# Observations of Selected Double Star Systems Using CCD Astrometry, Lucky Imaging, and Speckle Interferometry

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**Abstract**: In August 2013, a team of six undergraduate students were selected for a two week research program, *Consortium for Undergraduate Research and Education in Astronomy (CUREA)*, at the Mount Wilson Observatory-California. Each student completed a project related to observational astronomy and a joint project was done by Ariyawansa and Troville on measuring double stars. In this project, three different methods were used to measure the angular separation and the position angle of the double stars. CCD astrometry was the first method used to measure the star system WDS17574+3540, which has been identified as a quadruple system. Lucky imaging and speckle interferometry were the other methods used to measure the systems δ Cyg, ε1 Lyr, ε2 Lyr, and WDS23595+3343 with reduction using the REDUC software package.

## Introduction

In the summer of 2013, the CUREA program was held at the Mount Wilson observatory (situated at N $34^0$ 13' 25.53", W $118^0$ 3' 41.92") with the participation of six undergraduate students, expanding their knowledge on CCD image processing, spectrometry, and other principles of observational astronomy. Two students, Ashan Ariyawansa, representing the University of Colombo - Sri Lanka, and Jonathan Troville, representing Purdue University, jointly worked on a double star project which focused on measuring the separation and the position angle of five selected star systems.

Three methods were used in this task. The first one was CCD astrometry, where the students took CCD images of double star systems. This method is appropriate for wide pairs. Afterwards they observed three different double star systems which had smaller separations than the first two. For those they used two different methods, lucky imaging and speckle interferometry. Both methods comprised taking around a hundred images of each system with a very short exposure time (15 -500ms) and analyzing them with the REDUC software. The main objectives of this project were to provide students a hands-on experience with observational techniques used in astronomy and contributing observational data to the Washington Double Star catalog (WDS).

## Observations and Instrumentation

The students chose a set of double stars to be measured based on the magnitudes, separations, and zenith distances at the time of observations. It was found that the ideal range of RA and Dec were from 17h to 22h and from $+4^0$ to $+64^0$ respectively. Observations were made on August 6 and 8, 2013 at Mount Wilson Observatory, using a Meade LX600 SCT. In the first night, the students imaged WDS17574+3540 with a CCD

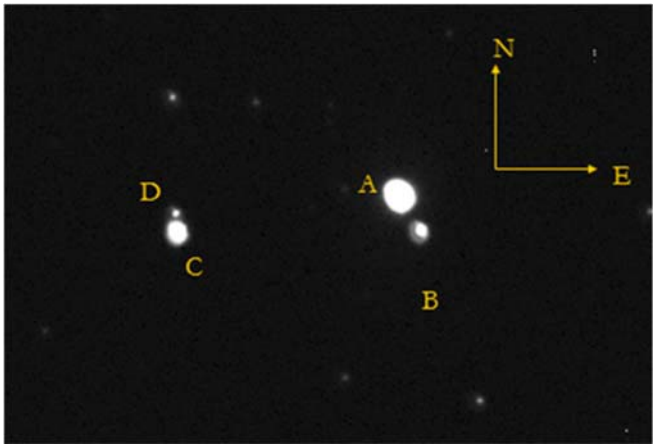


*Figure 1: WDS17574+3540 System*

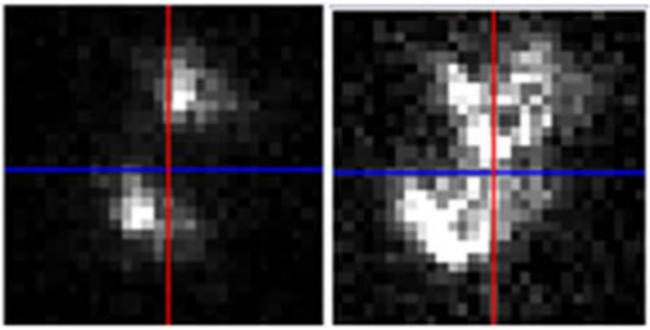

*Figure 2: Lucky image (left) and unlucky image*

camera attached to the 16" Meade SCT. Images were taken with 60 s and 30 s exposure times and ENVISAGE software was used in this task. Also, dark and flat frames were taken with the same exposure times. In order to calculate field rotation, a series of images of a bright star near the observed system was taken with an exposure time of 1 second. This was done after positioning the star in the east end of the frame and disengaging the tracking. Field rotation calculation was very important because the position angle would have been erroneous without this correction. WDS17574+3540 was an interesting system consisting of four distinctly identifiable members (labeled as A, B, C, and D in Figure 1).

On August 8, using a *DSI-III* high speed CCD camera, sets of images with short exposure times were taken of the systems WDS23595+3343 (15 ms), *δ Cyg* (22ms), *ε1 Lyr* (15ms), and *ε2 Lyr* (15ms). The reason for taking very short exposures was that the observed doubles were bright pairs. Each image set consisted of about 100 images. All of the observed systems happened to lie within $20^o$ range about the zenith, providing better seeing.

## Results and Analysis

Plate scales of both nights were calculated by matching some of the known stars within the field of an image with those in "The Sky" planetarium software package. Images were analyzed using MAXIM DL software. Once an image was edited to get the optimum view, it was copied and pasted on "The Sky" window and then the view was scaled to fit the image. Then the true angular distance between two stars was measured using "The Sky", and the number of pixels between the same stars were found using MAXIM. Thereafter the plate scales were calculated and they were 0.38 arcsec/pixel on the first night and 0.21 arcsec/pixel on the second night. Field rotation was calculated using the drift image method and were found to be $0.28^o$ and $0.21^o$ on first and second nights respectively. Measured separations and position angles of the stars of the WDS17574+3540 system are shown in Table 1.

The next observation session was reserved for observing close pairs and a *DSI-III* CCD camera was used in this task. The first technique used was lucky imaging. Aj total of 106 short exposure (15 ms) images of the WDS23595+3343 system were taken along with drift images and were analyzed using the REDUC software package. REDUC had some interesting features to select and analyze the best images which were less blurry and "lucky". The images in Figure 2 show examples of a "lucky" and an "unlucky" image.

Also, it was a handy tool for finding the position angle by selecting the primary and secondary stars manually and using the *'AutoReduc'* command. Field rotation was found by loading the drift images into REDUC and using the *'Drift Analysis'* option. Results obtained for this star system are also given in Table 1.

The next analysis method was speckle interferometry. *δ Cyg*, *ε1 Lyr*, and *ε2 Lyr* were imaged using this technique. Around 100 very short exposure images of each star system were taken and the best 10% of these images were selected using REDUC and analyzed to obtain autocorrelograms. Finally, the separations and position angles were found by left clicking on the primary star and right clicking on the secondary star in the autocorrelogram. (Since there is an $180^0$ ambiguity of the position angle inherent with autocorrelation, best images of the original set were observed to check whether the two stars can be seen barely separated in at least one image. Thus, the ambiguity could be re-

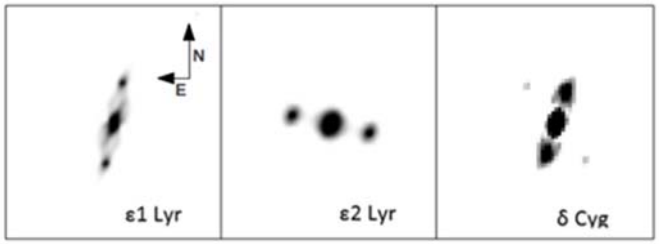


*Figure 3: Autocorrelograms Obtained with "REDUC"*

solved). Figure 3 shows the REDUC outputs of the double stars and their separations, and position angle values are given in Table 1.

## Conclusion

In this project, the authors observed and analyzed more double stars than any other previous CUREA students. It was a great experience for them as well as for the instructors because three different methods were used in analyzing the observations. Also the students learned about the difficulties and challenges that they have to face during night time observations such as auto guiding problems, imaging difficulties, and instrumentation issues.

## Acknowledgements

This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory. Also Paula Turner, Mike Simmons, Bob Buchheim, John Hoot, and Tom Meneghini are acknowledged here for their effort in making the CUREA program an invaluable experience for the undergraduate students.

## References

Buchheim, Bob. 2012. "CCD Camera Observations in Observing and Measuring Visual Double Stars", ed. Bob Argyle. New York: Springer.

Washington Double Star Catalog, US Naval Observatory. http://ad.usno.navy.mil/wds/

*Table 1: Measurements made in both nights*

| NAME | RA+DEC | PA | SEP | DATE | N |
|---|---|---|---|---|---|
| WAL86AB | 17574+3540 | 151.0 | 22.46 | 2013.5973 | 1 |
| WAL86AC | 17574+3540 | 260.1 | 121.58 | 2013.5973 | 1 |
| WAL86CD | 17574+3540 | 353.8 | 10.06 | 2013.5973 | 1 |
| STF3050AB | 23595+3343 | 327.3 | 2.05 | 2013.0627 | 1 |
| δCyg | 19450+4508 | 219.2 | 2.88 | 2013.6027 | 1 |
| ε1Lyr | 18443+3940 | 344.2 | 2.34 | 2013.6027 | 1 |
| ε2Lyr | 18443+3940 | 79.2 | 2.48 | 2013.6027 | 1 |