Visual and Photometric Measurements of a Selected Set of Double Stars

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Abstract: The observations and measurements using visual and photometric methods for a selected set of binary stars are reported. These tasks comprised the activities in a special mathematics course devoted to research and observational techniques being taught at the Estrella Mountain Community College in Avondale, Arizona for the fall 2012 semester.

Visual observations and measurements were taken with a Celestron 11" Schmidt Cassegrain Telescope (SCT) using the Celestron MicroGuide™ for binary star separation and position measurements. Photometric measurements were taken utilizing the suite of remote telescopes provided by the iTelescope network. FITs images were obtained and downloaded utilizing the iTelescope system. Analysis of separation and position angle of imaged binary star systems was provided utilizing the AstroImageJ image analysis software package.

Introduction

This observation program is part of a series of special mathematics classes conducted at the Estrella Mountain Community College located in Avondale Arizona. The observations presented here are a result of the class conducted during the fall 2012 teaching semester. This mathematics course is designed to give students an introduction to performing real-world research with the end goal of collecting measurement data which is of sufficient quality to be of value to the scientific community. 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] This observing program consisted of both visual and photometric observations.

The majority of visual observations were taken at a facility located at 33°30'8.82"N, 112° 21'46.99"W during evening hours which generally consisted of between 6:00 and 9:00 PM local time (01:00 to 04:00 UT). Visual observations and measurements covered the dates from mid September 2012 through early December 2012.

In addition to visual observing, a program of taking photometric imagery and measurements of selected binary stars utilizing a set of online telescopes was conducted. This exercise provided the students the learning opportunity to conduct astronomical observations and measurements utilizing online telescope systems. Online telescope systems in Spain and New Mexico were utilized provided by the iTelescope's network of Internet connected telescopes.

Observing Program and Instrumentation

The observing program consist of instructing the students through a process of learning basis of telescope and observing operations while at the same gaining a better understanding of double star sys-

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Figure 1: Celestron 11" F/10 Schmidt-Cassegrain

Figure 2: iTelescope Web Interface

tems through research and data collection. Students first gather a list of possible stars from the Washington Double Star (WDS) database and the Cambridge Double Star Atlas (CDSA) which fit a set of observing criteria for place and time. After narrowing down the candidate list, students measure the separation and position angles of the stars both visually and through the use of online telescopes. This allows the students to analyze data manually, as well as with the assistance of computer software. With the continuation of the program, the data collected will be collaborated with data from the WDS and CDSA archives to model the orbital patterns of the stars to investigate the presence of a binary star system.

The instrumentation used for visual observations and measurements consisted of a Celestron 11" LX200GPS F/10 Schmidt-Cassegrain telescope of the type shown in Figure 1. Visual 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. The portability of the LX200GPS allowed for observations from a remote site with darker seeing conditions. While the majority of observations were taken at the at 33°30'8.82"N, 112° 21'46.99"W location, additional observations and measurements were obtained from a relatively dark remote location west of Phoenix Arizona at 33°13'1.22"N, 112° 16'47.75"W.

For photometric measurements, a set of three online remote telescopes provided by the iTelescope network was used. iTelescope.Net is a network of Internet connected telescopes allowing members to take astronomical images of the night sky for the purposes of education, scientific research and astrophotography[2]. iTelescope.Net is a self-funding, not for profit membership organization with financial proceeds funding the expansion and growth of the network. iTelescope.Net is run by astronomers for astronomers. The network is open to the public where anyone can join and become a member including students, amateurs and professional astronomers. With 13 telescopes, and observatories located in New Mexico, Australia and Spain, observers are able to follow the night sky around the globe 24x7.

Entry into the iTelescope system and operations of the remote telescopes is via the Launchpad webpage as demonstrated in Figure 2.

The Launchpad portal in the iTelescope system allows access to the telescopes, all sky cameras, and telescope pricing. From here, access to acquired images, reservations and telescopes availability are provided. Signing into a telescope is simple, just clicking the telescope selected will prompt for username and password. Once logged in, access to the reservations currently in the system as well as making additional reservations is provided. The iTelescope system was a good tool in our observational pursuit.

The three online telescope systems consisted of a Planewave 0.51m CDK, Takahashi Epsilon 250mm, and a Takahashi FSQ-ED of 106mm. All of the telescopes utilized are located in Mayhill, in the Sacramento Mountains of New Mexico.

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Figure 3: iTelescope Planewave 0.51 m Telescope

The Planewave 0.51m designated as Telescope 11 and is shown in Figure 3.

The telescope system consists of the Planewave 0.51m corrected Dall-Kirkham Astrograph with a focal length of 2280mm, f/4.5 fitted with a 0.66 Focal Reducer. It is mounted on a Planewave Ascension 200HR mount system. The instrumentation package contains a FLI ProLine PL11002M CCD camera with a pixel size of 9um square and a resolution of 0.81 arc -secs/pixel. The CCD array is 4008 by 2672 (10.7 Megapixels) with a FOV of 36.2 x 54.3 arc-mins. Filters of Luminance, Red, Green, Blue, Ha, SII, OIII, U, B, V, R, I are provided as selected.

The Takahashi Epsilon 250 designated as Telescope 5, and is shown in Figure 4.

The telescope system consists of the Takahashi Epsilon 250 with a Hyperbolic Flat-Field Astrograph with a focal length of 850mm, f/3.4. The system is equipped with a SBIG ST-10XME CCD camera with an array of 2184 x 1472 (3.2 Megapixels) with a field of view of 40.4 x 60 arc-mins. It has a pixel size of 6.8um Square, and a resolution of 1.65 arc-secs/pixel. The system is mounted on a Paramount PME. Filters of RGB, Ha, SII, OIII & Clear and photometric BVR By Schuler are available.

The Takahashi FSQ-ED designated as Telescope 20 and is shown in Figure 5.

The telescope system consists of the Takahashi FSQ-ED, an Petzval Apochromat Astrograph optical design, with a focal length of 530mm, f/5.0. The telescope is mounted on a Paramount PME system. The

Figure 4: Takahashi Epsilon 250

Figure 5: Takahashi FSQ-ED

instrumentation consists of a SBIG ST-8300C One Shot Color CCD camera with pixel size of 5.2um square and a resolution of 2.02 arc-secs/pixel. The CCD array is 3326 x 2504 (8.3megapixels) with a field of view of 84.3 x 112 arc-mins. There are no available filters for this telescope.

Selection of Stars

The selection of stars for observation and measurement were taken from the Washington Double Star Catalog [3] and the Cambridge Double Star Atlas [4] cross referencing the standard northern hemisphere sky map provided by Sky and Telescope [5].

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.

The Cambridge Double Star Atlas (CDSA) was written by James Mullany and published by Cambridge University Press on March 23, 2009. This is the first modern star atlas dedicated to multiple and double stars. The CDSA consists of thirty detailed celestial maps drawn and detailed by celestial cartographer Wil Tirion. In addition to the maps, the author singles out 133 of the best double stars in the sky called, 'Showpiece Double Stars.' It is from this list that we selected some of our double star for observation and measurement.

Visual Measurements of Selected Binary Stars

The visual measurements of the separation distance and position angle of the selected target stars was accomplished using a standard visual observational approach. All measurements were acquired utilizing the Celestron MicroGuide™ [6] In order to produce high quality measurements, care was taken in calibrating the measurement instrument and performing a series of test measurements for validation of results before proceeding to the measurements of the target stars.

Figure 6: Beta Cygni Primary and Secondary Star

MicroGuide Calibration

Previous calibrations of the Celestron MicroGuide™ were via the standard star drift method with the process being carried out over several nights. A different approach was utilized during this semester in that a well known star was chosen and carefully measured using the Celestron MicroGuide™ to determine the number of divisions in the MicroGuide eyepiece to arcseconds. The double star Beta Cygni was chosen for the calibration star.

Albireo, designated Beta Cygni, is a celebrated binary star among amateur astronomers for its contrasting hues. The primary star is an orange-hued giant star of magnitude 3.1 and the secondary is a blue-green hued star of magnitude 5.1. The system is 380 light-years away and is divisible in large binoculars and all amateur telescopes. A typical small telescope image is shown in Figure 6.

Measurements Process

A round robin technique used for taking new measurement data was utilized. Separation was measured by orienting the selected 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 hibernated, allowing the binary system to drift

Table 1: Visual Summary Data for WDS Stars

	Magnitudes		Last			Current			Precise Coordinates	
	Primary	Secondary	Epoch	PA	SEP	Epoch	PA	SEP	RA (h m s)	Dec (0 ‘ “)
18535+7547	6.73	7.35	2010	218	5.6	2012	**216**	6.1	18 53 33.2	+75 47 14.6
20347+3230	6.99	8.75	2011	285	24.0	2012	284	25.1	20 34 44.6	+32 30 21.1
20264+5638	6.37	8.31	2010	117	26.2	2012	118	26.9	20 26 23.5	+56 38 19.3
18445+3400	7.91	8.66	2003	5	65.2	2012	6	61.2	18 44 30.7	+33 59 46.1
20234+3053	8.59	9.48	2004	176	20.7	2012	174	19.7	20 23 25.5	+30 52 52.8
18015+2136	4.85	5.20	2010	257	9.0	2012	258	6.9	18 01 30.4	+21 35 44.8

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. Based on the orientation, 90 degrees were then added or subtracted from this measurement to achieve the final position angle measurements.

Summary of measurement data are shown in two tables. Table 1 lists the measurements for the stars chosen from the WDS catalog and table 2 for the stars chosen from the CDSA.

Photometric Measurements of Selected Binary Stars

Imagery of Selected Stars

Along with the visual observation program, a set of online telescopes provided by iTelescope were utilized to obtain CCD imagery and corresponding photometric measurements. A set of target stars was assigned to each of the three telescopes. Imagery was acquired and analysis performed using the AstroImageJ software analysis package [7].

AstroImageJ is the ImageJ (ImageJ is a public domain, Java-based image processing program developed at the National Institutes of Health) with some customizations to the base code and a packaged set of astronomy specific plugins. The plugins are based on the Astronomy Plugins package written by Frederic V. Hessman et al. of Inst. f. Astrophysik, Georg-August-Universität Göttingen. The AstroImageJ customizations are by Karen Collins and John Kielkopf of the University of Louisville. The application is open source.

An image of the calibration star Beta Cygni is shown in Figure 7.

Measurements of Separation

Measurements of separation distances on the iTelescope imagery were obtained using a straightforward process of calculating the distance based on image pixel positions provided off the AstroImageJ display window. However, since each telescope utilized had a different camera system with corresponding FOV, imagery distances in terms of pixel positions had to be calibrated using Beta Cygni. Once this was accomplished, positions of the primary and secondary star were obtained using the photometry measuring

Table 2: Visual Summary Data for CDSA Stars

Discover	Magnitudes		Last		Current			Precise Coordinates	
	Primary	Secondary	PA	SEP	Epoch	PA	SEP	RA (h m s)	Dec (0 ‘ “)
Beta Cyg	3.40	4.70	55	35.0	2012	55	34.7	19 30 43.3	+27 57 34.8
STF 2840	5.60	6.40	196	18.0	2012	189	17.0	21 52 00.0	+55 47 00.0
Gamma Del	4.50	5.00	266	9.0	2012	278	9.4	20 46 38.7	+16 07 38.0
61 Cyg	5.30	6.10	144	31.0	2012	149	31.9	21 06 53.9	+38 44 57.9
Sigma Cas	5.00	7.20	326	3.0	2012	326	2.3	23 59 00.5	+55 45 18.0
8 Lacertae	5.70	6.30	186	22.0	2012	177	21.4	22 35 52.3	+39 38 03.6
Zeta Lyr	4.30	5.60	150	44.0	2012	149	41.1	18 44 46.3	+37 36 18.0
Beta Lyr	3.30	6.70	149	46.0	2012	147	44.8	18 50 04.7	+33 21 46.0
Delta Cep	3.50	6.10	192	41.0	2012	188	39.9	22 29 10.3	+58 24 54.7

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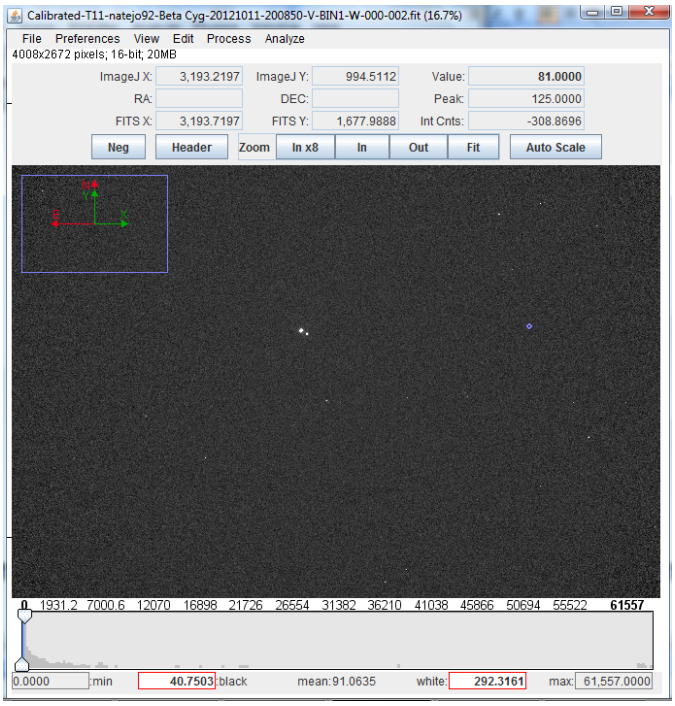

Figure 7: AstroImageJ Image of Binary Star Beta Cygni

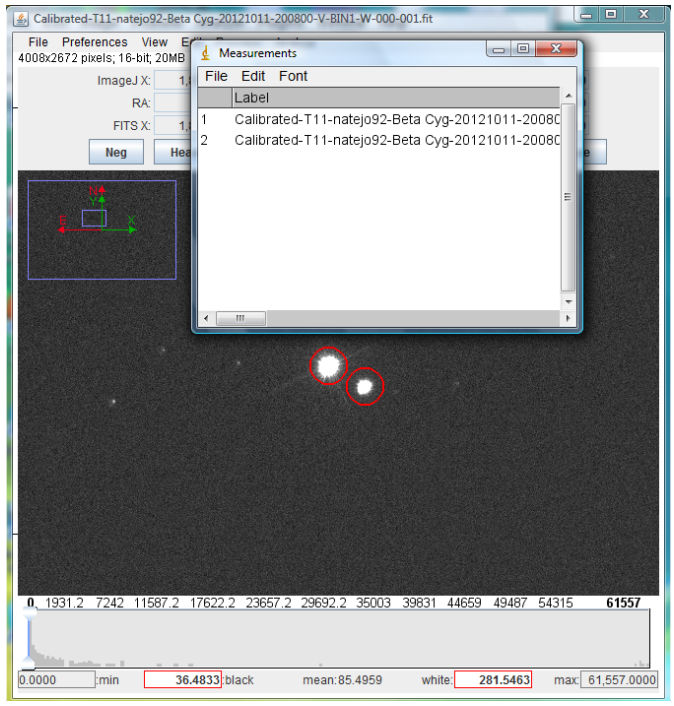

Figure 8: Positions Measurements of Primary and Secondary Stars

tool as shown in Figure 8. From these measurements, separation distances were obtained.

Measurements of Position Angle

Measurements of position angle off the imagery resulted in a set trigonometric calculations being performed in order to establish a baseline angle on the calibration star which could then be used to estimate the position angle of imaged stars. Like in the case for distance separations, baseline calibrations had to be performed for each telescope. However, when this baseline reference line was applied to other stars imaged with the same telescope, calculated angles were not close to previously established position angles. As such, only a few position angles were calculated for imaged stars. Results are shown in Table 3.

Conclusion

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

Acknowledgments

We would to thank Becky Baranowski, Department Chair for Mathematics, Physics, and Astronomy for offering this course for the fall semester year 2012 and to the Estrella Mountain Community College for use of equipment and facilities.

Table 3: Photometric Measurement Data for Measures 2012

WDS ID	Discover	Magnitudes			Last		Current		
		Primary	Secondary	Epoch	PA	SEP	Epoch	PA	SEP
22129+7318	STF2893	6.19	7.91	2010	347	28.8	2012	348	28.7
18433+1100	J_1189	9.80	9.80	2010	16	7.1	2012		6.2
18054-2930	RST2026 (N)	10.70	10.90	1940	321	3.6	2012		4.4
19593+2215	WFC 262	9.64	9.71	2004	32	13.3	2012		13.3
21236+6456	STF2798	8.36	9.93	2010	144	6.4	2012		6.2
19050-0402	SHJ 286	5.52	6.98	2011	210	38.2	2012	263	39.6
18015+2136	STF2264	4.85	5.20	2010	257	6.3	2012		6.1

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