Double Star Observations Conducted at the Fernbank Observatory

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Abstract: Thirty-two binary star pairs were observed and photographed at the Fernbank Science Center Observatory from June 19, 2009 to July 1, 2009. The telescope used was an 11" Cassegrain Reflector with a Cannon EOS 350-DSLR camera. The position angle and separation of each pair were measured and notes were made.

Introduction

For my research, and in the spirit of 2009 being The International Year of Astronomy, I collaborated with astronomers from the Georgia Institute of Technology, Georgia State University, Fernbank Science Center Observatory and the US Naval Observatory's Washington Double Star Catalog (WDS). Observations were conducted at the Fernbank Observatory in Atlanta, Georgia using their 11 inch Cassegrain Reflector atop the Observatory's 36 inch Cassegrain Reflector on a guided mount. The camera used was a Cannon EOS 350-DSLR with exposures of 3-30 seconds.

Methods

To begin the project, an observing list was requested from the Washington Double Star Catalog using the site's observing capabilities as search parameters. They were as follows: The portion of the sky observable from Fernbank during the summer, in R.A. and Dec., was determined using the location of the Observatory, Atlanta, GA, and the time and date ranges for possible observing nights, 9-12 p.m., May-July. The right ascension and declination limits were determined to be: R.A. 10hr 00min 00s to 16hr 00min 00s and Dec. -20° 00' 00" to + 90° 00' 00". Using a sample photograph taken at the Observatory with the EOS 350-DSLR camera, the observable magnitudes and separations were found to be: 15th magnitude and brighter and from 1 arc second to 800 arc seconds separations.

This list was reordered by hand with the most suitable pairs first. The coordinates of the binary star to be observed were input into the computerized mount, and the telescope then slewed to the system. The binary star was found and aligned in the telescope and then photographed. The exposure was varied, chosen by considering the system's magnitude and controlled by a remote camera shutter release trigger. For most systems, a 5-10 second exposure and a 20-30 second exposure were taken; however for particularly bright systems, with both magnitudes less than 8th, a 3-5 second exposure was also taken. On the 30 second-exposure photographs using this setup, stars down to 10th to 14th apparent magnitude were visible without being washed-out by the light pollution of Atlanta.

To determine the rotation angle for each photograph, the clock drive was turned off as the shutter was held open for 45 seconds. This stopped the telescope tracking; allowing the picture to capture the star trails over the 45 seconds that indicate the stars' observed movement in the sky as the Earth rotates. This method was used for each system to determine their respective rotation angle.

A substitute for turning off the clock drive was also tested during the project. The camera shutter

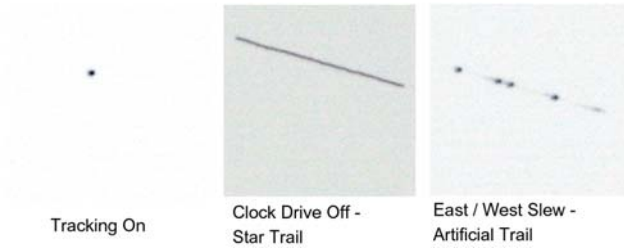

Figure 1: Shows the resulting star trails: clock drive on, clock drive off, slew

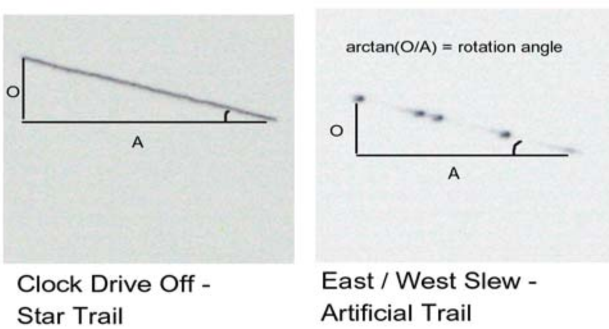

Figure 2: An illustration of finding the rotation angle using the pixel coordinates

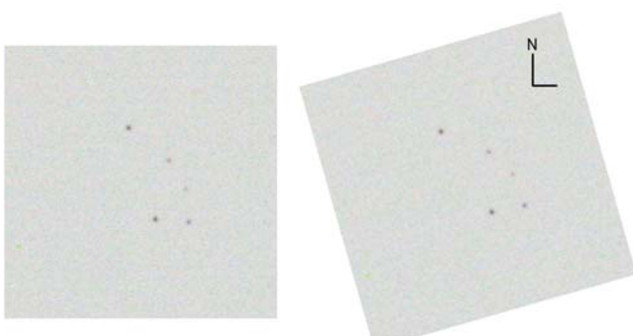

Figure 3: Shows the rotated photographs with Celestial North pointing upwards.

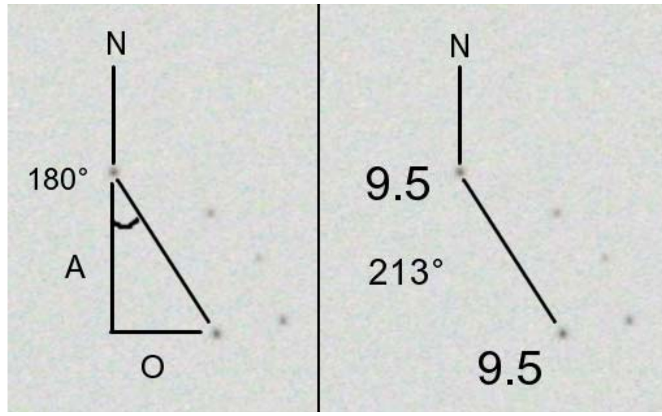

Figure 4: Figures used in finding the position angle.

was held open as the telescope was slewed to the East, creating artificial star trails. The accuracy of this method was compared to turning off the clock drive and it was discovered that this is a potentially accurate method, given the alignment of the telescope at the Fernbank Observatory. Results are detailed in Table 1 and the process is shown in Figures 1 and 2.

Using Arcsoft PhotoStudio 5.5 to view each photograph's pixel coordinates, each system's rotation angle to Celestial North was found and each photo was rotated by this angle. Shown in Figure 3.

Then, the position angle (θ) of the companion star to the primary and the North Celestial Pole for every pair visible in the photo was trigonometrically determined and plotted along with magnitudes on the system's best picture, usually the 20-30 second exposure image. The position angles were calculated by taking the difference in the pixel coordinates of the primary and the secondary stars for the horizontal and vertical axis and inputting these differences, one divided by the other, into the arctangent function and adding this to an offset angle, determined by quadrant location of the secondary. The order in which to divide them was determined by the added angle: 0, 90, 180 or 270. The determination of the PA for a binary pair is illustrated in Figure 4.

Table 1: Shows the calculated rotation angle for methods: slewing telescope and turning off telescope tracking. "Trail x/y-initial/final" are the pixel coordinates (x,y) of the beginning(initial) and end(final) of the star trail. The differences ("Delta-x/y") are divided and the arctangent of this is the Rotation Angle (RA). The RA by the two different methods disagree by 0.032 degrees (for the Fernbank Observatory).

	Trail x-initial	Trail x-final	Delta x = A	Trail y-initial	Trail y-final	Delta y = O	Pixel O/A	Rotation Angle (Degrees)
East/West Slew	2109	2309	200	1258	1315	57	0.285	15.908
Turning off Tracking	2719	3046	327	1315	1408	93	0.2844	15.876

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Table 2: Shows the calculated arcsecond/pixel ratio for the camera-telescope setup using standards: Albireo, Mizar A and B, and Epsilon Lyrae. The pixel coordinates (x,y) of the primary and secondary of each double star pair are used to calculate the pixel distance between stars and the known SA (Sep.) of the stars is divided by this to determine the arcsec to pixel ratio for the camera.

Double	Pixel x Primary	Pixel x Secondary	Δx= A	Pixel y Primary	Pixel y Secondary	Δy= O	a.s./Pix	Sep. (known)
Albireo	1536	1481	55	1219	1167	52	0.4663750	35.3
Mizar	1706	1722	16	1361	1333	28	0.4465250	14.4
ε Lyrae	2887	2949	62	1432	998	434	0.4767268	209
AVERAGE							0.46320897	

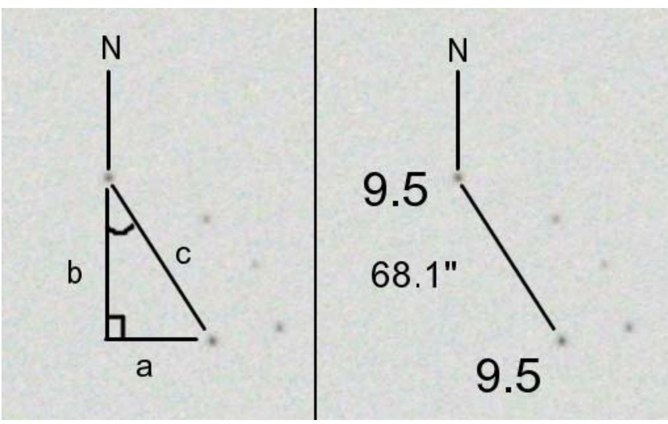

Figure 5: Illustration of finding the separation angle.

Before calculations began, the arcsecond to pixel ratio was determined by photographing binary star systems with known separations using the setup to be used for the project's binary star photos. The systems used as standards were: Albireo, Mizar A and B, and Epsilon Lyrae. The measurements for each system are detailed in Table 2.

The separation angle, ρ, of each pair of stars was also determined using the, trigonometrically determined, pixel separation and the arcsecond-to-pixel ratio of the picture. Using the horizontal and vertical pixel differences of the unrotated photos and the Pythagorean Theorem, the pixel separations were found for each pair. The pixel separations were then multiplied by the arcsecond to pixel ratio to yield the separation angle in arcseconds and this information was then recorded and plotted on each double's photograph. The process is illustrated in Figure 5.

Results

The results are detailed in Table 3 and its accompanying Figures 6 - 20 and notes. Thirty-two doubles were studied: 23 experienced small/no change in position angle and separation, 6 saw probable change in PA and Sep., and 3 were questionable. Seventeen of the thirty-two pairs were "neglected" doubles. Margin of error is ±2 degrees and ±5 arcseconds.

Acknowledgments

Thank you to Dr. James Sowell, Ph.D., Astronomer at Georgia Tech, for his mentoring when I had questions during the project.

Thank you to Dr. Ed Albin, Ph.D., head Astronomer at Fernbank Science Center for facilitating access to the Fernbank Science Center Observatory and advising me on astrophotography.

Thank you to Dr. John Wilson, Ph.D., Astronomy Laboratory Coordinator at Georgia State University, for teaching me the methods of double star observation and measurement.

Thank you to Dr. Brian D. Mason, Ph.D., head of the WDS, for helping me to compile an observing list and advising me on my final questions.

Table 3 starts on page 238.

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Table 3: Results of the double star observations from June 19, 25, and July 1, 2009. Names, RA/Dec and magnitudes are from the WDS Catalog.

Name	RA ± Dec	Mags	PA(θ)	Sep(ρ)	Date	N	Notes	Image
STTA108AB	11125+3549	6.48, 7.32	66.18	158.63	2009.468	24	1	Fig. 6
STTA108AC	11125+3549	6.48, 13.58	142.58	86.88	2009.468	5	2	Fig. 6
STF1540AC	11268+0301	6.55, 9.9	192.64	203.33	2009.468	4	3	Fig. 7
STF1540AB	11268+0301	6.55, 7.5	143.13	29.60	2009.468	3	4	Fig. 7
STFA 19AB	11279+0251	5.05, 7.47	180.60	87.74	2009.468	52	5	Fig. 8
STF2083AC	16427+1336	9.13, 9.1	191.14	118.45	2009.468	2	6	Fig. 9
STF2083AB	16427+1336	9.13, 9.56	334.36	13.68	2009.468	2	7	Fig. 9
STF1930AB	15193+0146	5.06, 10.11	34.29	12.03	2009.484	46	8	Fig.10
STF1930AC	15193+0146	5.06, 9.1	19.40	147.32	2009.484	6	9	Fig.10
STF1930AD	15193+0146	5.06,	274.63	713.63	2009.484	5	10	Fig.10
STF1561AD	11387+4507	6.53, 7.56	76.85	710.56	2009.484	3	11	Fig.11.1
STF1561AB	11387+4507	6.53, 8.23	248.75	8.90	2009.484	111	12	Fig.11.1
STF1561AC	11387+4507	6.53, 9.46	90.48	167.01	2009.484	23	13	Fig.11.1
STF1561AE	11387+4507	6.53, 12.08	337.25	60.74	2009.484	7	14	Fig.11.1
STF1561BC	11387+4507	8.23, 9.46	89.40	175.04	2009.484	18	15	Fig.11.2
STF1561BE	11387+4507	8.23, 12.08	345.45	61.75	2009.484	6	16	Fig.11.2
STF1561CD	11387+4507	9.46, 7.56	72.74	549.85	2009.484	4	17	Fig.11.2
KZA 51	13217+3403	8.5, 9.5	59.30	19.01	2009.484	3	18	Fig.12
SLE 921AB	14013+0042	9.1, 9.2	6.52	32.69	2009.501	3	19	Fig.13
BUP 168AC	16240+4822	10.44, 8.6	331.53	30.51	2009.501	2	20	Fig.14
BUP 168AB	16240+4822	10.44, 13	243.04	148.44	2009.501	2	21	Fig.14
DOO 58AC	15170+1416	8.46, 8.7	236.94	34.43	2009.501	5	22	Fig.15
DOO 58AB	15170+1416	8.46, 10.5	57.72	21.29	2009.501	3	23	Fig.15
KZA 110AB	16440+4459	9.5, 11	145.89	17.44	2009.501	4	24	Fig.16
KZA 110AC	16440+4459	9.5, 10.5	354.53	140.81	2009.501	2	25	Fig.16
KZA 114AD	16477+4615	9.5, 9.5	212.50	68.15	2009.501	3	26	Fig.17
KZA 114AB	16477+4615	9.5, 10	228.97	80.18	2009.501	4	27	Fig.17
KZA 114AC	16477+4615	9.5, 10.5	246.89	37.55	2009.501	4	28	Fig.17
KZA 114AE	16477+4615	9.5, 11	239.26	60.30	2009.501	4	29	Fig.17
KZA 112	16468+4528	9.5, 10.5	350.31	37.72	2009.501	3	30	Fig.18
HJ 2609AB	12182+0515	10, 10.3	122.81	167.57	2009.501	2	31	Fig.19
SEI 526	11396+3125	10.5, 10.7	236.99	409.24	2009.501	2	32	Fig.20

Notes:

1. The change observed in PA is -0.824, and the change observed in Sep. is 2.134
2. The change observed in PA is -1.42, and the change observed in Sep. is 0.378
3. Neglected. The change observed in PA is 5.642, and the change observed in Sep. is 112.83. Indicates that this component is most likely optical.
4. The change observed in PA is -6.87, and the change observed in Sep. is 1.595
5. The change observed in PA is -0.397, and the change observed in Sep. is -1.158
6. Neglected. The change observed in PA is 88.136, and the change observed in Sep. is 69.146. Given the extended period of time since last observed, change plausible.

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7. The change observed in PA is 0.359, and the change observed in Sep. is 0.878
8. The change observed in PA is -0.713, and the change observed in Sep. is 0.626
9. The change observed in PA is -20.6, and the change observed in Sep. is 20.121. Change plausible; proper motion of A so great, that significant change in relative position of C and D not unlikely, given extended time since last observation. For both C and D, the trend in recorded measurements in both PA and Sep. are continuous with these new measures. It is most likely that C and D are optical.
10. Neglected. The change observed in PA is 6.632, and the change observed in Sep. is 38.928. Change plausible; proper motion of A so great, that significant change in relative position of C and D not unlikely, given extended time since last observation. For both C and D, the trend in recorded measurements in both PA and Sep. are continuous with these new measures. It is most likely that C and D are optical.
11. Neglected. The change observed in PA is 0.851, and the change observed in Sep. is 6.358
12. The change observed in PA is 0.749, and the change observed in Sep. is -0.402
13. The change observed in PA is 0.476, and the change observed in Sep. is 2.107
14. The change observed in PA is 6.249, and the change observed in Sep. is -3.756
15. The change observed in PA is 0.395, and the change observed in Sep. is 1.745
16. The change observed in PA is 5.45, and the change observed in Sep. is -2.252
17. The change observed in PA is 0.741, and the change observed in Sep. is -3.047
18. Neglected. The change observed in PA is 0.3, and the change observed in Sep. is 0.714
19. Neglected. The change observed in PA is -0.48, and the change observed in Sep. is 0.492
20. Neglected. The change observed in PA is 236.526, and the change observed in Sep. is 11.705. Conflicting data indicates that the image may be of a unrecorded binary star, not BUP168AC.
21. Neglected. The change observed in PA is -40.963, and the change observed in Sep. is 77.736. Conflicting data indicates that the image may be of a unrecorded binary star, not BUP168AB.
22. The change observed in PA is -1.056, and the change observed in Sep. is -1.07
23. Neglected. The change observed in PA is -1.276, and the change observed in Sep. is -0.307
24. Neglected. The change observed in PA is 0.886, and the change observed in Sep. is 0.137
25. Neglected. The change observed in PA is 115.533, and the change observed in Sep. is 109.911. Given the extended period of time since last observed, change plausible.
26. Neglected. The change observed in PA is -0.499, and the change observed in Sep. is -0.452
27. Neglected. The change observed in PA is -0.031, and the change observed in Sep. is -0.617
28. Neglected. The change observed in PA is -0.106, and the change observed in Sep. is -0.054
29. Neglected. The change observed in PA is -0.735, and the change observed in Sep. is -0.301
30. Neglected. The change observed in PA is -0.689, and the change observed in Sep. is 0.522
31. Neglected. The change observed in PA is 16.811, and the change observed in Sep. is 154.673. Given the extended period of time since last observed, change plausible.
32. Neglected. The change observed in PA is -72.008, and the change observed in Sep. is 384.14. Questionable. Original WDS notes read: "... may be either variable star or flaw on AC Potsdam plate."

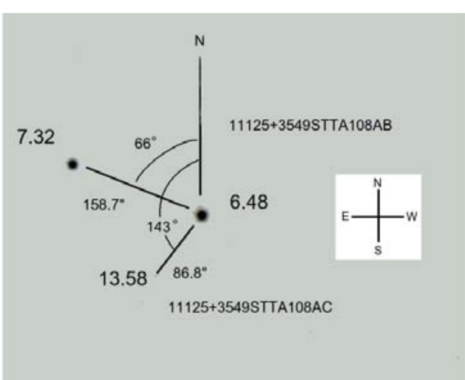

Figure 6: Shows measurements of STTA108 AB and AC. This was the first multiple star system observed, on June 19, 2009, from the Fernbank Observatory

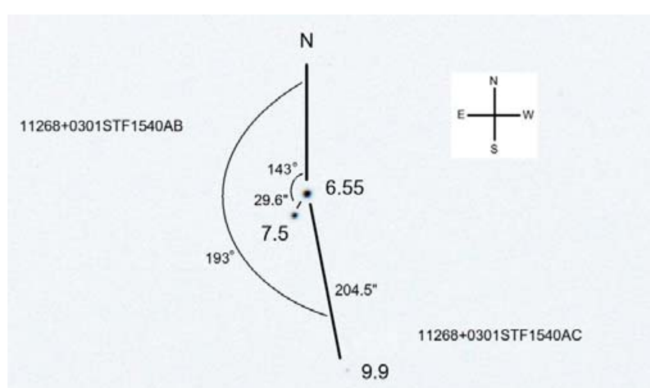

Figure 7: Image of STF1540 AB and AC observed on June 19, 2009 from the Fernbank Observatory

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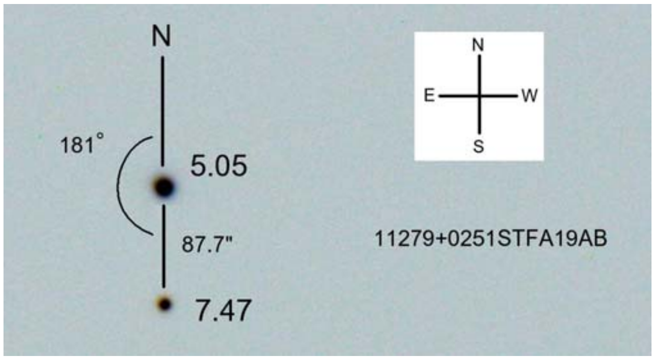

Figure 8: Image of STFA19 AB observed on June 19, 2009 from the Fernbank Observatory

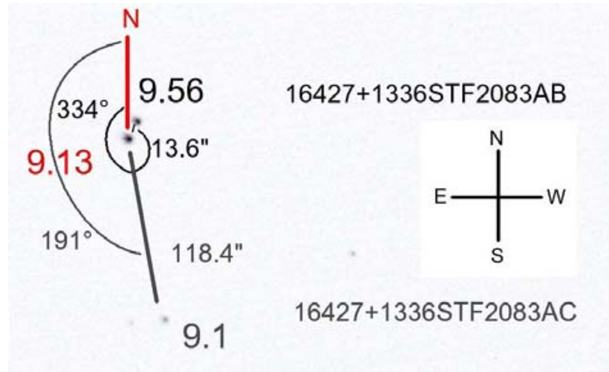

Figure 9: Measurements of STF2083 AB and AC observed on June 19, 2009 from the Fernbank Observatory.

Figure 10: Shows measurements of STF1930 AB, AC, and AD. Observed on June 25, 2009 from the Fernbank Observatory.

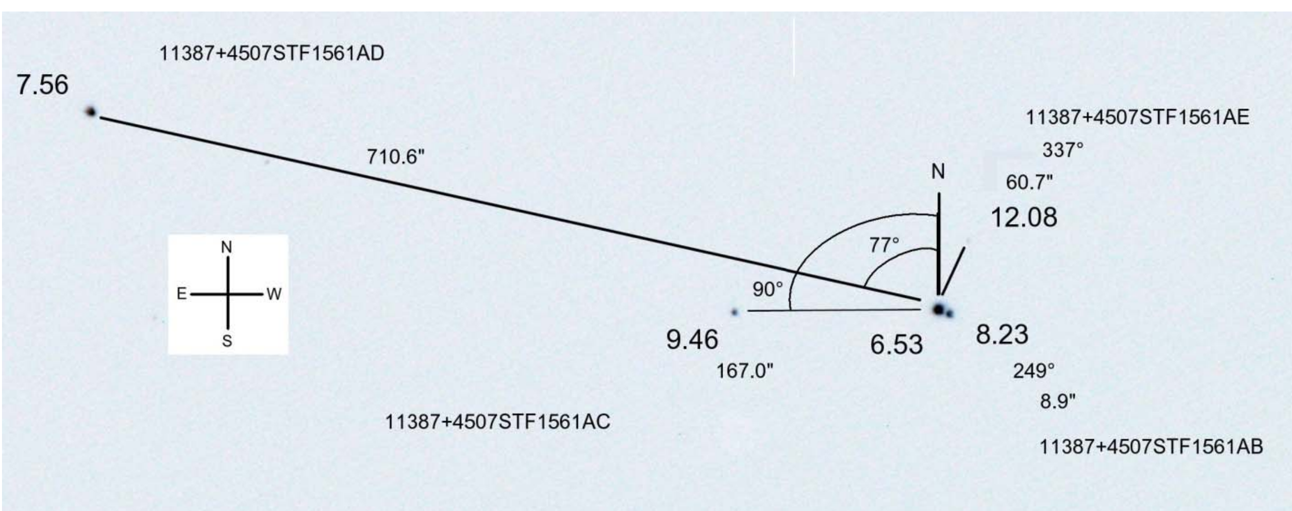

Figure 11.1: Measurements of STF1561 AB, AC, AD, and AE, observed on June 25, 2009.

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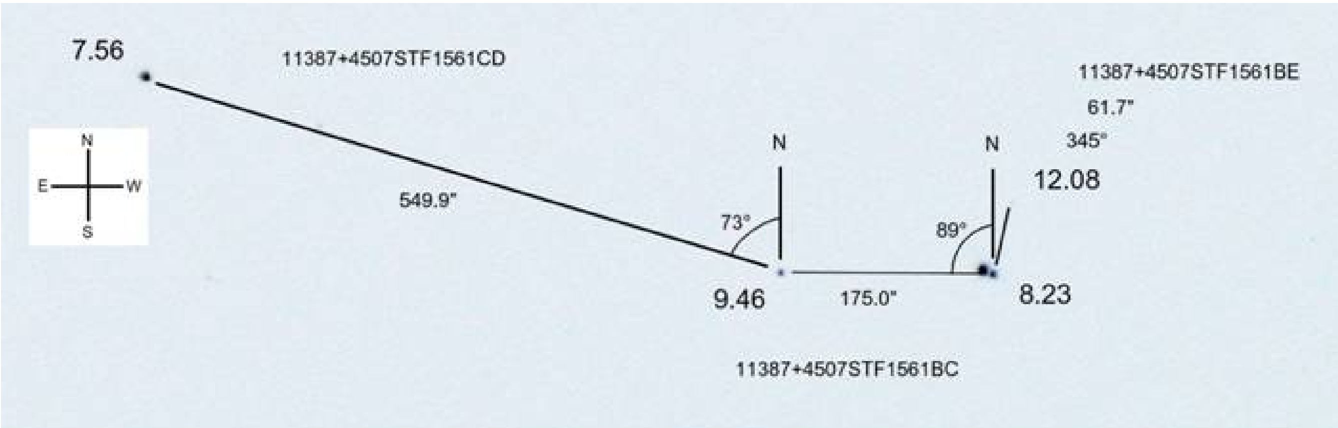

Figure 11.2: Shows measurements of STF1561 BC, CD, and BE. Observed on June 25, 2009 (separated from 11.1 for visual clarity).

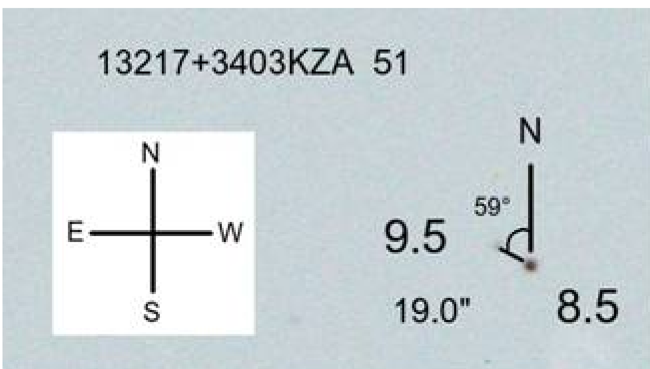

Figure 12: Measurement of KZA 51, observed on June 25, 2009.

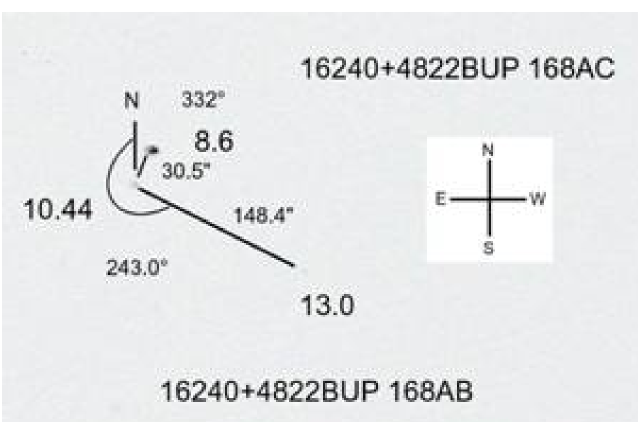

Figure 14: Measurements of BUP 168 AB and AC, observed on July 1, 2009.

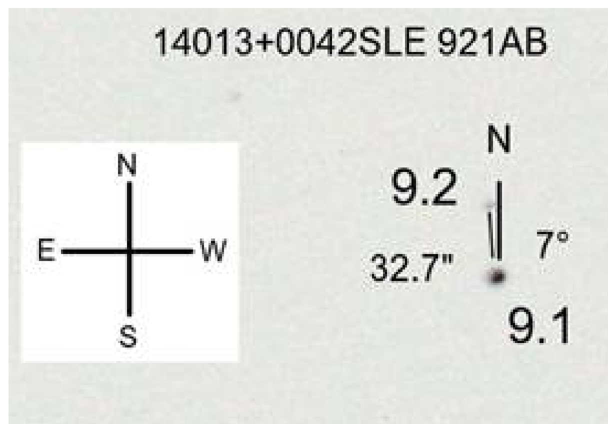

Figure 13: SLE 921AB, the first multiple star system observed on July 1, 2009 from the Fernbank Observatory.

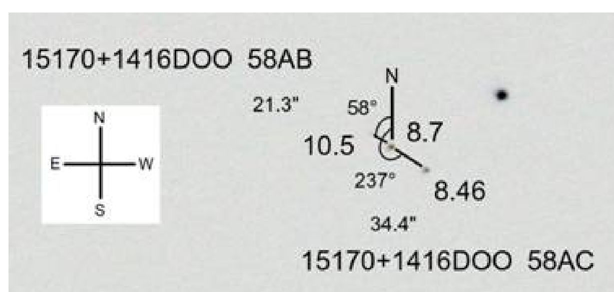

Figure 15: Measurements of DOO 58 AB and AC, observed on July 1, 2009.

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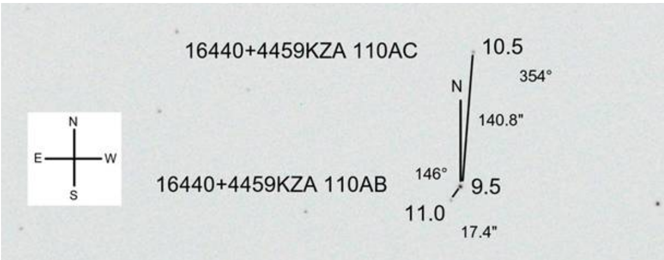

Figure 16: Measurement of KZA 110 AB and AC. Observed on July 1, 2009.

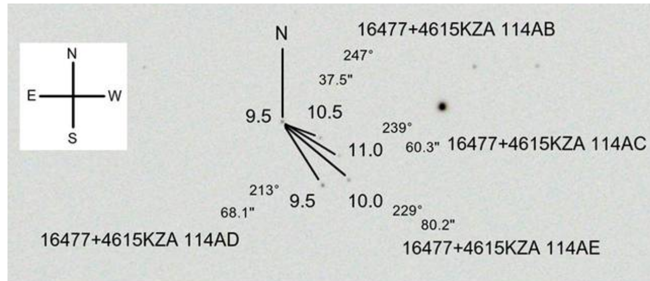

Figure 17: Measurement of KZA 114 AB, AC, AD, and AE. Observed on July 1, 2009.

Figure 18: Measurement of KZA 112, observed on July 1, 2009.

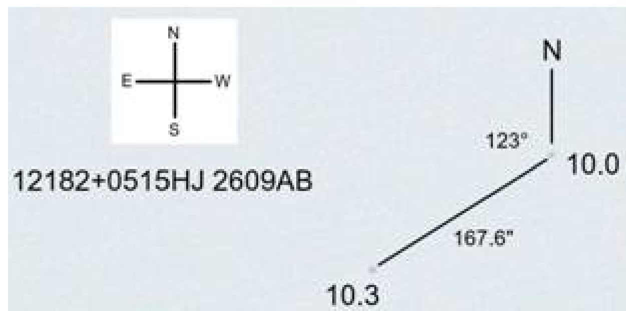

Figure 19: Measurement of HJ 2609 AB, observed on July 1, 2009.

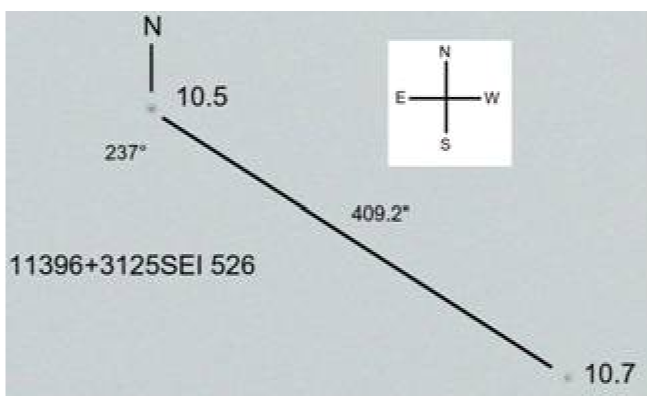

Figure 20: Measurement of SEI 526, observed on July 1, 2009.

The author is a student at the Georgia Institute of Technology working towards a B.S. in Electrical Engineering Degree with a minor in Chinese anticipated 2012. She has been working with the Fernbank Science Center since 2006.