Double Star Research with Speckle Interferometry

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Abstract Six double stars were recorded and analyzed using speckle interferometry. Results were generally in accordance with previous observations provided by the Washington Double Star Catalog.

Introduction

Observations were made by several students (Figure 1) on two separate dates, the first on Saturday, August 31, 2013 (B2013.665), a still, cloudless night. This run gathered data on five stars: STF2404, STF 2492AB, STF2613AB, STF2725AB, and STF2978. The second run was conducted on Friday, September 13, 2013 (B2013.700), also a still, cloudless night, where data was gathered on STF2848 and STF2727AB. Through these observations and the experiences that they offered, new students were provided an introduction to double star research and the recording of scientific data, and experience in the process of writing and publishing research papers.

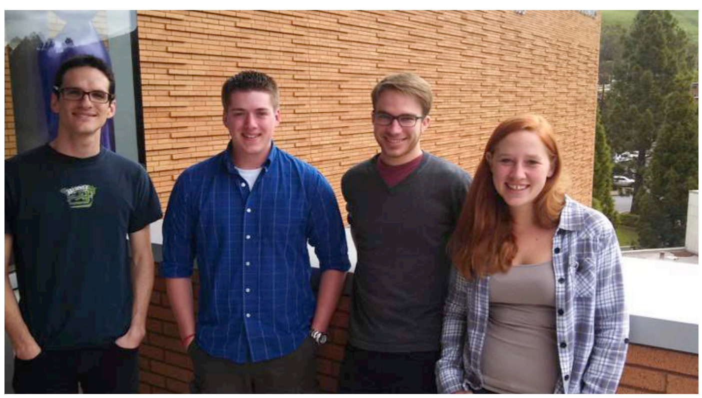

Figure 1. Cal Poly students left to right:
Jason Goad, Cameron Allen, Ryan Morshead, and Kaitlin McArdle.

Equipment

For observations, a 10 inch f/10 Meade Schmidt-Cassegrain equatorially mounted telescope was used with a x5 Barlow lens, yielding a 500 inch effective focal length. This telescope is the primary instrument used at the Orion Observatory in Santa Margarita, CA. The control system was made by Sidereal Technology (SciTech) based in Portland, Oregon. The SciTech control system was interfaced with TheSky6 for quick slewing to stars.

The equipment used for our speckle observations was a camera and optical system designed for portability and use on a wide range of telescopes (Genet et al. 2013). In the past, this system had been taken to a variety of telescopes, including the Pinto Valley Observatory's 0.5 meter and to the Kitt Peak National Observatory's 2.1 meter telescopes. At the heart of this portable speckle imaging system is an Andor Luca-S front illuminated EMCCD camera.

This camera has a 658x496 pixel CCD chip with 10 micron square pixels. Andor's electron multiplication system allows for very fast exposures to be taken at a very high signal to noise ratio. The optical system also included a slide mirror which allowed a wide-field CCD acquisition camera to be attached. We used an SBIG 402. The slider was modified by Reed and Chris Estrada, who attached a linear stepper motor, allowing the mirror to be moved with no external torque being applied to the telescope.

The last piece of equipment on the portable speckle system is a Nautilus Controller filter wheel. This motorized wheel has seven removable filter positions. In our system we had Cousins R, I, B, and V, Sloan R and V, and a narrow-band Hα filter. For our observations we used the Cousins R filter to observe double stars and drift calibrations, and we used the Hα filter for slit mask calibrations (Figure 2).

Methods

All integration times in this experiment were 15 milliseconds and stored in .fits format. Our data was analyzed using REDUC, a software developed by the French double star observer Florent Losse. The data acquisition and analysis were accomplished using the built-in functions in this software.

At the beginning of our run we calibrated the camera using Altair. First we took seven 2,000 frames using a slit mask and a Hα filter. For the first three of these, the slit mask was not rotated, but the last four we rotated the mask by an arbitrary angle to mitigate any systematic bias introduced by having only one mask orientation. The angular distance from the central to first order diffraction peaks was found to be z = 7.914 arc seconds by the formula:

$$\frac{206{,}265\lambda}{d}$$

(Maurer 2012), where λ is the central wavelength of the Hα filter (656.281 nanometers) and d is the spacing between the centers of the slits (17.1 millimeters). Using z, we found the pixel scale to be 0.2537±0.0010 arc seconds per pixel.

We then did five drifts using Altair and a Cousins R filter. The drift integration times were 15 milliseconds long and took 250 frames to cross the entire field of view. Using the "Synthetic Drift" feature in REDUC, we found our camera angle to be -3.35 degrees, with a standard deviation of 0.19 degrees. A total of five drifts were taken with Altair.

For observing our target stars, we used the Cousins R filter. Six runs of 2,000 images each were taken for each double star system (seven runs were done for STF2725AB). Each of these runs was then analyzed using the "Autocorrelation" function in REDUC. This function runs each image through a series of ten distinct Fast Fourier Transforms (FFT) to produce ten 'masks' (S0-S9) that compress the frames into a single image with varying contrasts (Figure 3). From this image, we reduce the data by selecting our points, and after inputting our pixel scale (E) and camera angle (Δ), we found our position angle (Θ) and separation (ρ). There is a 180° ambiguity in the position angle measurement when using autocorrelation. To resolve the issue, we compared our position angles to recent measurements catalogued in the Washington Double Star Catalog, and chose the value that agreed with recent measurements. Due to the slow-moving nature of the observed systems, rapidly changing position angles were not an issue.

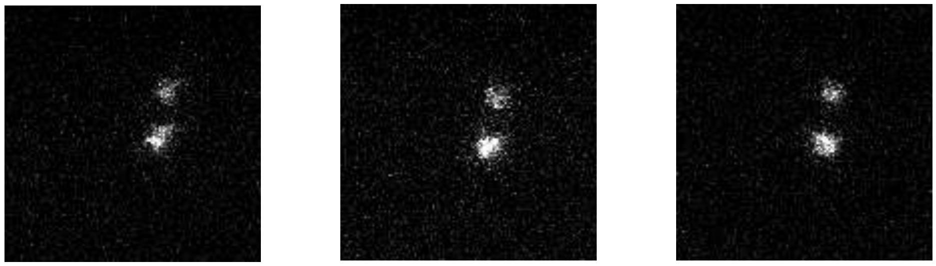

Figure 2. Three of 2000 initial frames of STF2725 showing the "speckles" that are present before undergoing speckle interferometry.

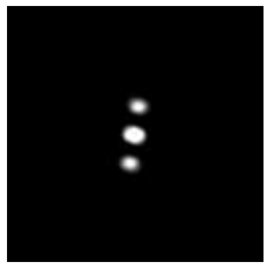

Figure 3. Autocorrelogram image of STF2613.

Data

One auxiliary goal of this project was to provide the observers with an estimate of the limits of speckle interferometry and, specifically, of the limitations of our equipment. To this end we allowed STF 2492AB to remain on our observing list, even though it has a delta magnitude of 3. Normally such egregious stars would be overlooked. When we reduced the data on this star, only two of our six observations yielded any measurable results. Because we could not do any statistical analysis with only two data points, we did not report the position angle and separation for this star (Table 1).

In addition, when looking at the WDS data for STF2727AB, we averaged the last ten data points, excluding two that had position angles that were off by 2-3 standard deviations where the average was inclusive, and between 15-16 standard deviations where the average was exclusive. The observations excluded were observed on 2012.8 and 2011.778.

	PA (°)	Sep. (")	Date	N	WDS PA (°)	WDS Sep. (")	Note
STF2404	180.745	3.639	B2013.665	6	181.34	3.407	a
STF2613AB	355.198	3.591	B2013.665	6	354.26	3.568	b
STF2725AB	11.670	6.153	B2013.665	7	10.82	6.059	c
STF2727AB	265.85	8.986	B2013.700	6	266.20	8.921	d
STF2848	123.750	10.894	B2013.700	6	123.99	10.839	e
STF2978	144.73	8.424	B2013.665	6	144.31	8.351	f

Table 1: Our data in left columns and average of the past ten observations reported to the WDS.

Notes: Standard deviations of our observations and the past ten observations in the WDS.
[a]Our Data: PA 0.22°; sep. 0.017" WDS: PA 1.50°; sep. 0.221"
[b]Our Data: PA 0.01°; sep. 0.001" WDS: PA 0.26°; sep. 0.111"
[c]Our Data: PA 0.01°; sep. 0.002" WDS: PA 0.29°; sep. 0.067"
[d]Our Data: PA 0.03°; sep. 0.019" WDS: PA 0.76°; sep. 0.114"
[e]Our Data: PA 0.04°; sep. 0.026" WDS: PA 0.40°; sep. 0.052"
[f]Our Data: PA 0.20°; sep. 0.201" WDS: PA 1.03°; sep. 0.193"

Analysis

We compared our data to the last ten measurements in the WDS provided by Brian Mason and William Hartkopf to see whether our measurements were similar or awry. The reason for utilizing only ten measurements as opposed to linear trends or larger data sets is because the stars themselves are slower moving and the previous ten measurements are from recent years. This provides a stable subset of data that we could compare against, which would not be possible if the star was moving much faster or erratically.

For STF2404, the average separation in the last 10 recorded measurements was calculated to be 3.407", while we recorded an average of 3.639". Given the WDS standard deviation of 0.221", our measurements are just over one standard deviation of difference. When comparing the position angles, the WDS average is 181.34° ± 1.5°, while our measurements show a position angle of 180.75°, which is well within one standard deviation. Overall, our recorded data is in agreement with previous observations.

For STF2613AB, the WDS reports an average separation of 3.57 ± 0.11", while our results average out to 3.59". Our separation is therefore within one standard deviation of the WDS values. For position angle, the WDS average is 354.26° ± 0.26° while our data shows the position angle to be 355.20°. Our recorded position angle is nearly 4 standard deviations off of the mean, and thus not in agreement with other recently recorded measurements. Because of this difference, we cannot say that our observations are in agreement with the WDS mean.

For STF2725AB, the WDS reports an average separation of 6.059 ± 0.067", while our results average out to 6.153". Our separation is just over one standard deviation away from the mean value. For position angle, the WDS average is 10.82° ± 0.29° while our data shows the position angle to be 11.67°. The discrepancy between our value and the WDS mean puts our position angle at just under 3 standard deviations off, and therefore is not in agreement with other recent measurements.

For STF2727AB, the WDS reports an average separation of 8.921 ± 0.114", while our results average out to 8.986". Our separation is therefore within one standard deviation of the WDS values, although on the far end. For position angle, the WDS average is 266.20° ± 0.76° while our data shows the position angle to be 265.85°. This too is within the standard deviation of the WDS mean, but again on the far end of the deviation. We can then say that our observations for this star system are in agreement with previous measurements.

For STF2848, the WDS reports an average separation of 10.839 ± 0.052", while our results average out to 10.892". Our separation is just barely over one standard deviation, differing by 26 ten-thousandths of an arc second. For position angle, the WDS average is 123.99° ± 0.40° while our data shows the position angle to be 123.75°. Our measured position angle is well within one standard deviation of the WDS average. Based on these differences, our observations can be said to be in agreement with previous values.

For STF2978, the WDS reports an average separation of 8.351 ± 0.193", while our results average out to 8.424". Our separation is therefore well within one standard deviation of the WDS values, and in agreement. For position angle, the WDS average is 144.31° ± 1.03° while our data shows the position angle to be 144.73°. Our data is well within the standard deviation of the WDS average, and thus also in agreement.

Conclusion

Overall, this research fulfilled its goal of introducing students to double star research, the use of speckle interferometry, and the process of writing and publishing a research paper.

Acknowledgments

We thank Russ Genet for the use of Orion Observatory and guidance over the course of the research. We also thank Brian Mason and William Hartkopf for providing past observations of the stars we observed. A final thanks to Vera Wallen, Mark Brewer, and Robert Buchheim who gave time to reviewed our paper.

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