Chico High School Students' Astrometric Observations of the Visual Double Star STF 1657

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Abstract: In the spring of 2011, Chico Senior High School students participated in an astronomy seminar at the Gateway Science Museum, University of California, Chico. The observers used a Celestron NexStar 6 SE telescope and a Celestron MicroGuide eyepiece to determine the separation and position angle of the visual double star STF 1657. Observations were made in approximately one hour on the evening of May 1, 2011. The observers determined that the separation of STF 1657 was 22.1" and the position angle was 273.4°. Seminar members then used the spectral type, parallax, and proper motion vectors of the two stars to determine if they are a line-of-sight optical pair or physically bound by gravity. Due to large errors in the parallax and the proper motion vector for the secondary star, the results were inconclusive. Through this experience, the students learned the skills needed to observe, analyze, and report on double stars.

Introduction

In the spring of 2011 Jolyon Johnson led an astronomy research seminar of fourteen enthusiastic students from Chico Senior High School, California. The seminar was offered through the Gateway Science Museum at California State University, Chico, and focused on the study of visual double stars. It followed a model developed at Cuesta College in San Luis Obispo, California and the University of Oregon's Pine Mountain Observatory (Johnson 2007, Genet et al. 2010a, Genet et al. 2010b).

The goals of the seminar were both scientific and educational. The scientific goals were to: 1) contribute observations to the Washington Double Star (WDS) catalog, and 2) determine whether or not this double star is likely a chance optical line-of-sight

Figure 1: Students gathered at the Gateway Science Museum on the evening of May 1, 2011 to observe the double star STF 1657 with a Celestron NexStar 6 SE telescope and a Celestron MicroGuide eyepiece.

double or a binary star bound by gravity. The educational goals were to: 1) gain a better understanding of astronomy through hands-on experience, 2) learn and apply a method for measuring the separation and position angle of a double star, and 3) learn the process for analyzing data and writing and editing a scientific paper.

Methods

The students searched the WDS catalog to identify observable stars based on their magnitude and separation. The stars had to be bright enough and far enough apart to observe in a 6-inch telescope and bright city skies. The visual double star STF 1657 fit the criteria with a primary magnitude of 5.1, a secondary magnitude of 6.3, and separation of 19.9 arc seconds (Mason 2008). Observations were made on May 1, 2011 (B2011.353) with a Celestron NexStar 6 SE telescope and a 12.5 mm illuminated Celestron Micro Guide eyepiece.

Several past seminars have used the same telescope and eyepiece as the present study to observe double stars. The scale constants they derived were averaged and used in the present study. Table 1 shows the three scale constants used, their average, standard deviation, and standard error of the mean. The mean error of 0.1”/div is significantly less than the mean observational error.

The separation of the two stars was estimated to the nearest 0.1 division on the linear scale (Teague 2004). Each student noted at least one observation and whispered it to a designated recorder so others could not hear, thus preventing bias. A total of 12 measurements were made. Three outliers were excluded from the mean because they were more than three times the standard deviation from the average. These outliers were due to the stars drifting away from the linear scale because of polar misalignment. The mean distance in divisions was multiplied by the scale constant of 12.3 arc seconds per division to convert the measured value into arc seconds. The students then calculated the standard deviation and standard error of the mean of this separation.

The drift method was used to measure the position angle between celestial north and the secondary star with the primary star at the vertex (Teague 2004). First the primary star was centered at the midpoint of the linear scale and the eyepiece was rotated until the secondary star was between the parallel lines of the scale. The RA motor was then disabled and the stars drifted toward the outer protractor. Where the primary star crossed the protractor was noted to the nearest degree and secretly told to the recorder to avoid bias. A 90° position angle correction was added to the measurements as is required for the Celestron MicroGuide eyepiece (Teague 2004). A total of 10 measurements were made and their average, standard deviation, and standard error of the mean were calculated with one outlier rejected because it was more than three times the standard deviation. The outlier was precisely 20° off and likely the result of misreading major divisions.

Observational Results

Table 2 shows the results of the separation and position angle measurements including the averages, standard deviations, standard errors of the mean, and the average of three catalog values, the first and last from the WDS Catalog and one from Eagle Creek Observatory (Mason 2008 and Muenzler 2003).

The difference between the observed and average catalog separation value of 1.8” is higher than would be expected—four times the standard error of the

Table 1: The measured scale constants of past research seminars using the NextStar 6 SE and Celestron Microguide eyepiece used in the present study.

	Scale constant (arc seconds per division)
Baxter et al. 2011	12.2
Brashear et al. 2011a	12.5
Brashear et al. 2011b	12.2
Average	12.3
St. Dev.	0.2
Mean Err.	0.1

Table 2: The averages, standard deviations, and standard errors of the mean for the separation and position angle compared to catalog values.

	Separation		Position Angle	
	Observed	Catalog	Observed	Catalog
Average	22.1″	20.3″	273.4°	272°
St. Dev.	1.2″	0.4″	0.5°	1.7°
Mean Err.	0.4″	0.2″	0.2°	1.0°

mean of 0.4”. The maximum for the catalog values is still 0.2” different from the minimum observed value. If the minimum scale constant of 12.2”/div is used, the average separation is 22.0”. This is still four times the standard error of the mean away from the average of catalog values. The authors attribute the difference primarily to polar misalignment (which caused the stars to drift away from the linear scale) or other systematic errors.

The observed position angle was also significantly different from the average catalog value. The difference of 1.4° is 7 times the standard error of the mean of 0.2°. However, there is overlap between the maximum catalog values and minimum observed value. The difference may have been caused by an imprecise alignment of the stars on the linear scale.

System Analysis

The students referenced the SIMBAD (2011) database to determine whether or not the stars could be a gravitationally bound binary. The pair of stars selected has the WDS designation of STF 1657, which corresponds to HD 109511 and HD 109510 for the primary and secondary stars, respectively. To determine if it is possible that the two stars are bound by gravity, we first compared the spectral types and apparent magnitudes of the two stars. The primary star is spectral type K2III and has a primary magnitude of 5.11, making it likely to be a red giant. The secondary star is on the main sequence with spectral type A9V at magnitude 6.33. It is difficult to estimate how bright a red giant should be compared to an intrinsically bright main sequence star, so a more quantitative analysis had to be made.

The group then attempted to calculate the actual distance to the two stars from Earth based on their respective trigonometric parallaxes. The distance in light years can be calculated as the inverse of the parallax in arc seconds multiplied by 3.26 (the number of light years in one parsec). The parallax of the primary star is 0.00531 arc seconds which corresponds to a distance of 614 light years. The parallax of the secondary star is 0.00124 arc seconds which corresponds to a distance of 2,629 light years. While this would certainly suggest the stars are not bound by gravity, the error statement of the secondary star's parallax is 0.00991 arc seconds. The secondary star could be infinitely far away (since there cannot be a negative parallax the minimum value is 0.0 arc seconds) or as close as 292 light years. This range of values makes the calculated distance unreliable. Therefore, we could not use the distance estimates to determine the likelihood that the stars are bound by gravity.

Finally, the students analyzed the proper motion vectors of the two stars to determine if they are traveling through space in approximately the same direction. Most binary star components have proper motion vectors within 10% of each other (Arnold 2010). Table 3 shows the proper motion vectors of the two stars of STF 1657.

While the vectors appear different, the errors for the secondary star are very large, 25.11 milliarcseconds per year (mas/yr) in RA and 15.97 mas/yr in dec. Thus the secondary star could be traveling as slow as -0.29 mas/yr in RA and as high as 28.75 mas/yr in dec. Additionally, the error in RA for the primary star is 2.12 mas/yr giving a maximum value of -2.46 mas/yr. With the errors taken into account, the two stars can be shown to travel essentially in the same direction through space. Yet, this can only be done with the extremes of the uncertainties, making it possible, though unlikely, that the stars are moving in the same direction.

Table 3: Proper motion vectors for the primary and secondary stars

	RA (mas/yr)	Dec (mas/yr)
HD 109511	-4.58	23.30
HD 109510	24.82	12.78

Conclusions

Due to the large error margins reported for the trigonometric parallax and proper motion vectors in the SIMBAD database for HD 109510, it is uncertain whether or not the system is bound by gravity. More precise parallax and proper motion vectors may help determine if the stars do, in fact, orbit one another. If this is proven, continued research may yield the semi-major axis, orbital period, and stellar masses. Though it could not be determined if the system was binary, the seminar proved a valuable learning experience.

The students also learned some frustrations associated with astronomical observing. For example, the prime observing time happened to be the evening before a full moon so a new observing night had to be scheduled. This second evening was found to be cloudy in local weather forecasts. Thus, the observing night had to be on a school night in May when astronomical twilight did not occur until approximately 9:00 and everyone had to leave by 10:00. Observations had to be limited to just the double star unlike previous seminars that also determined the scale constant for the linear scale. Once sufficient separation and position angle measurements were taken, observing time was over. The students are hopeful that the separation and position angle values they determined may be added to the WDS catalog and used by future researchers if STF 1657 proves to be binary.

On the evening of observations, the students learned how to polar align the NexStar 6 SE, apply the astrometric vocabulary they learned during the seminar, and avoid potential research biases. The following meetings taught students how to turn simple measurements into meaningful data by using basic statistics. Finally, the students learned the tools astronomers use to identify binary stars and compiled the information into a research paper. Such skills are invaluable to high school and undergraduate students headed for careers in science.

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