Astrometric Observations of Double Stars Using Altimira Observatory

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Abstract Binary stars, distant pairs of gravitationally bound stars, can only be distinguished from optical double stars through calculations defining the movement of the two stars. This paper reports several double star measurements, which will contribute to determining whether the target pairs are gravitationally bound or not. Three high school students from Crean Lutheran High School observed and analyzed the double stars HJ 372, POU 1019, and DOO 35. Team members made observations, recorded separations and position angles, and compared them to previous data.

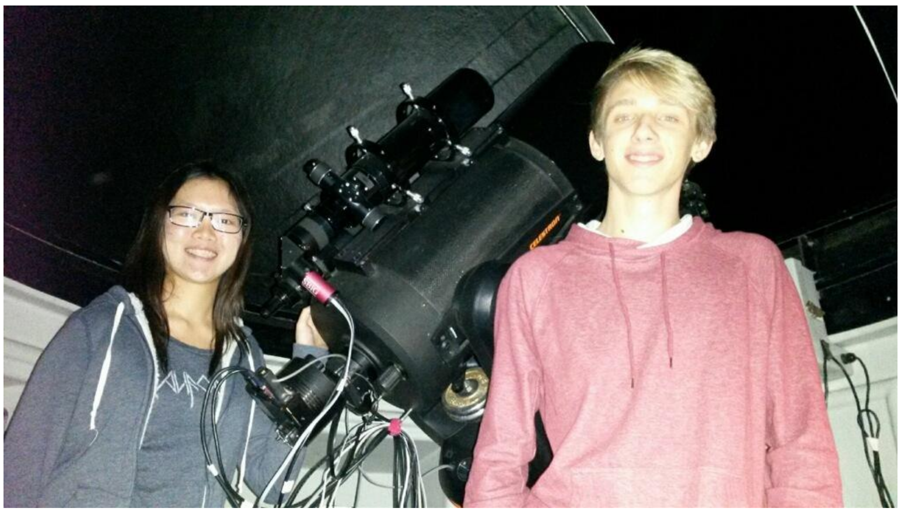

Figure 1: Crean Lutheran High School students, Sherry Liang (left) and Lucas Senkbeil (right), at Altimira Observatory in Coto de Caza, California.

Introduction

Under the guidance of professional astronomer Buchheim, a group of three students from Crean Lutheran High School in Irvine, California, were involved in a binary star research project. These students, Sherry Liang, Lucas Senkbeil, and Karthik Nair, completed their project as part of the Astronomy Research Seminar offered to high school students through Cuesta College. The four main objectives for our project were: 1. Learn how to use a CCD camera to collect photographic evidence; 2. Reduce the raw data and complete a statistical analysis; 3. Learn how to use advanced software to calculate the separations and position angles of double stars based on CCD camera images; and 4. Compare the calculated data to past observations. Figure 1 shows two students preparing to make observations.

Methods

Observations were made from Altimira Observatory in Coto de Caza, California. The observatory's 11-inch NexStar telescope was used for all observations. TheSky (Software Bisque) was used to control the observatory, and CCDSoft (Software Bisque) was used to obtain the images. The observations were taken by two groups of students with the first group making observations between 7 p.m. and 10 p.m. on March

7th, 2015. The second group made observations on March 27th, 2015 between 8 p.m. and 11 p.m. Along with the observations of the designated double star pairs, two calibration pairs were recorded each night. Figure 2 shows a student collecting data with Buchheim.

During data reduction, a dark frame (picture taken under same exposure time with the shutter closed) and a bias frame (picture taken with zero exposure) were subtracted from a raw science frame. This eliminates electronic noise. The revised image was then divided by a flat image (picture with uniform brightness). This reduced the difference of brightness of the center and the edges caused by the three-dimensional geometric shape of the CCD. The calibration pairs were used to ensure the information collected from the target stars was correct. Images were then analyzed using the program Reduc.

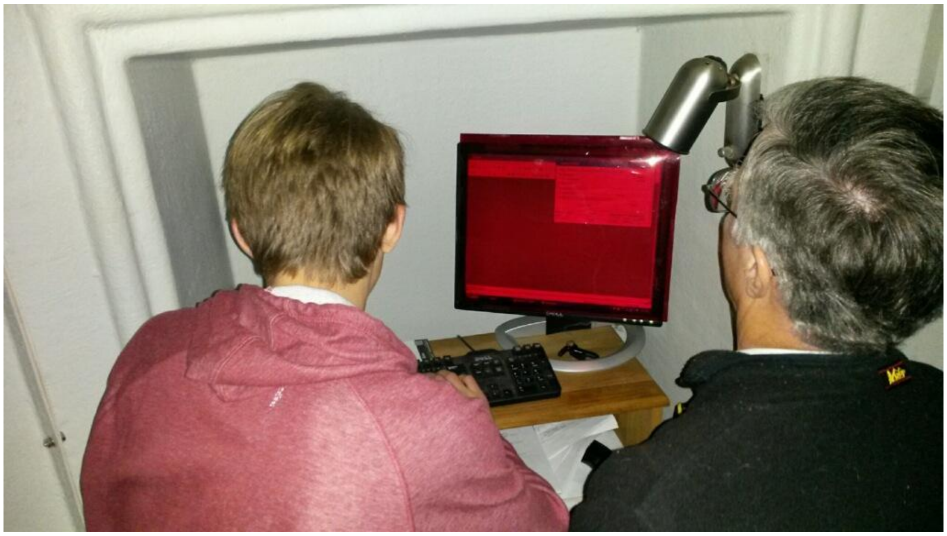

Figure 2: Lucas Senkbeil (left) collecting images of double stars with Buchheim (right).

HJ 372 Results and Analysis

Table 1 shows the data collected for the target star HJ 372 and the ephemeris of the calibration star STF 859 AB compared to its measured separation and position angle. The measured values of the calibration star are within one standard deviation of the ephemeris. Exposure length was 180 seconds for each image. The standard deviations are shown for separation and position angle. The position angle for HJ 372 was measured as 204.27° and the separation was measured as 15.91″.

Target	Date	Sep	St. Dev.	PA	St. Dev.
STF 859 AB	2015 Ephemeris	45.27”	1.11”	242.0°	1.20°
STF 859 AB	2015.237	45.16”	0.05”	242.0°	0.06°
HJ 372	2015.237	15.91”	0.08”	204.3°	0.12°

Table 1: Separations and position angles of the calibration star STF 859 AB (including ephemeris and measured values) and the target star HJ 372.

Figure 3 shows the complete history of measurements of HJ 372, from 1827 through this paper (the measurement reported here is highlighted in gray). Two of the data points (the original in 1827 and the other in 1951) are discordant. The remaining measurements (including the one reported here) indicate a slow relative motion of the two stars. There is not enough data to conclude that the motion of these two stars is related to an orbital pattern.

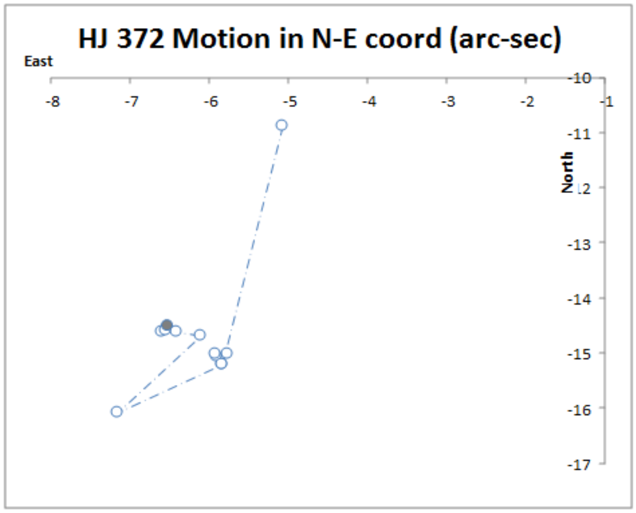

Figure 3: Historical Measurements of HJ 372. There is not enough data to draw conclusions on the physical nature of the double star.

POU 1019 Results and Analysis

POU 1019 is located in a field with many other double stars in a range of intensities. Figure 4 shows the locations of each double star in the star field. The image scale was 0.656″/pixel and the field rotation was 3.36°. Table 2 shows the measured separations and position angles for each pair of double stars as well as their standard deviations. All exposures were 180 seconds and the images were taken on 2015.182.

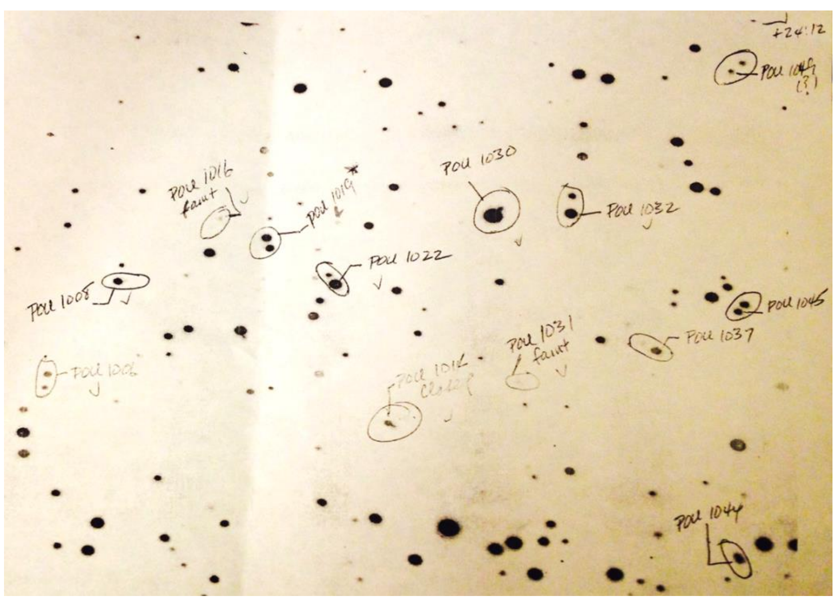

Figure 4: Field of POU 1019.

Target	Sep	St. Dev.	PA	St. Dev.
POU 1019	13.009″	0.079″	12.8°	0.60°
POU 1022	12.224″	0.065″	207.8°	0.16°
POU 1030	10.538″	0.065″	134.5°	0.45°
POU 1032	19.368″	0.114″	172.8°	0.14°
POU 1008	8.452″	0.198″	93.3°	0.94°
POU 1016	13.870″	0.085″	322.8°	0.40°
POU 1024	6.559″	0.460″	53.8°	4.07°
POU 1031	10.342″	0.134″	67.9°	0.77°
POU 1006 AB	14.899″	0.053″	349.7°	0.23°
POU 1037	13.465″	0.119″	233.5°	0.28°

Table 2: Separations and position angles of POU 1019 and some nearby double stars.

The last measurement for POU 1019, recorded in the Washington Double Star Catalog (WDS) in 2009, had a separation of 13.1” and a position angle of 13°. The measurements made in the present study are within two standard deviations of 2009. Future observations will determine the significance of this difference. The values of nearby stars match closely with recent measurements reported in the WDS.

DOO 35 Identification

The confirmed binary star pair STF 859 AB was measured to provide calibration. After the calibration images were taken, we observed DOO 35. However, Figure 5 shows only a single star at the reported position in the WDS. An astrometric fit of this image (using MPO Canopus) confirmed the celestial coordinates of the field of this image. We didn’t make accurate photometric assessment of the star at the center of this image, but it is very bright in this 30 second exposure. A comparison with our photometry of DOO 35 puts it at about magnitude 7.5. This star appears to be single at the resolution of our images (0.65″/pixel, seeing FWHM ≈3″). So, based on the significant brightness difference and the absence of a plausible double star, the WDS coordinates may not point to DOO 35.

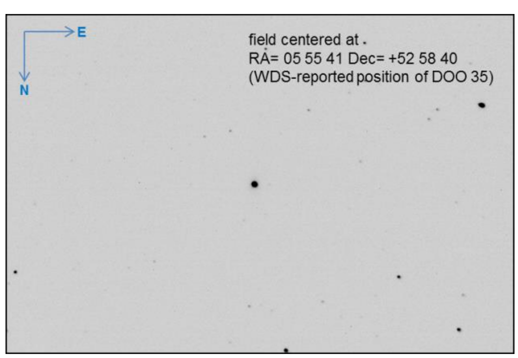

Figure 5: Image of the star given at the coordinates for DOO 35 (FOV≈ 11.3 X 17′).

The WDS identifies DOO 35 with star BD+52 1012 (from Bonner Durchmusterung) and gives its precise J2000 coordinates as 05h 55m 41.23s +52° 58m 40.3s. The Vizier database reports BD+52 1012 as a 9.3 magnitude star and gives the precessed coordinates 05h 56m 03.9s +52° 50m 16s. Note that this position is about 8′ south of the WDS coordinates given for DOO 35. Our image of the location of BD+52 1012 is shown in Figure 6. It displays a cleanly-separated, nearly-equal-brightness pair that matches the description of DOO 35. This is the pair whose separation and position angle we report for DOO 35.

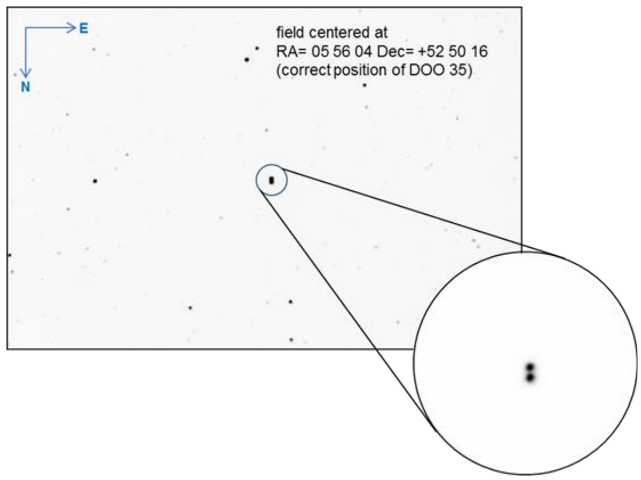

Figure 6: Image of the location of BD+52 1012.

The image shown is a 180-second V-band CCD exposure, illustrating that the pair is significantly fainter than the bright star at the (probably erroneous) WDS precise coordinates given for DOO 35. Photometric analysis of our images, based on comparison star V-magnitudes from APASS stars in the field, put the two components at 10.7 and 10.8 respectively ±0.07, with the northern star being the brighter. The delta-magnitude of 0.1 matches the Third Photometric Magnitude Difference Catalog entry for DOO 35. We also note that this pair is listed as two stars in the UCAC3 catalog, separated by 6.1″ in declination (which is a reasonable match to our astrometry). We believe:

- the identification of DOO 35 with BD+52 1012 is correct
- the WDS J2000 coordinates for DOO 35 are in error
- the correct J2000 coordinates for the primary star are: 05h 56m 03.9s +52° 50m 16s
- DOO 35 is the pair that we imaged at this location.

DOO 35 Results and Analysis

Table 3 (below) shows the measurements of the calibration star STF 859 AB and the target star DOO 35. The history of measurements, including the present study, of DOO 35 is shown in Figure 7.

Two position angles are discordant by nearly 180° with past observations. As shown in Figure 8, the magnitudes are both approximately 9. In the present study, the northern star was assumed to be the primary. If the two discordant measurements assumed the almost identically bright southern star was the primary, the measurement of position angle would be reversed about 180°. These changes are shown at right in Figure 7 (below)

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Target	Date	Sep	St. Dev.	PA	St. Dev.
STF 859 AB	2015 ephemeris	45.272		242.0	
STF 859 AB	2015.182	45.193	0.094	241.8	0.05
DOO 35	2015.182	6.133	0.095	177.8	1.03

Table 3: Measurements of position angle and separation of STF-859 and DOO 35.

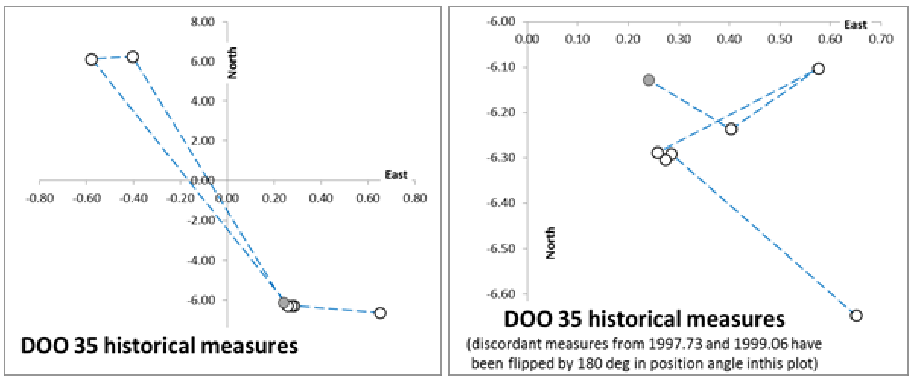

Figure 7: Historical measures of DOO 35. Left: Two discordant measures of position angle are left unaltered. Right: Two discordant measures have been given a 180° correction.

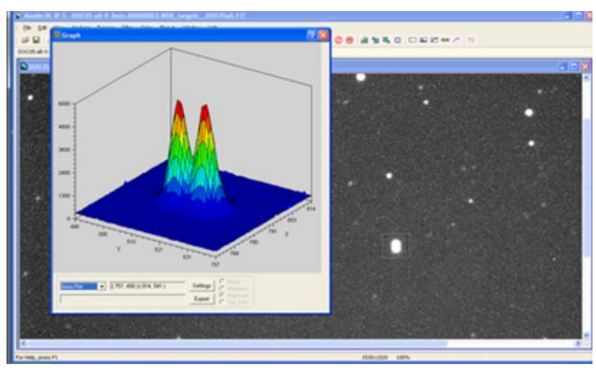

Figure 8: The intensity map of DOO 35 shows that the primary and secondary stars are nearly identical in brightness.

Even with the 180° correction, it is not clear how to interpret the relative motion of this pair. Between the initial measurement in 1897 and 2015, the change in separation is 0.567″ and the change in position angle is 3.75°. These minute changes over the course of 118 years indicate no significant change in either separation or position angle, making it difficult to determine if the two stars are gravitationally bound or not. Future observations may allow characterization of DOO 35.

Conclusions

Based on the analysis of each double star, it is reasonable to conclude that more data from periodic monitoring will be necessary to determine whether the measured pairs are gravitationally bound. In addition, DOO 35 is located at 05h 56m 03.9s +52° 50m 16s.

This project met all four goals described in the introduction. The students successfully used a CCD camera to collect photographic evidence and reduced raw data to complete a statistical analysis. The students learned how to use advanced software (CCDSoft, MPO Canopus, Reduc, and TheSky) to calculate the separations and position angles of double stars. Finally, the students compared their measurements to past observations.

Acknowledgements

This research has made use of the Washington Double Star Catalog as well as the VizieR catalogue access tool and the AAVSO Photometric All-Sky Survey. The students thank Altamira Observatory for the use of their facilities. The students thank Dr. Russell Genet for organizing the Cuesta College astronomy research seminar and making it available for high school students.

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