Visual Measurements of the Neglected Double Star ARY 52 at the Pine Mountain Observatory Summer Science Research Workshop 2009

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Abstract: Teachers and students from St. Mary's School, Medford, Oregon attended the astronomy research workshop at Pine Mountain Observatory. They learned the techniques and acquired proper instrumentation skills necessary to perform visual double star measurements of known and neglected double stars, analyze data, and write a paper on their findings for publication. Their intent is to take these skills back and incorporate them into science projects at St. Mary's.

Introduction

Students and teachers from St. Mary's School in Medford, Oregon and Willamette University in Salem, Oregon participated in a summer research workshop at the University of Oregon's Pine Mountain Observatory (PMO) near Bend, Oregon, that was conducted by both professional and amateur astronomers, and an engineer from Celestron. Participants made observations with telescopes ranging from 6-28 inches in aperture. Projects included double star measurements, light curve generation of pulsating variable stars, and monitoring the proper motion of a nearby star. The students carried out research projects, analyzed data, gave presentations on their data, and wrote up their findings for publication.

The teachers and students from St. Mary's School were especially interested in performing work that could be applied to classroom projects at the high school level. When they return, the work carried out at PMO should enable the team to do this.

Figure 1: The St. Mary's Team pictured, left to right: Thomas Frey, Professor Emeritus, California Polytechnic State University, with his 18" Obsession telescope; Monika Ruppe, student at St. Mary's and her father, David Ruppe; Holly Bensel, science teacher at St. Mary's; Ryan Gasik, student at St. Mary's; Dave Scimeca, retired technician, Ames Research Center; and Fred Muller, retired science teacher and substitute teacher at St.

Equipment

The St. Mary's team performed double star projects with an f/4.5 18-inch Newtonian telescope that utilized an alt-az mount. This Obsession telescope was provided by team member Frey. The tracking unit used a ServoCAT GOTO system and an Argo Navis computer. A Celestron 12.5 mm MicroGuide astrometric eyepiece was used for all double star measurements. A RadioShack LCD Stopwatch with a 0.01 second resolution was used to calibrate the linear scale on the Celestron eyepiece.

Locale

The University of Oregon's Pine Mountain Observatory is located at 43.8°N latitude and 120.9°W at an elevation of 6500 feet, near Bend, Oregon. The surrounding area is desert-like with low humidity and very dark skies. Observing sessions were plagued, however, with high altitude clouds that periodically moved in, creating hazy conditions. Of course, once the workshop was over and the students had left, the sky cleared becoming pristine and steady.

Double Star Measurement

Double stars have been observed visually for over 200 years. Studies involve determining the separation between the stars and their position angle, which is measured in degrees defining the orientation of the pair with respect to celestial north. Double star research traditionally makes use of equatorial mounted telescopes (Argyle and Teague). Frey (2008) described methods used to make visual double star measurements with an alt-az telescope.

The separation between double stars is measured in arc seconds. Binary stars usually have separations less than 10 arc seconds whereas optical double stars, with different proper motions, can have separations as large as 200 arc seconds. Due to the inexperience of the students in making double star measurements, double stars were chosen for study that had separations greater than 30 arc seconds.

The position angle determination is especially challenging with alt-az telescopes. The astrometric eyepiece is rotated until the two stars are aligned with the linear scale. The scope is then moved manually to a position where the primary star is allowed to drift through the mid-mark of the linear scale and outward to an outer circular protractor scale, where the position angle is observed and recorded.

In this study, fairly bright double stars were chosen for evaluation for two reasons. First, for those doing double star measurements for the first time it is necessary to choose a system that has stars that are easy to see with sufficiently different magnitudes to be able to assign as primary and secondary. Second, the hazy sky conditions made it challenging to see the secondary. If it had been much dimmer, making the alignment on the linear scale would have been difficult.

Calibration of the Celestron Astrometric Eyepiece

The linear scale on the astrometric eyepiece requires calibration. Each division on the scale must be converted to the correct number of arc seconds. Argyle (p.152) suggests using a reference star of medium brightness at a declination between 60-75° to avoid timing errors. The reference star is allowed to pass along the linear scale and timed to the nearest 0.01 seconds. Many trials were performed to reduce random errors. The average of all of these trials was used to determine the scale constant (*Z*) for the telescope-eyepiece system. The scale constant is calculated using the formula:

$$Z = \frac{15.0411 T_{ave} \cos \delta_{RS}}{D}$$

where Z is the scale constant (in arc seconds per division), T_{ave} is the average drift time, 15.0411 is the arc seconds per second of the Earth's rotation at the celestial equator, $\cos\delta_{RS}$ is the cosine of the reference star's declination, and D is the number of divisions on the linear scale.

Alderamin (α Cephei) was used as the reference star. The declination of this star is 62.58°. The average drift time was 88.32 seconds (standard deviation, 0.4766 seconds; mean error, 0.1231 seconds). These values yielded a scale constant of 10.20 arc seconds per division.

Separation and Position Angle Measurement: Known Double Star

To determine the accuracy and precision in measuring double star parameters, and to give the students practice, an extensively studied double star with published separation and position angle values was observed so experimental values could be compared to literature values. This was designated the "known" double star.

Delta (δ) Cephei was chosen as the known double star. The telescope was properly aligned and the tracking motors were engaged. Delta Cephei was aligned parallel with the linear scale so both stars were bracketed by the two parallel lines of the linear scale. The distance between the centers of each star was to be estimated to the nearest 0.1 division and recorded. Using the slow motion controls of the ServoCAT, the pair was moved along the linear scale to a new location and the distance between the stars recorded again. The double stars were continually moved to reduce the random error in the assignment of the distance between the two stars. Twenty different distance measurements were taken.

The separation measurements showed a standard deviation and mean error of zero. Obviously this is not the actual case. Observers were taking measurements for the first time so they estimated the divisions between the centers of the stars to the nearest whole or half division instead of the nearest 0.1 divisions as instructed. As a result, all of the distances were recorded as 4.0 divisions separating the stars. With more experience at the eyepiece, the observers should be able to estimate division increments with 0.1 division resolution.

The position angle measurements indicated a significant variance in estimating the angle as the primary crossed the outer protractor scale. With separation measurements, the tracking motors were engaged so the observers had as much time as needed to make their evaluations since the stars were not moving. In determining the position angle, however, the observers had to estimate when the primary drifted across the exact center of the scale (star in motion), and read (on the fly) the angle on the protractor as the primary made contact (star in motion). Also, as the primary star crossed the protractor scale, a parallax error could be introduced as different values could be observed depending on the angle as the observer looked through the eyepiece.

The results of these measurements are shown in Table 1. The Besselian (Bess.) Epoch is the observation date in a fractional form as described by Argyle (p.273). Standard deviation (SD) and standard error of the mean (ME) are given for both measurements.

After initially measuring the position angle of the reference star, a comparison of the experimental value with the literature value showed that it was in error by 20°. After examining the MicroGuide eyepiece more closely, it was observed that the two outer protractor scales had values going in opposite directions. The inner scale, which was easier to read (larger numbers), was used initially. But this scale is intended for use with telescopes using a diagonal mirror between the eyepiece and the telescope where the image is reversed. For the Newtonian telescope used in this study, however, the outer scale should be used, where the values are the 360° compliment to those of the inner scale. The values were quickly modified to the outer scale values and the comparison of the experimental to the literature values were much better.

Another possible source of error occurred in determining the position angle. When using an alt-az telescope, the image viewed through the eyepiece is in constant rotation since the azimuth axis is oriented around the zenith instead of the north celestial pole as in the case of an equatorial mount. As a result, it is necessary to constantly readjust the alignment of the double star with respect to the linear scale. If not done frequently enough, the primary will begin to drift and inaccurate position angles will be recorded. Instead of rotating the eyepiece 180 degrees after every other drift and realigning with the linear scale, observers only rotated the eyepiece after every 6-7 drift runs which would have increased the chance of error, albeit perhaps insignificantly.

Separation and Position Angle Measurements of a Neglected Double Star

Once the techniques of determining separation and position angles were practiced with the known double star, the team observed the neglected double star ARY 52 in the constellation Boötes. Neglected double stars obtained from the Washington Double Star (WDS) Catalog include unconfirmed binaries as well as double stars that have not been studied or resolved for many years. Again, due to hazy sky conditions, this star system was chosen because the magnitudes of both stars (7.6, 8.4) were bright enough to make effective measurements.

The double star ARY 52, right ascension 15h 12.4m, declination 52° 56m, had been studied in 2005. The WDS cited the separation and position angle as 147.1 arc seconds and 331 degrees, respectively. The results of measurements of ARY 52 are shown in Table 2.

It can be seen that the accuracy in determining separation and position angle of the neglected star had improved from the measurements performed on the

Table 1. Separation and Position Angle Measurements of Delta Cephei

			Separation (arc seconds)					Position Angle (degrees)				
Double Star	**Bess. Epoch**	**Lit. Epoch**	**# Obs**	**SD/ME**	**Obs. Sep.**	**Lit. Sep.**	**DSep.**	**# Obs.**	**SD/ME**	**Obs. PA**	**Lit. PA**	**DPA**
δ Cephei	B2009.540	2007	20	0.0/0.0	40.8	40.8	0.0	20	1.6/0.4	187.0	191	-4.0

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Table 2. Separation and Position Angle Measurements of ARY 52.

			Separation (arc seconds)					Position Angle (degrees)				
Double Star	Bess. Epoch	Lit. Epoch	# Obs.	SD/ME	Obs. Sep.	Lit. Sep.	DSep.	# Obs.	SD/ME	Obs. PA	Lit. PA	DPA
ARY 52	B2009.543	2005	25	0.3/0.1	147.5	147.1	+0.4	15	1.6/0.4	330.5	331	-0.5

known double star. A greater amount of time was taken in estimating the divisions separating the stars in ARY 52, and this translated into a separation very close to the WDS value. In determining the position angle, the astrometric eyepiece was rotated after every 2-3 drift cycles instead of after every 6-7 drift cycles as was done with the known double star. This resulted in a more precise alignment of the double stars with the linear scale prior to each drift.

Analysis

The results of these measurements show why it is necessary to have inexperienced observers practice first on double stars of known, well established values before attempting double star measurements of lesser studied double stars with fainter magnitudes. It is also possible that since ARY 52 had a separation that spanned about 14 divisions on the linear scale, it was easier to align the two stars between the two lines than it was with δ Cephei that only spanned 4 divisions. Even though the skies were hazy, ARY 52 was bright enough to obtain excellent measurements that correlated very well with the published data in the WDS catalog.

Double stars can be designated two ways. Binary stars are bound by gravity and rotate about a common center of mass. Over time, their separation and position angle can change, but their net direction of motion through space, i.e., their proper motion, is the same. Optical double stars are not bound by gravity and their chance line of sight separation is purely coincidental. These stars are commonly separated by vast distances, and they usually have significantly different proper motions through space. Data collected and analyzed by Medley and Johnson indicate the proper motion of the primary star in the ARY 52 system (SAO 29443) is 15.44 arc seconds per thousand years in right ascension and 20.58 arc seconds per thousand years in declination (Hipparchus Catalog). The proper motion of the secondary star (SAO 29442) in right ascension and declination is 1.70 and 50.60 (Tycho Catalog), respectively. In a personal communication with Johnson, Dave Arnold, an experienced double star observer in Flagstaff, Arizona, said a binary system should have approximately 90% agreement in the proper motion vectors of the two stars in order to be considered a true binary double star. Also, according to the Tycho Catalog, the trigonometric parallax of the primary star is 7.39 milli-arc seconds and that of the secondary is 2.00 milli-arc seconds. This equates to distances of 441.14 and 1630 light years, respectively. This data leads to the conclusion that ARY 52 is an optical pair and not a binary star.

The sky conditions at PMO were usually hazy every night during the workshop. This made detecting the dimmer secondary star a problem for inexperienced observers. Teaching the technique of averted vision was very helpful to moderate this problem.

Conclusions and New Directions

The students and teachers from St. Mary's School were very excited to participate in the summer research workshop at Pine Mountain Observatory. Except for Frey and Johnson, none of the participants had ever attempted double star measurements, yet were able to obtain excellent scientific agreement between their experimental values and those of published data from the WDS catalog. Their five-day effort involved instrument setup, orientation, instruction, observations, analysis, presentation of data, and writing up findings for publication.

The teachers had expressed an interest in developing astronomy projects that they could take back to their high school. Double star analysis is relatively straight forward and can be performed with equipment available to most high schools. Here are some of views expressed by the teachers and students about the workshop:

The main techniques that were presented to the participants in this project were calibrating a Celestron astrometric eyepiece, learning what calibration is, and why it is done, and measuring the angular distance and position angle between double stars. The students, parents, and faculty members from St. Mary's School were pleased to find that these measurements were easy to make. This gives them confidence in duplicating this sort project once they return to St. Mary's School. Keeping track of and accurately recording data is a useful and important skill for all students to learn. The data sheet provided by Frey used to record data was straight forward and easy to use, making the learning process much simpler. Another important skill in all areas of life is learning to work together to accomplish a specific goal. This project allows novice and experienced observers to work hand-in-hand to accomplish a specific goal.

One of the most important aspects of this workshop was the exposure of high school students to professionals, sophisticated equipment, the scientific community, and a research-oriented environment; an experience most students would not have until college or later. The types of projects, along with the professional and amateur astronomers administering this workshop, showed that much thought and care went into its planning. The fact that each group finished the weekend workshop with a publishable paper was quite an amazing accomplishment in itself.

Workshops are important for the exchange of ideas and the development of teaching techniques. The St. Mary's team worked on how to implement the double star project into the school year. The size, scope, cost, and the research component make this project a perfect match for a semester long astronomy class as well as a project for our astronomy club. Students who have completed several observations could teach others how to do the same. For students who like technology, further studies could be conducted using the schools CCD camera and astronomy software. Other research projects could be performed such as a comparison between the Meade and Celestron astronomic eyepieces, a comparison of the accuracy and ease of viewing between different makes, sizes of telescopes, etc. One student's suggestion was to emphasize the "why?" Why are we doing this? Why study that star? Why does it matter? The emphasis on publishing and writing up the data is something the teachers and students need to keep in mind, that way the data taken can be used for future research.

Acknowledgments

The St. Mary's team would like to thank Russell Genet, Research Scholar in Residence at California Polytechnic State University for organizing and conducting this summer research workshop as well as for his candid suggestions in reviewing this paper. A lot of time, energy, and dedication went into making this experience a memorable one and an experience that will kindle excitement and the desire to come back next year. We also want to thank Gregory Bothun, Director of Pine Mountain Observatory, Rick Kang, Mark Dunaway, Kent Fairfield, and Allan Chambers for opening the facility and being on hand to answer questions and assist our needs. Acknowledgement is also directed to the faculty and staff at St. Mary's School for urging their students to participate in this workshop.

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