Double Star Research as a Form of Education for Community College and High School Students

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Abstract

The measurement of the separations and position angles of double star makes an ideal science activity for small research group at the community college and even high school levels. The concepts involved are relatively simple and only modest equipment is required. Observations and analysis can be included in a paper and submitted to the *Journal of Double Star Observations*, which welcomes student papers. Through this process, students learn about science, become coauthors of a published paper and, as a result of their research and publication, can obtain a scholarship to the college of their choice.

1. Introduction

Perhaps the most effective way to teach science to undergraduate and high school students is to conduct original research and present their results in a published paper. Russ Genet initiated a one semester research seminar at Cuesta College in San Luis Obispo, California, in the Fall of 2006. The students made photometric measurements of variable stars and discovered two new ones. Genet again led the research seminar in 2007 where a mixture of sixteen high school students, undergraduate students, and PhD's made observations of visual double stars. The students completed the semester with five double star research papers in the *Journal of Double Star Observations (JDSO)*, along with several other published projects.

The key to success for the 2007 research seminar was the form of the research conducted by this mixture of students. Astrometric measurements of double stars are ideal for teaching students the fundamentals of science. The instrumentation is inexpensive and easy to use, and the mathematical concepts involved are straight forward.

2. Equipment Required

One of the most appealing aspect of visual double star research as a form of undergraduate education is that very little equipment (and expense) is required to make modest contributions to astronomical science. A small aperture telescope can make surprisingly precise and accurate measurements. Darrel Grisham (2008), an amateur astronomer in California Valley and Cuesta research seminar student, made double star measurements with his modified vintage 1960's three inch Tasco Telescope twice as accurate as what Ronald Tanguay says is "excellent work" in his book, *The Double Star Observer's Handbook*.

Besides a modest telescope, an inexpensive illuminated astrometric eyepiece (both Meade and Celestron sell these for about $150) is also required. The astrometric eyepieces include a linear scale across the center and a protractor around the edge. Figure 1 shows an illuminated Meade Astrometric Eyepiece. Lastly, a low cost (less than $10) stopwatch that reads out to 0.01 seconds is required to calibrate the linear scale in arc seconds per division.

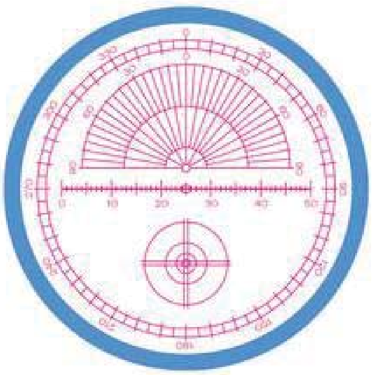

Figure 1. The linear scale and outer protractor of an illuminated Meade Astrometric Eyepiece.

3. Discussion

Most concepts involved in visual double star research are straight-forward compared to more technical astronomical research projects such as photometry and spectroscopy. The linear scale on the astrometric eyepiece is calibrated using the following calculation (Teague 2004).

$$Z = \frac{15.0411t + \cos d}{D}$$

Where z is the scale factor in arc seconds per eyepiece division, 15.0411 is the arc seconds per seconds of time that the Earth rotates, t is the average time in seconds for a calibration star to drift across the entire linear scale, d is the declination of the calibration star in degrees, and D is the number of divisions on the scale (60 for the Celestron eyepiece, 50 for the Meade eyepiece).

The time component is measured using the "drift method" in which a star is placed on the Eastern-edge of the linear scale and allowed to drift in Right Ascension directly across the scale to the other side. This drift is timed using a stopwatch. Several trials are averaged to provide the final drift time.

Separation is measured by centering the primary star (which is usually the brightest) and rotating the astrometric eyepiece until the linear scale passes through the precise centers of both stars. The distance on the linear scale between the primary and secondary are then estimated several times to the nearest 0.1 divisions. The scale factor, z, is then multiplied by the resulting average to obtain the separation in arc seconds (Teague 2004).

The position angle is determined using one of two methods. In the "drift method," the eyepiece is adjusted similarly to the separation measurement. The clock drive is then turned off so that the double star drifts to the protractor that circles the eyepiece. The position of the primary star when it crosses the protractor is estimated to the nearest 0.5°. Multiple drifts are averaged to obtain the final position angle (Teague 2004).

A protractor-pointer can be built by gluing a protractor to a piece of foam board and fitting it around the eyepiece. A pin is then attached to the red light switch on the eyepiece to act as a pointer. In the protractor-pointer method, position angles are determined by rotating the eyepiece so that the primary star moves along the linear scale with minimal deviation as the telescope slews in Right Ascension. The pin is aligned horizontally to the linear scale in the eyepiece and pointed to 90.0° on the external protractor. The eyepiece is readjusted so the linear scale passes through the centers of both stars. The angle indicated by the pointer is then estimated to the nearest 0.1° (Johnson and Genet 2007). Figure 2 shows a protractor-pointer built by Johnson for measurements of the double star STF 2079.

Figure 2. A protractor-pointer designed by Johnson to measure the position angle of the double star STF 2079.

4. Scientific Value

For several centuries, the largest telescopes in the world were making astrometric measurements and cataloguing visual double stars. Today, few professional astronomers measure the separations and position angles of double stars. This is partly due to the fact that it takes many decades (often centuries) to obtain enough data points to refine the orbits of binary stars and calculate their masses, a key astrophysical parameter. The Sixth Catalogue of Orbits of Visual Binary Stars lists only 2,106 orbits out of 103,694 double stars in the Washington Double Star (WDS) Catalogue (Hartkopf and Mason 2008). In other words, only 2% of the double stars in the WDS Catalogue have at least roughly determined orbits, granted that many of the remaining pairs may not be true binary stars.

Furthermore, there are many star systems that have not had published measurements for decades. Many of these have very different proper motions between their components and thus, are most likely not true binary systems. Astrometric measurements can help determine if the double star is a gravitationally bound system or simply an optical double. There is still much research that needs to be done in the field of double stars. Because professional astronomers are now busy observing distant quasars and other faint objects with their gigantic mountaintop behemoth, the opportunity has opened for amateurs and students to engage in real albeit modest, scientific research.

5. Educational Value

One of the most important lessons that students learn from double star research is how to exercise their mathematical skills in real science. As mentioned earlier, the basic double star concepts are not difficult. All observations deserve a statistical analysis of standard deviation and mean error. For more advanced projects, double stars should have their proper motions analyzed, which involves straightforward vector analysis.

Additionally, students learn how to work cooperatively together in groups to complete their research projects. Johnson et al 2008 describes the "synergetic effect" of having students work together with experienced astronomers: "those who had little experience with telescopes learned how to operate them and use them. Others learned the proper methods of recording, analyzing, and reporting observations."

One of the most appealing aspects of double star research is that students end the course as published researchers, college admissions are impressed with student applications citing published astronomical research papers. Several high school students in the Fall 2007 research seminar at Cuesta College were accepted to the university of their choice because of their double star research (Marble et al 2008).

Lastly, students learn the complicated publication process. Students receive constructive criticism when reviewing and editing research papers. This can be the most involved portion of a project as the paper needs to be of professional caliber before being submitted to the *JDSO*. The other side of this process is students learning humility in their work. Papers will be edited many times and ideas will be rejected or refined. That is the nature of science and students will catch on quickly. During the previously mentioned research seminar, Genet would edit entire papers a dozen times or more before students could send them out to experts for external review. The paper is finally sent out to external reviewers who are experts in the field of visual double stars. Most suggestions are immediately used to improve the paper. The papers are again internally rewritten until all who participated in the project are satisfied.

One thing Johnson and Genet learned from the publication process is the value of English majors in scientific research who find more spelling and grammatical errors regardless of how many times the paper is rewritten. The final edition of the paper is then submitted to the editor of the *JDSO*, Kent Clark, with a cover letter that is also written by the students who wrote the paper. The openness of the *JDSO* to student papers and its prompt publication makes it ideal for a single semester research seminar. Papers submitted in the first half of the seminar were published before the end of the semester.

6. Conclusion

The combination of relatively straight-forward processes by which visual double star measurements can be made and a journal dedicated to their study makes them an ideal project for undergraduate and high school education. Any school with a modest budget for science can take advantage of double star research provided there is an instructor who is familiar with the scientific publication process.

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8. References

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