Astrometric Measurements of Selected Visual Double Stars

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Abstract: The observations and measurements for a selected set of 13 double stars are reported. These tasks comprised the activities in a special course designated as a Learning Community which combines a standard astronomy course with a mathematics course devoted to research techniques. This class was taught at the Estrella Mountain Community College in Avondale, Arizona during the fall semester 2011. This course is a result of expanding the special research mathematics courses offered during the fall 2010 and spring 2011 semesters. Observations and measurements were taken with a Meade 12" Schmidt Cassegrain Telescope (SCT) using the Celestron MicroGuide™ and supplemented with imagery acquired with the Tzec Maun Foundation remote telescope system located in New Mexico.

Introduction

This observation program is part of a special combination introductory astronomy and mathematics course dedicated to teaching research techniques and applied mathematics. Astronomy course AST 111 which is an introduction to astronomy for non-science majors was combined with mathematics course MAT 298 AA which provides the opportunity for independent study to create what is called a Learning Community (LC). The general goal of this LC was to provide a greater depth of science exposure than could be achieved in either the astronomy or mathematics course alone. Specific objectives for the LC was to expose the students to real-world application of mathematics in the process of observing and reducing data taken under less than ideal conditions. These same approaches and data techniques are widely used in a variety of professional fields and applications.

The observational areas chosen were the visual measurements of double stars. The selection of stars for observation and measurement were taken from the Washington Double Star Catalog (WDS), a web-based repository for double and multiple star information. The selection of researching binary stars was chosen since the observation and measurements of double star systems are an area which can be achieved with the use of small telescopes. [1]

Instrumentation: Meade 12" LX200

The instrumentation used for observations and measurements consisted of a Meade 12" LX200GPS f/10 Schmidt-Cassegrain telescope. This system is an azimuth type system featuring automatic calibration and GPS location. The GPS feature made initial setup and calibration fast and easy. Double star measurements were obtained using the Celestron MicroGuide eyepiece which is a 12.5 mm F/L Orthoscopic with a reticule and variable LED.

All visual observations were taken on the campus of Estrella Mountain Community College campus located at 33º28'49.46"N, 112 º 20'36.47"W during evening hours which generally consisted of between 7:00 and 10:00 PM local time (02:00 to 05:00 UT). Observations and measurements covered the dates from mid September 2011 through late November 2011.

Tzec Maun Remote Telescope

The Tzec Maun Foundation is a non-profit foundation which strives to provide students from all over the world with access, through teachers and professors, to astronomical instruments that can be easily incorporated into the classroom and even used from home. The foundation allows students to access quality telescopes in the northern and southern hemispheres, providing a view of the entire sky from locations in New Mexico and Australia. Accesses to the remote telescopes were utilized to image selected double star targets in order to contrast visual observations with image analysis.

Several telescope systems were available for advanced reservation and use. The system chosen was the Takahashi Epsilon 180 with an f/2.8 focal length (Figure 1). These setups are typically reserved for beginners only. The E180s has a ST-2000C camera as it's imaging system. This provides a field of view of 80.5 x 60.4 arcminutes with a pixel count of 1600 x 1200 providing an image scale of 3.02"/pixel (arcseconds per pixel).This camera system provides a JPEG image - there is no FITS file for data. A full-range and an adjusted (processed) image of each shot are provided.

Figure 1: Takahashi Epsilon 180 f/2.8

Research Teams

In order to maximum the individual student's observing time, the class was broken up into observation/research teams. Teams were the best option as having the entire class observing simultaneously would have limited the amount of stars able to research, while individually would prove to be too time inefficient. Teams were chosen at the beginning of the semester based on the number of students enrolled. Initially, the class was divided into five teams of 3-4 students. As the semester progressed, due to normal student attrition, the class finally settled into four teams for maximum time efficiency. Teams would rotate on an approximate hourly basis with each team getting one hour per rotation to gather observational data. Each rotation was completed by two class periods. Teams proved to be flexible due to the fact team members could compare individual measurements and share workloads. Participants in the project are shown in Figure 2.

Selection of Stars

The selection of stars for observation and measurement were taken from the WDS Catalog, a web-based repository for double and multiple star information. The WDS is maintained by the United States Naval Observatory and is the world's principal database of astrometric double and multiple star information. The WDS Catalog contains positions (J2000), discoverer designations, epochs, position angles, separations, magnitudes, spectral types, proper motions and when available, Durchmusterung numbers and notes for the components of 108,581 systems based on 793,430 means. The current version of the WDS is updated nightly. The selection of target stars resulted from reviewing the list of both common observed and neglected double stars referenced on the WDS main web page.

In order to try and provide observational coverage of the widest range of double stars, the selection of target stars off the WDS website assigned to a research team consisted of the target star row location in the database corresponding to the research team identification number. For example, Team 1 candidate target list consisted of stars in rows 1, 6, 11, etc. Team 2 had candidates in rows 2, 7, 12, etc. This ap-

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Figure 2: Fall 2011, Astronomy and Mathematics Learning Community

proach provided an even distribution of target stars across the WDS list in the appropriate right ascension location.

The actual selection of the stars for attempted observation was a critical step to the measurement of the binary star systems. In order to select stars off the WDS catalog, a series of specific guide lines were established and followed. The magnitude of the primary and secondary stars had to be less than magnitude 8, anything greater was not visible through the telescope with the current observing location and conditions. The separation measurement was also a selection criteria in that the separation had to also lie between 7 and 200 arc seconds. The limitation of 7 arc seconds was a hard constraint due to only being able to measure about 1 separation hash mark on the MicroGuide eye piece. This corresponds to approximately 7.43 arc seconds. Finally, the right ascension and declination coordinate had to be appropriate for location and the time of observing. [2]

Visual Measurements of Selected Binary Stars

Measurements of the separation distance and position angle of the selected binaries was accomplished using a standard visual observational approach. In order to produce high quality measurements, care was taken in calibrating the measurement instrument by performing a series of test measurements for validation of results before proceeding to the measurements of the target stars.

MicroGuide Calibration

As performed in the previous two semesters of observing double stars, the technique for calibrating the MicroGuide was the standard star drift method. The calibration process was carried out using measurement data collected by each team and combining results for an average measure. The star used for calibration measurements was Vega at coordinates 18h 36m 56.33s, +38^0 47' 01.28".

Using a stopwatch, each team member timed the transit of Vega from one edge of the MicroGuide scale to the opposite edge. This process was repeated five times by each team member. After the measurements were taken, the data was collected and an average time of 38.139 seconds was arrived from the total number of measurements with a standard deviation of 1.544 seconds. Next a plot of the histogram was generated and using the standard deviation of 1.544 seconds, outliers were identified and removed that fell outside a ± one standard deviation range. Using the adjusted average time in the formula "SC = Avg Time * Cos (Dec) / 4", the class calculated that the scale constant to be 7.427 arc seconds per MicroGuide division. This scale constant was used to measure the separation distance between the binary stars chosen by each group. [3]

The histogram of the timing measurements for Vega drift rates is shown in Figure 3. These measurements are contrasted against those taken in the fall 2010 and spring 2011 semesters. Drift measurements were averaged to produce the calibration for the same observing system for the fall 2010 which resulted in an average of 38.26 seconds per drift. The corresponding histogram is shown in Figure 4. The separation was calculated to be 7.26 arc seconds.

The process was repeated for spring 2011 which

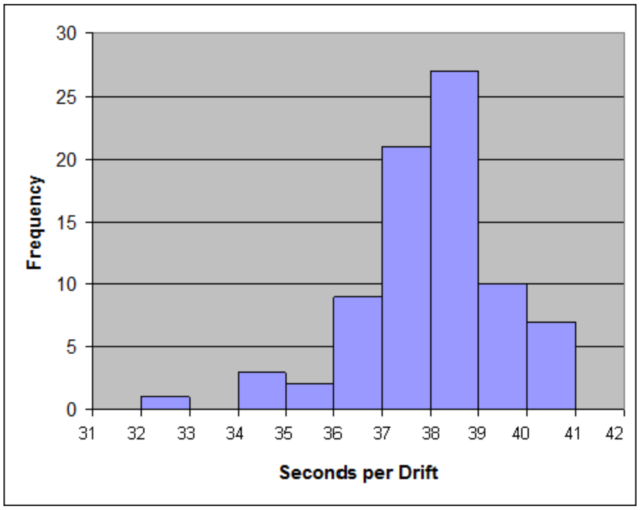

Figure 3: Histogram of Timing Measurements for Fall 2011

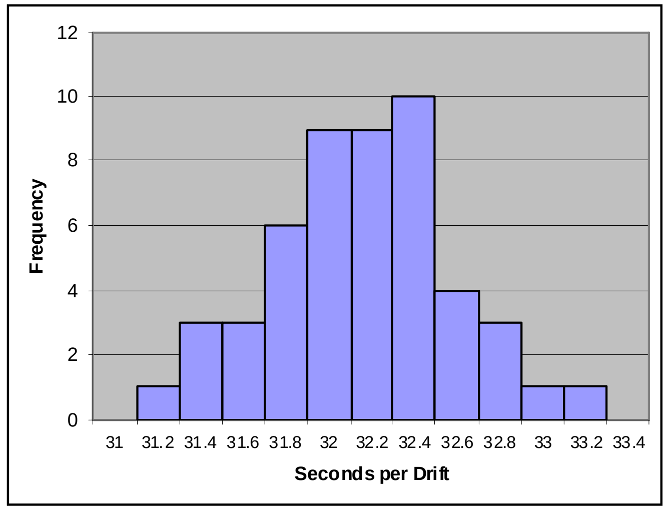

Figure 5: Histogram of Timing Measurements for Spring 2011

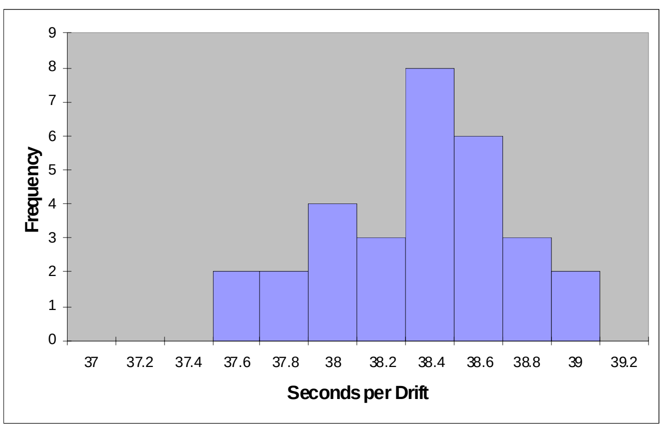

Figure 4: Histogram of Timing Measurements for Fall 2010

Table 1: Summary Results for MicroGuide Calibration

Period	Drift Measurement (sec)		Scale (arcsec)
	Average	1 STD	Average
Fall 2010	38.26	0.38	7.26
Spring 2011	32.21	0.43	7.39
Fall 2011	38.14	1.54	7.43

resulted in the histogram shown in Figure 5 with a mean drift time of 32.21 seconds. Based on the timing average, a separation between scale divisions was calculated to be 7.39 arc seconds.

A review of the progression of the scale factor over three semesters of measurements is shown in Table 1. Notice that the arcsec distance for a MicroGuide division has been increasing. No apparent reason for the lengthening of the drift was found.

Measurements Process

As in the previous semesters observing sessions, a round robin technique was utilized for taking new measurement data. Separation was measured by orienting the selected double star systems along the Microguide's linear scale, and noting their separation as indicated by the scale's division marks. Position angle was then measured by aligning the binary systems along the linear scale, with the primary star directly on mark 30, and the secondary along the scale between marks 30 and 60. After the stars were aligned, the telescope's tracking system was temporarily disabled, allowing the binary system to drift out of the eyepiece's field of view. The binary system crossed over the circular scale which runs along the edge of the telescope's FOV, as this happened the position of the secondary star along this circular scale was noted. These processes were repeated several times per system for separation accuracy. Summary of measurement data are shown in Table 2.

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Table 2: Summary Data for Measures Fall 2011

WDS ID	Discover	Magnitudes		Last			Current		
		Primary	Sec	Epoch	PA	SEP	Epoch	PA	SEP
21543+1943	STF2841A,BC	6.45	7.99	2010	110	22.3	2011.965	114	22.3
20136+4644	STFA 50AC	3.93	6.97	2008	174	106.7	2011.965	174	111
22038+6438	STF2863AB	4.45	6.4	2010	275	8	2011.957	267	6.9
18562+0412	STF2417AB	4.59	4.93	2010	104	22.4	2011.764	99	24.7
21069+3845	STF2758AB	5.2	6.05	2010	152	31.4	2011.778	175	34.2
19050-0402	SHJ 286	5.52	6.98	2010	210	41.5	2011.835	210	38.2
20375+3134	STFA 53AB	6.29	6.54	2003	177	182.7	2011.835	185	187.3
19418+5032	STFA 46AB	6	6.23	2010	141	39.7	2011.822	310	51.3
20467+1607	STF2727	4.36	5.03	2010	266	9	2011.778	280	12.1
20302+1925	S 752AC	6.8	7.3	2001	288	106.7	2011.797	330	111.0
12492+8325	STF1694AB	5.29	5.74	2008	236	21	2011.823	235	29.2
15292+8027	STF1972AB	6.64	7.3	2010	169	31.4	2011.874	165	37.3
21287+7034	STF2806AB	3.17	8.63	2009	250	14.1	2011.879	256	14.8

Measurements of Selected Binary Stars using Tzec Maun Remote Telescope

Background

The Tzec Maun Takahashi Epsilon 180 remote telescope system was used to determine the utility of utilizing a remote system to perform measurements on double star systems. Each team selected one star from their target list to image and then perform an analysis on the measured separation distance. Due to time constraints, only separation distances between the primary and secondary stars were measure and compared. The image analysis package used was the ImageJ. ImageJ is a public domain, Java-based image processing program developed at the National Institutes of Health. ImageJ was designed with an open architecture that provides extensibility via Java plugins and recordable macros

Calibration of Imagery

Σ2470 and Σ2474 is known as the Double-Double's double located in the constellation Lyrae. Lying southeast of Epsilon Lyrae, the system consists of two similarly bright double stars set approximately 10 arcminutes apart. Both double star systems have nearly identical separations and position angles. Σ2474 was chosen as the double star used for calibration being located at 19h 09.1m RA and +340 36' Dec. [4]

The image of Σ2474 taken with the Takahashi Epsilon 180 and ST-2000C camera is shown in Figure 6.

Based on utilizing the double star set with the known separation of 16 arc seconds, a scale factor of 0.0999 arc secs per ImageJ linear pixel measurement was derived. This value was then used to measure the separation distance of the target stars.

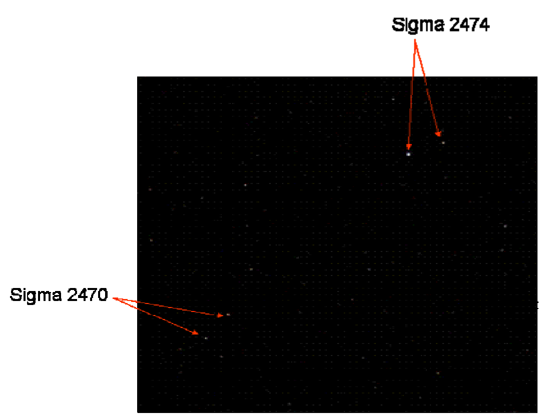

Figure 6: Σ2474 used as Calibration Double Star

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Comparisons of Measurement Results between Visual and Remote Telescope

Each team selected one star from their observing list to perform a comparison. The largest task turned out to be locating the target stars on the imagery. Various techniques were employed to match up the observed stars with imagery including going back to the telescope to confirm the visual field. The most productive approach was to image the selected area with varying exposure times and then comparing imagery to locate the target stars.

Individual team assessments and comparisons are given below.

Team 2

Team 2 selected the double system STF2863AB (R.A: 22h 03m 47s DEC: +64d 37m 39s) for comparison analysis. The averaged separation distance for STF2863AB was measured as 6.9 arc seconds. Figure 7 below shows the images of the same stars taken with the remote online telescope. Using the ImageJ software, the amount of pixels in the line was obtained and using the conversion factor of approximately 0.0999, a measured separation distance of 7.9 arc seconds was acquired. The last measurement documented was taken in 2010 and indicated a separation distance of 8 arc seconds. The difference could be due to the fact that the eyepiece used was measure in 7.43 arc seconds per MicroGuide division mark which created a slight deviation compared to the remote telescope imagery measurements. The initial image showing a FOV of 80.5 x 60.4 arc minutes is shown in Figure 7 with an enlargement and separation measurement between the primary and secondary star shown in Figure 8.

Team 3

Team 3 initial list of stars proved difficult for initial observation. Five attempts were tried before the first star. STF1694AB (RA: 12h 49m 13.80s DEC: +83d 24m 46.3s) was located. Once the star was verified as being the target star, 15 measurements using the telescope were obtained. Once all team members took measurements, the mean was obtained and multiplied by the calibrated conversion factor to obtain 28.93 arcseconds on the star. References in the WDS database indicated that the star had a measured separation of approximately 21 arc secseconds. The difference was attributed to lack of experience. With the learning curve behind the team, the next two stars measured were nearly dead on. The image taken with the Takahashi Epsilon 180 for STF1694AB is

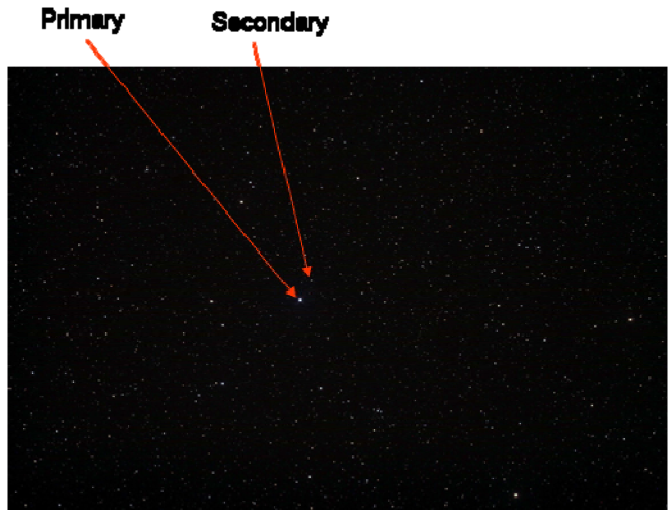

Figure 7: STF2863AB

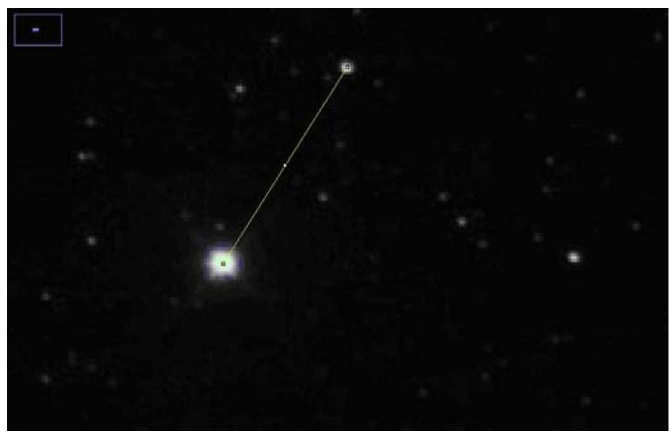

Figure 8: ImageJ Measurement of STF2863AB

Figure 9: STF1694AB

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shown in Figure 9 and in addition to the binary stars of interest, showed many additional stars. After some additional work, the stars of interest were located and measuring the star separation (Figure 10) by pixeland utilizing the conversion factor of .0999 arcseconds per pixel, the separation distance matched up perfectly.

Team 5

Team 5 took a total of 20 measurements with the Meade 12" LX200GPS f/10 Schmidt-Cassegrain telescope on October 27, 2011. Each team member took 5 measurements, rotating out, one at a time. We averaged a separation distance of 6.9 arc seconds for the binary stars STFA46AB (R.A: 19h 41m 48s DEC: + 50d 32m 0s). The initial images of the same stars taken with a Takahashi Epsilon 180 telescope is shown in Figure 11. Using image software, ImageJ, we calculated the amount of pixels in the line between the stars using a conversion factor of approximately 0.0999 arcseconds per pixel. We measured a separation distance of 3.82 arc seconds with the image software (Figure 12). We realized this was a significant difference so we measured again with the Meade 12" LX200GPS f/10 Schmidt-Cassegrain telescope and got the same result. We cannot account for the difference between the Meade 12" LX200GPS f/10 Schmidt-Cassegrain telescope and the Takahashi Epsilon 180 but we made numerous attempts to verify our measurements.

Team 4 obtained very accurate visual measurements of four double stars, but had difficultly locating the target stars in the Takahashi Epsilon 180 imaging. The lack of access back to the remote telescope forced the team not to be able to obtain imagery of the stars of interest; hence, their analysis is not included.

Results of Comparison Analysis

An analysis of the separation distances between selected double stars described by the individual teams above is shown in Table 2. It is clearly shown that the accuracy of using an online remote telescope system to obtain measurements of double star systems can be quite feasible. It also demonstrates the difficultly of obtaining the correct stars for measurement and if care is not taken, erroneous measurements can result.

Conclusion

These observations provide additional information for researchers to investigate the nature of binary systems.

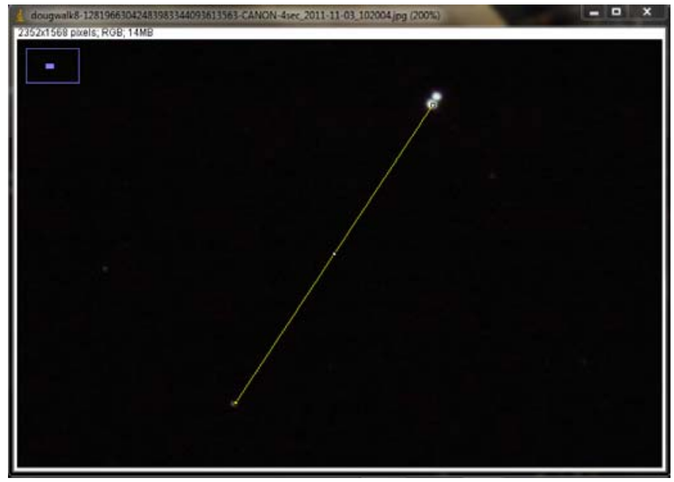

Figure 10: ImageJ Measurement of STF1694AB

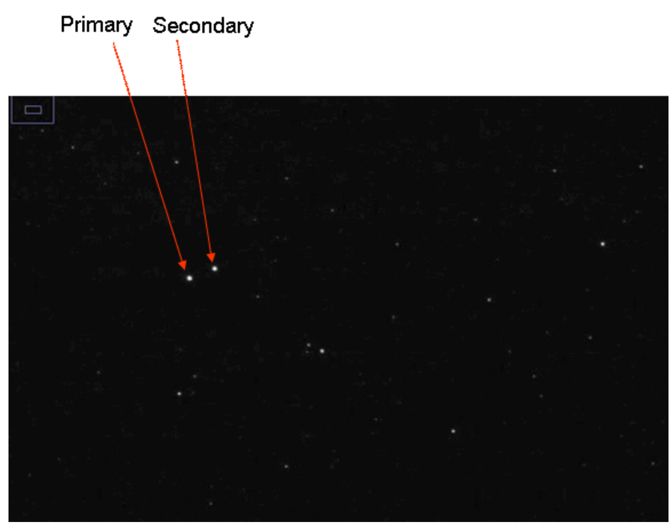

Figure 11: STFA46AB

Figure 12: ImageJ Measurement of STFA46AB

Table 2: Comparison of Observed and Imaged Measures

	Separation – Arcseconds			
Star	**WDS**	**Observed**	**Imaged**	**Arcsec Difference to WDS**
STF2863AB	8	6.9	7.9	0.1
STF1694AB	21	28.9	21	0
STFA 46AB	39.7	51.3	38.2	35.9

Acknowledgments

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