of longer wavelength filters in terms of precision and accuracy may be insignificant due to limitations of seeing.

Finally, blue light is more easily scattered in Earth's atmosphere than red light. Therefore, redder filter observations tend to gather more photons than those using bluer filters. The data for this study was insufficient to determine the significance of the scattering effect on CCD counts as a cause of filter-dependent precision. Along with this consideration, if one is concerned with obtaining the highest precision in the shortest time, it may be best to use no filter, more observations, and shorter integrations.

## Conclusions

This study compared the precision and accuracy of observations made using color filters. While redder filters generally had smaller standard deviations and errors than bluer filters, the measured effect may have been due to limitations of seeing or atmospheric scattering of shorter wavelengths. The study also contributed separations and position angles of four nearly-neglected double stars containing a secondary with a high proper motion and high magnitude, indicative of M-type stars. This data may be used by future researchers for orbital analysis.

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