Visual Measurements of the Binary Star S 654

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Abstract: A member of the faculty and students from The Evergreen State College, Olympia, Washington, participated in the 2010 summer astronomy workshop at Pine Mountain Observatory. They learned the proper techniques and skills required for measuring the separation and position angle of binary star S 654. They learned how to calibrate an astrometric eyepiece, make appropriate measurements, do a statistical analysis, and analyze the data. The separation and position angle values obtained were 69.9 arc seconds and 237 degrees, respectively. The percent difference for each value was less than 0.5% from the literature value.

Introduction

An interdisciplinary group of undergraduate liberal arts and science students from The Evergreen State College (TESC) in Olympia, Washington, and students from other institutions, joined an invitational summer research workshop at Pine Mountain Observatory (PMO) near Bend, Oregon. The workshop ran from August 5-8, 2010. The observatory, run by the University of Oregon, hosted the workshop conducted by both professional and amateur astronomers. The projects included double star observations and measurements, photometry, and spectroscopy. The students from TESC participated in the double star research as part of a course entitled, *Astronomy and Cosmology: Stars and Stories*, taught by team member, Rebecca Chamberlain. None of the students had ever done any type of astronomy research, so a bright double star with moderate separation was selected for their project.

Figure 1: The Evergreen State College team, left to right: Thomas G. Frey, Professor Emeritus, California Polytechnic State University, Rebecca Chamberlain, Faculty, The Evergreen State College, followed by Chandra Alduenda, Irina Achildiyev, Reid BrIdgeman, and Alex Hendrix, all students at Evergreen State College. The team is standing by Frey's 18-inch Obsession alt-az telescope used in this investigation.

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Background

Double star observation began in 1650 when the Italian Giovanni Roccioli recorded Mizar, in the constellation Ursa Major, as a double star. But Sir William Herschel in the late 18th century is credited with the initiation of double star investigations. He utilized his 20 and 40-foot alt-azimuth reflectors without clock-drives to observe double stars. He therefore had to continuously move the telescope in both coordinates to keep the stars in the field of view. He published catalogs in 1782, 1784, and 1821 citing a total of 848 double stars. (Aitken 1935)

In 1802, Herschel presented a paper to the Royal Society entitled *Catalogue of 500 new Nebulae, nebulous Stars, planetary Nebulae, and Clusters of Stars; with Remarks on the Construction of the Heavens,* where it cites the distinction between optical and binary stars. Namely, "a real double star-the union of two stars that are formed together in one system, by the laws of attraction." (Aitken 1935)

Following in Herschel's footsteps, the German-Russian astronomer Friedrich G.W. von Struve, performed unparalleled observations using the Dorpat refractor, constructed by Joseph Fraunhofer. This telescope was undoubtedly the largest and finest refractor of its time. It was 13 feet long with a 9.5-inch objective lens and utilized a clock-drive on an equatorial mount. Struve stated that the telescope was so easy to manipulate and the optical properties were so excellent that he was able to examine 400 stars per hour. He surveyed 120,000 stars from 1823-1827. (Aitken 1935)

Other astronomers followed these historic beginnings into the modern period of astronomy research. S. W. Burnham of Chicago, who worked at the Dearborn, the Lick, and the Yerkes observatories, discovered over 1340 new double stars and made thousands of very accurate measurements. His 1906 *A General Catalogue of Double Stars within 121° of the North Pole* contained 13,665 double stars with measurements, notes, and complete references to all published papers regarding each pair. (Aitken 1935)

Presently, the Washington Double Star Catalog, under the direction of Brian Mason at the US Naval Observatory, has accumulated over 107,000 double star measurements (Mason 2009).

Historically, most double star measurements have been made using telescopes on equatorial mounts (Argyle 2004, and Teague 2000). In recent years, telescopes on altitude-azimuth mounts have been shown to be effective in these studies (Frey 2008). The double star research at Pine Mountain Observatory was conducted with Frey's 18 inch, f/4.5 Obsession telescope, equipped with a ServoCAT GOTO system and an Argo Navis computer. Double star measurements were made with an illuminated Celestron 12.5 mm Micro Guide astrometric eyepiece. Calibration of the eyepiece was done with a stopwatch having 0.01-second resolution.

Pine Mountain is located at +43.79 degrees north latitude and 120.94 degrees west longitude. During the observing period the transparency was very good with the exception of some smoky haze produced by a nearby forest fire, which had minimal effect on the observations. The seeing was excellent with minimum scintillation. The temperature during observing hours of 9:00 PM to 2:00 AM was 40-45 degrees Fahrenheit. Breezy conditions existed each night with occasional strong gusts which did hamper some results.

Calibration of the Celestron Micro Guide Astronomic Eyepiece

Double star measurements can only be carried out after the astrometric eyepiece-telescope system has been calibrated. The linear scale on the eyepiece is divided into 60 equal divisions. It is necessary to determine the number of arc seconds per division for each eyepiece-telescope setup. This calibration procedure has been described at length (Frey 2008). The reference star used for the calibration was Dubhe (Alpha Ursae Majoris), which fulfilled the requirement of a declination between 60-75 degrees. The students worked together as a team to learn the calibration procedure. The results of the calibration and determination of the scale constant is summarized in Table 1. Twelve observations were made with one outlier deleted. The statistical standard deviation and mean error are given to show the precision of the observations. The scale constant for the Celestron-Obsession setup is given in arc seconds per division.

Star	Bess. epoch	Declin.	#Obs	AvDrift time(sec)	Std dev	Mean error	Scale constant
Dubhe	B2010.594	61°75′	11*	86.30	0.94	0.29	10.23

Table 1. Scale Constant Determination. * One outlier

Double Star S 654

After determining the scale constant, the Obsession was two-star aligned and the tracking motors engaged. The double star selected for observation was S 654 in the constellation Canes Venatici. The primary star is a K0III giant star with a magnitude of 5.6. The secondary star is a F8V main sequence star with a magnitude of 8.9. These stars are sufficiently bright to be easily measured with the 18-inch aperture Obsession. This binary pair was first studied in 1825 when a separation of 71.3 arc seconds and position angle of 238 degrees was reported. The pair has been observed 24 times since then. The latest published observation in the Washington Double Star catalog was in 2004 with a separation of 70.1 arc seconds and position angle of 236 degrees.

There appears to have been little change in the orientation over 179 years. The primary star has a proper motion of RA: -134.18, Dec: -21.64 milli-arc seconds per year (SIMBAD, RA: 13 46 59.7, Dec: 38 32 33.7) and the secondary star has a proper motion of -135.20, -15.80 milli-arc seconds per year (TheSky6, RA:13 47 27, Dec: 38 29 30), indicating similar motions through space and the possibility of it being a visual binary star.

Separation Measurements of S 654

The telescope was two-star aligned and the servo-motors engaged. The Celestron Micro Guide eyepiece was rotated until the central linear scale was parallel with the axis joining the two stars. The distances between the centers of the two stars was estimated to the nearest 0.1 divisions and recorded. Then, using the slow motion controls, the stars were shifted to a new location along the linear scale, a new measurement was made, and the process repeated many times. This method of moving the stars to new locations each time is to negate any systematic error that might exist if the stars were continually kept and measured at the same division marks. The method seemed to work very well since our standard deviation was only 0.37 divisions and the standard error of the mean was 0.11 divisions. The results of the separation measurements for S 654 are shown in Table 2. Thirteen observations were recorded with one outlier deleted due to a wind gust. The SD/ME are the standard deviation and standard error of the mean. The observed and literature separations are given in arc seconds. The percent difference is based on the difference between our observations and the most recently reported literature values.

Position Angle Measurements of S 654

The determination of the position angle using the drift method with an alt-az telescope has been described at length in a previous paper (Frey 2008). Briefly, it involves disengaging the servo-motors so the telescope becomes a “push Dob”. The double star is aligned with the linear scale and adjusted manually so when it is released the primary star drifts through the central division (the 30th division) and continues to drift to the outer protractor scales. It usually takes several attempts to get the star to drift precisely through the center. To compensate for field rotation, the eyepiece was continually adjusted so that the two stars remained aligned with the linear scale. The results of the position angle measurements for S 654 are shown in Table 3. Position angles (PA) are given in degrees. The SD/ME are the standard deviation and standard error of the mean. The percent difference for the positional angle is based on the difference between our observations and the most recently reported literature value.

Table 2. Separation Measurements for S 654 * One outlier

Double star	Identifier	Bess. epoch	Lit. epoch	# Obs.	SD/ME	Obs. sep	Lit. sep	% difference
S 654	134659+3832	B2010.594	2004	12*	0.37/0.11	69.9	70.1	-0.29%

Table 3: Position Angle Measurements for S 654

Double star	Identifier	Bess. epoch	Lit. epoch	# Obs.	SD/ME	Obs. PA	Lit. PA	% difference
S 654	134659+3832	B2010.594	2004	12	2.04/0.59	237	236	0.42%

Discussion

The separation measurements from 1825 and 2004 were 71.3 and 70.1 arc seconds, respectively. Our experimental separation taken in 2010 is 69.9 arc seconds, indicating a further statistically significant decrease in separation. If the orbit is elliptical, this could indicate that the secondary star is approaching the periastron since the change in separation from 1825 to 2004 was 1.2 arc seconds and the change from 2004 to 2010 was a proportionally larger 0.2 arc seconds. If the change had continued at the same rate from 2004 to 2010 as it did from 1825 to 2004, we would have expected a change of only 0.07 arc seconds instead of the observed 0.20 arc seconds. Yet, our precision was very good with a percent difference based on the literature value of -0.29%.

The position angle measurements were similarly close in agreement with the literature values. Yet the standard deviation of 2.04 indicated a much broader distribution of observed position angles. This is probably due to the fact that students taking position angle measurements for the first time have some problems aligning the double stars on the linear scale before allowing the drift to the protractor scale. There is also a slight parallax that occurs when looking at the values on the protractor scales. First-time investigators find it frustrating to read the angles on the protractor scale, seeing the numbers move slightly, resulting in erroneous values. This is one reason 12 observations were made to reduce these random errors. Even though the standard deviation was fairly high, by making many observations the percent difference of 0.42%, indicated a very close agreement between our observations and the most recent literature value.

Conclusions

The purpose of Rebecca Chamberlain's interdisciplinary course, *Astronomy and Cosmology: Stars and Stories*, is the introduction of "… cosmological concepts from mythology, literature, philosophy, and history, to an introduction to astronomy, archeo-astronomy, and theories about the origins of the universe" (Chamberlain 2010). She wanted the students "... to deepen their understanding of the principles of astronomy and refine their understanding of the role that cosmology plays in our lives ..." By attending the summer research workshop at Pine Mountain the students enhanced their observing skills and learned how to make fairly rigorous physical measurements of a double star, winding up with precise and accurate results.

The workshop experience consisted of a combination of rapidly learning the operation of a sophisticated telescope in a professional research context, the pleasure of the impressive viewing conditions at Pine Mountain Observatory, the satisfaction of successful class teamwork, and additional understanding of binary stars and telescope operation. Some students were surprised and perplexed by the ability of the telescope to focus the image of such distance objects. Some had experience using telescopes before the workshop but were never involved in scientific investigations. Through developing skills in making accurate readings, students discovered latent talents and achieved remarkably accurate results for new researchers, thus enhancing their motivation, focus, and discipline. Each member of this diverse team developed and offered different skills as they rotated through a variety of tasks, from recording observations, to assessing the data through analysis, to writing narratives that described their experience. Throughout the process, they supported each other's learning. Mentorship from the professional and amateur astronomers, along with the cutting edge scientific research being conducted and presented by various teams at PMO throughout the week, provided students with a guided, hands-on, professional experience in scientific methods of investigation and inquiry. This team of students, new to astronomical research, left trained and enthusiastic about continuing binary star research at their own institutions.

Acknowledgements

The team wants to thank Russ Genet, Jo Johnson, and Tom Smith for reviewing this paper and for their suggestions and corrections. We also want to thank Gregory Bothun, Director of Pine Mountain Observatory, Mark Dunaway, Kent Fairfield, Allan Chambers, and Rick Kang, for opening the facility and being on hand to answer questions and assist our needs. A special thanks goes to Danyal Medley at Celestron for the donation of a 12.5 mm Micro Guide astrometric eyepiece to Evergreen State College, and to Theresa Aragon (Dean of TESC Summer School), and Peter Robinson (Director of Lab I and Lab II, and Science Technician at TESC), for purchasing an additional 12.5 mm Micro Guide astrometric eyepiece. Thanks to Sarah Pederson, Tina Pearson, Lori Moore, Sharon Wendt, Frank Barber, Katie Frank, and the other members of the TESC community for their support. The workshop would never have been as successful with out the organization, dedication, and tireless effort of Richard Berry as Workshop Director. Our team also wants to recognize the other double star team leaders, Jo Johnson and Chris Estrada, for their cooperation and assistance with the project. Finally, if it weren't for Russ Genet's initial efforts, none of the double star projects would have taken place.

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