Measuring the Position Angle and Separation of WDS 13550-4235 and WDS 14082+3645

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Abstract

Measurements were made for the binary star systems WDS 13550-4235 and WDS 14082+3645 to find the position angle and separation of each star system's primary and secondary components. Images were obtained from the Las Cumbres Observatory Global Telescope Network using the 0.4-meter telescopes. The measured separation of WDS 13550-4235 is 13.573″ +/ -0.103″, and the position angle is 6.9° +/- 0.4°. The measured separation of WDS 14082+3645 is 9.7″ +/- 0.3″, and the position angle is 70.95° +/- 1.04°. These measurements were compared to measurements in Stelle Doppie and are consistent with past measurements.

In addition, images were collected of the tertiary component of the triple star system WDS 14082+3645 using speckle interferometry on the Mount Wilson Observatory 60-inch telescope. The measured separation is 1.588″, and the position angle is 209.35°; the position angle is consistent with Stelle Doppie; however, the separation is not. More data is needed to understand the nature of this star system.

Introduction

Our team of researchers working with the Institute for Student Astronomical Research (InStAR) made astrometric measurements of two star systems: WDS 13550-4235 and WDS 14082+3645. Our group measured the position angle and separation of the double star WDS 13550-4235 located in the constellation Centaurus. According to the US Naval Observatory's historical data, it was last observed in 2016. Our second star system is WDS 14082+3645 in the constellation Boötes, which was last observed in 2015. The goal of this research project is to help determine if our double star systems are visually bound, meaning that they are only a double star system visually, but not physically, and gravitationally bound systems, which appear bound visually and *are* bound physically due to their proximity. This can be accomplished by taking each star system's astrometric measurements (such as separation and position angle) over time.

Wijngaarden (2015) stated there is a lack of observational data on binary star systems; there are over 100,000 systems in the WDS catalog, and only of the order of about 100 systems of them have a grade 1 orbit. Observations of binary stars (or star systems in general) are essential, as they help scientists

calculate the defining characteristics of the companions. The binary systems' gravitational influence on each other causes a 'tug' on the stars, and from this, astronomers can determine the mass of the stars that are tugging on each other. From there, other characteristics such as radius and temperature can be calculated. Data must also be accessible to complement space survey missions such as Gaia.

Equipment and Procedures

Double stars for this research were selected based on whether they could be observed using the Las Cumbres Observatory Global Telescope Network (LCOGT) 0.4-meter telescopes during the summer of 2022 when this research took place. Furthermore, we selected a triple star system that would be observable from Mount Wilson Observatory in Pasadena, California using speckle interferometry. These restrictions limited our locations and star separation angles. Also, it was essential to select star systems that have not recently been measured, in order to provide the most value to the scientific community.

LCOGT Observations

Using a Bessel-V filter, a variety of images were requested using LCOGT (specifically the 0.4-meter telescopes) for each binary star system with an exposure time of 10 seconds. We took two sets of twelve images of the WDS 13550-4235 star system, with the first taken on 2022-06-08, and the second taken on 2022-06-16 at the Cerro Tololo Inter-American Observatory.

The same image procedure applied to the WDS 14082+3645 system images, taken on 2022-06-08 at the McDonald Observatory (Texas, USA), as well as 2022-06-16 at the Teide Observatory (Tenerife, Spain).

All four sets of images were taken with a SBIG 6303 camera with a 6.3 megapixel CCD sensor. The images were analyzed in AstroImageJ (AIJ; Collins et al., 2017) which measured the position angle and separation between the primary and secondary stars.

Mount Wilson Observations

Observations of the tertiary component of the triple star system WDS 14082+3645 were made at Mount Wilson Observatory using the 60-inch telescope, which has a 60-inch primary mirror with a 24-meter focal length and Cassegrain focus. The camera is a ZWO ASI 6200MM CMOS instrument with an Astronomik 642BP filter, and is shown in Figure 1 below. The camera was maintained at a constant temperature of 0°C to increase precision and reduce noise.

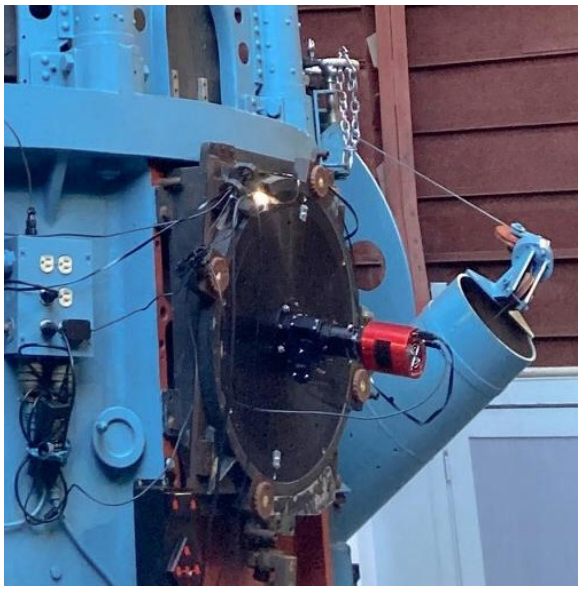


Figure 1. The ZWO ASI 6200MM CMOS camera mounted on the MWO 60-inch telescope.

While observing our target and reference stars, one thousand 40 ms images were collected for speckle interferometry analysis. The speckle interferometry method is a manner of image processing that utilizes many short duration image captures and Fourier transforms to produce an image of close and faint double stars. (Rowe, et. al., 2015).

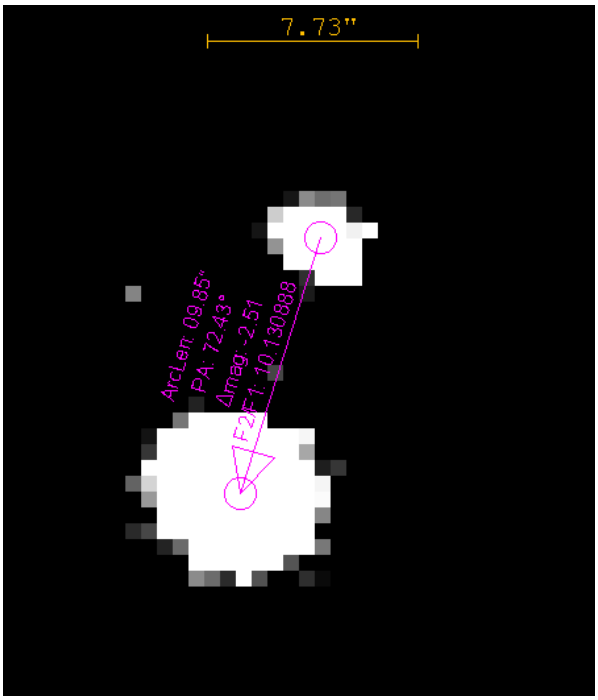
Image data was collected by the SiTechZWO cam software and the data were reduced using Speckle Toolbox 1.14 (Rowe et al, 2015).

Results

CCD Astrometry of WDS 13550-4235 and WDS 14082+3645

Measurements of separation and positional angle were made in AstroImageJ for each of the 12 images for each binary star; afterward, the averages and standard deviations were calculated. An example measurement of an image of WDS 14082+3645 is shown in Figure 2 below.

Figure 2. AstroImageJ measurements of WDS 14082+3645



Results for WDS 13550-4235 are given in Table 1 below, and the results for WDS 14082+3645 are given in Table 2. Stelle Doppie (Sordigliani) was used as a reference for the measurements calculated. The measured separation of WDS 13550-4235 is 13.573″ +/ -0.103″, and the position angle is 6.9° +/- 0.4°. The measured separation of WDS 14082+3645 is 9.7″ +/- 0.3″, and the position angle is 70.95° +/- 1.04°.

Table 1. Separation and position angle measurements for WDS 13550-4235. Stelle Doppie reference data is a separation of 13.6″ and a position angle of 7°.

	Average	Standard Deviation	SEM
Separation (arcsec)	13.57	0.103	0.0298
Position Angle (deg)	6.96	0.383	0.110

Table 2. Separation and position angle measurements for WDS 14082+3645. Stelle Doppie reference is 9.5″ and 72°

	Average	Standard Deviation	SEM
Separation(arcsec)	9.70	0.317	0.0915
Position Angle (deg)	70.95	1.037	0.299

The historical data was requested from the US Naval Observatory and is provided in Tables 3 and 4 below.

Table 3. Historical Data of WDS 13550-4235

Data	PA	Sep	Aperture	# of obs	Disc. Code	Obs. Type	Notes
1835.32	8.4	13.5	0.5	2	HJ 1847a	Mb	0
1882.53	6.8	13.65	0.2	1	Hrg1892	Ma	0
1899.4	5.2	13.653	0.3	1	WFC1998	Pa	6
1905.26	8.4	13.763	0.3	1	WFC1998	Pa	6
1920.18	7.6	13.7	0.4	2	Daw1922	Ma	0
1930.47	7.3	13.7	0.7	4	B 1931b	Ma	0
1942.28	8.1	13.198	0.2	1	WFC1970	Pa	6
1991.67	6.7	13.569	0.3	1	TYC2000b	Ht	5
1998.488	6.8	13.562	0.2	4	UC 2013b	Eu	P 7
2000.09	6.7	13.61	1.3	1	TMA2003	E2	7
2010.5	6.8	13.28	0.4	1	Dam2021h	Hw	7
2015.5	6.3	13.63	1	1	Dam2021h	Hg	7
2016	6.6	13.69	1	1	Dam2021h	Hg	7

Table 4. Historical data for WDS 14082+3645

Date	PA	Sep	Aperture	# of obs.	Disc. Code	Obs. Type	Notes
1843.33	71.1	9.67	0.3	2	Mad1844	Ma	4
1846.33	72.1	9.38	0.4	2	Stt1878	Ma	4
1867.74	74.4	9.58	0.2	3	D 1870h	Ma	7
1869.37	74.2	9.57	0.2	5	D 1883	Ma	3
1880.09	74.5	9.55	0.2	3	Sp 1888	Ma	3
1884.38	73.2	9.68	0.4	2	Per1887	Ma	3
1884.386	73.2	9.68	0.4	2	Per1885	Ma	6
1887.408	72.8	9.76	0.7	2	Hl 1892c	Ma	3
1898.32	72.7	9.7	0.9	3	Hu 1901a	Ma	3
1905.42	73.8	9.74	0.3	1	Lau1905	Ma	3
1908.3	71.8	10.06	0.6	1	Dgn1914	Ma	3
1908.374	73.3	9.62	1	1	Fox1915	Ma	3
1908.417	71.6	9.54	0.3	2	Fox1915	Ma	3
1910.41	72.8	9.55	0.2	3	Dob1927	Ma	3
1910.45	75.2	3.41	0.7	1	Bow1911	Ma	7
1911.1	72.8	9.58	0.7	3	Bow1921	Ma	3
1919.4	73.4	9.58	0.3	1	Gui1931	Ma	3
1930.31	68.4	10.03	0.2	1	WFC1998	Pa	6
1930.37	73.4	9.54	0.3	4	Kui1933	Ma	0

1931.8	71.4	9.74	0.2	2	Ali1955	Pa	0
1933.29	76.2	9.978	0.2	1	WFC1998	Pa	6
1934.44	73.1	9.39	0.3	2	Baz1936c	Ma	0
1953.32	72.1	9.6	0.7	3	Dju1953b	Ma	0
1961.44	71.67	9.63	0.3	1	Hau1965	Pa	2
1979.999	73	9.5	0.1	3	Cll2003	Ma	6
1991.25	72.4	9.47	0.3	1	HIP1997a	Hh	5
1991.66	72.9	9.584	0.3	1	TYC2000c	Ht	5
1998.3	71.7	9.54	1.3	1	TMA2003	E2	7
2002.255	71.2	9.607	0.2	3	UC 2013b	Eu	7
2008.144	73.3	9.38	0.2	1	Arn2008c	Mg	7
2012.38	72.11	9.422	0.2	1	UR 2015	Er	7
2013.3	71.76	9.537	0.2	6	UR 2015	Er	7
2013.31	71	9.7	0.3	1	FyM2014	C	7
2014.3	71.73	9.542	0.2	14	UR 2015	Er	7
2014.481	71.69	9.37	0.3	1	Loc2015b	C	7
2015.185	71.72	9.545	0.2	10	UR 2015	Er	7
2015.28	71.5	9.61	0.3	1	StJ2015	S	7
2015.37	72.2	9.5	0.3	1	StJ2015	S	7

Using the historical data, our team converted the position angle and separation into cartesian coordinates. The horizontal components represent the offset from the primary component in right ascension, and the vertical components represent the offset from the primary component in declination. The figures below show the plotting of the historical data for WDS 13550-4235 (Figure 3) and WDS 14082+3645 (Figure 4). The plots utilized a color scheme separating the data collected by century. The earliest data is light in color and more recent data is darker. The final data point determined by our team is black.

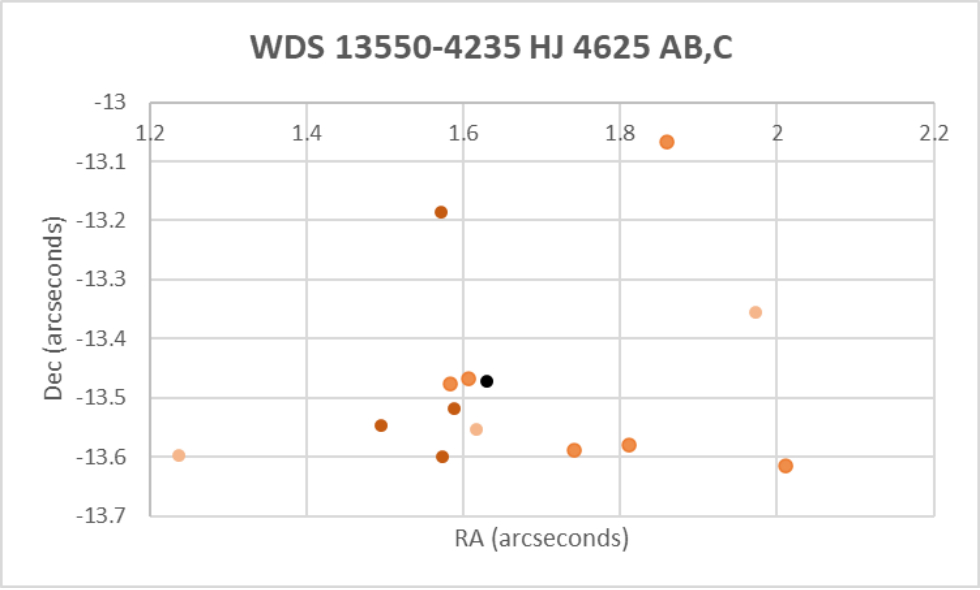


Figure 3. Plot of the Historical Data for WDS 13550-4235AB. The team's measurement is the black point.

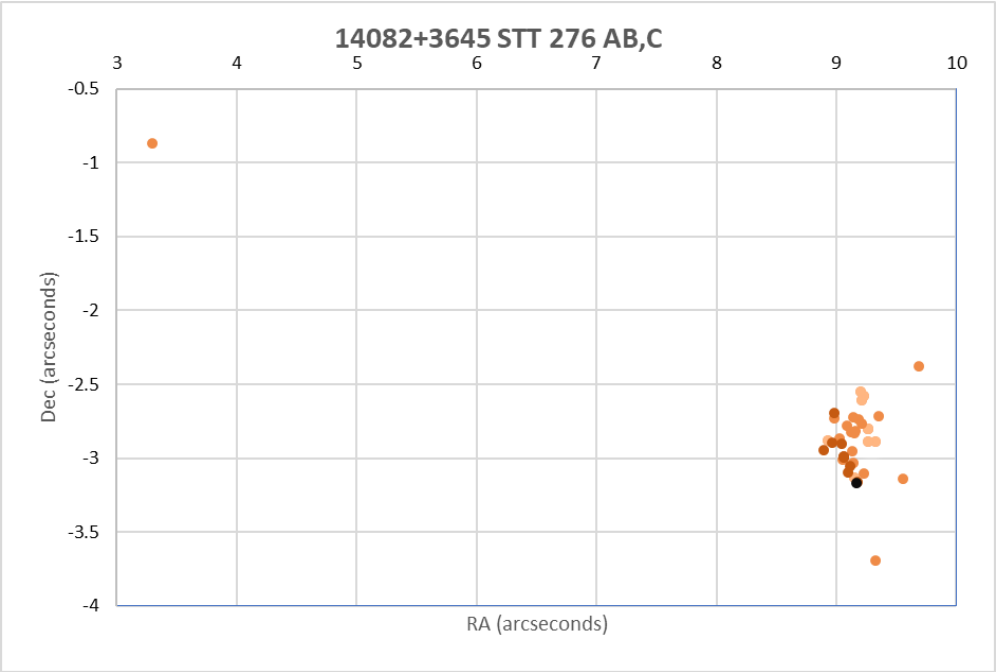


Figure 4. Plot of the Historical Data for WDS 14082+3645AB. The team's measurement is the black point.

One data point for WDS 14082+3645 seemed to be an outlier and so the data was plotted with that point removed (Figure 5).

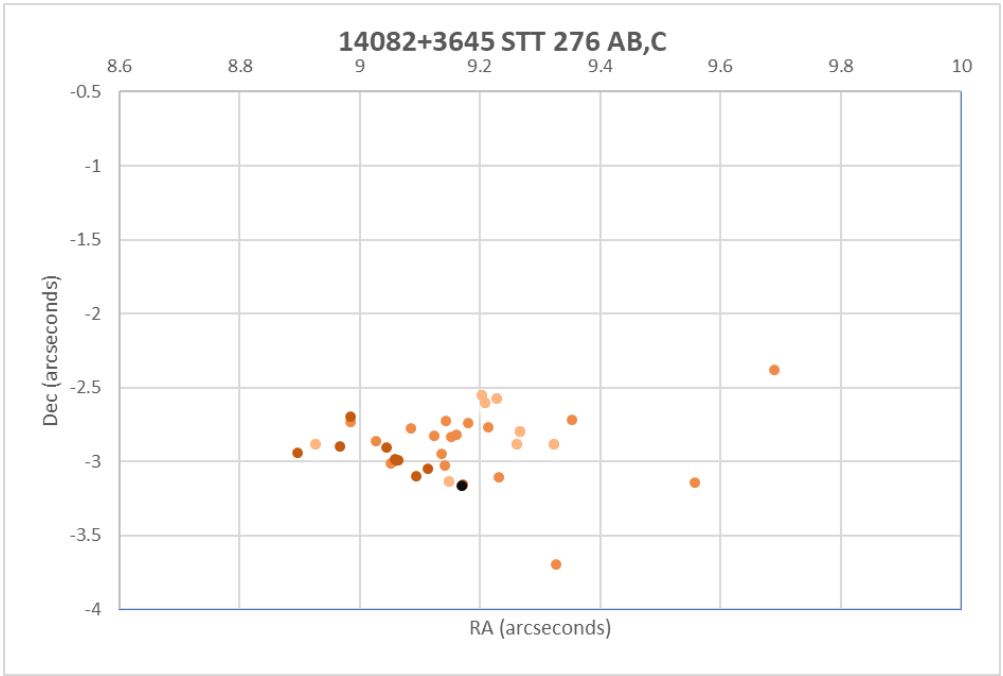


Figure 5. In Figure 4, an outlier in 1910.45 is indicated by the data point in the upper left. This data point was excluded in Figure 5 as it does not seem congruent with other observations.

Speckle Interferometry of the Tertiary Component of WDS 14082+3645

On June 15, 2022, data was taken at Mount Wilson Observatory. During the observational run, 1000 images were taken of the primary and reference stars. On Mount Wilson, the pixel scale was 0.1215″ and the camera angle was 171.733°. The position angle was measured to be 209.35° and the separation was 1.588″, as shown in Figure 6.

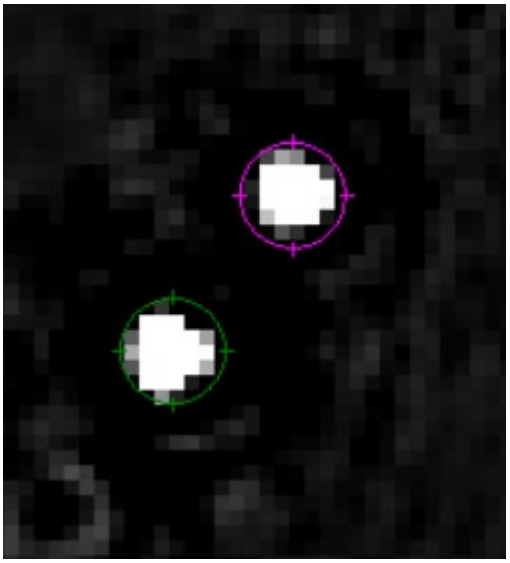


Figure 6. Speckle Interferometry of the tertiary component of WDS 14082+3645.

Discussion

WDS 13550-4235

WDS 13550-4235 is known to be a physical double (Stelle Doppie) with primary and secondary proper motions in milliarcseconds per year as shown in Table 5 below.

Table 5: Primary and secondary proper motion values in milliarcseconds per year for WDS 13550-4235 from Stelle Doppie.

Primary motion RA	+005	Secondary motion RA	+001
Primary motion dec	+013	Secondary motion dec	+015

In the Gaia DR3 catalog (Gaia collaboration et al., 2022j), the primary star for WDS 13550-4235 has no data for parallax or proper motion; the secondary star has the parallax and proper motion values shown in Table 6 below.

Table 6: Gaia DR3 Values for WDS 13550-4235

	Parallax (mas)	Parallax error (mas)	PM RA (mas/yr)	PM RA errors (mas/yr)	PM Dec (mas/yr)	PM Dec error (mas/yr)	GMag

Primary	N/A	N/A	N/A	N/A	N/A	N/A	9.181
Secondary	5.810	0.0192	1.831	0.018	11.814	0.023	9.339

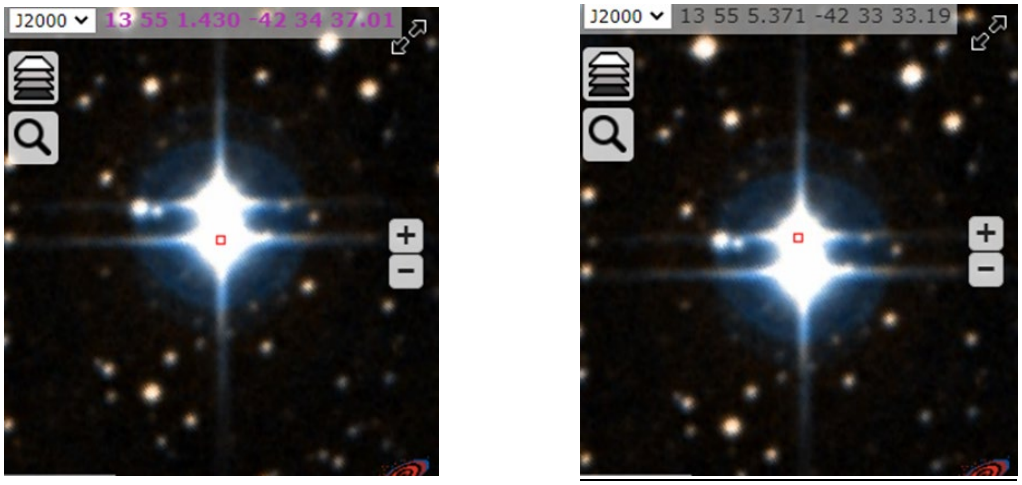


Figure 7: WDS 13550-4235 Vizier image of the Primary Star (left) RA: 13 55 1.230 Dec: -42 34 37.01 and Secondary Star (right) RA:13 55 5.371 Dec: -42 33 33.19

The data collected on WDS 13550-4235 over the past 188 years show significant scatter with no clearly defined orbit. The current measurement falls within the range of the recent data points.

WDS 14082+3645

The primary star and secondary star for WDS 14082+3645 have no data for the parallax or proper motion in Gaia DR3; the third star has a parallax of 3.6866 mas, the parallax error of 0.0177 mas, and a proper motion of 28.895 mas/yr.

Table 7: Gaia DR3 Values for WDS 14082+3645

Star	Parallax (mas)	Parallax error (mas)	PM RA (mas/yr)	PM RA error (mas/yr)	PM Dec (mas/yr)	PM Dec error (mas/yr)	Gmag
A	N/A	N/A	N/A	N/A	N/A	N/A	8.5747
B	N/A	N/A	N/A	N/A	N/A	N/A	8.9570
C	3.6866	0.0177	24.868	0.010	-14.715	0.0152	10.7273
D	N/A	N/A	N/A	N/A	N/A	N/A	21.0722

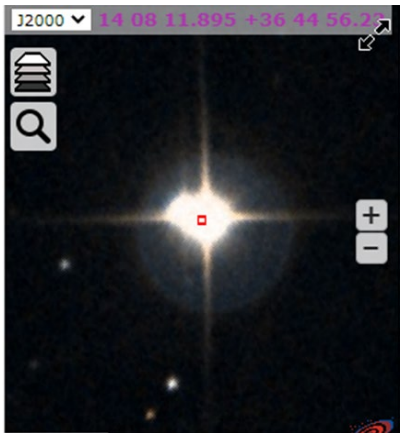


Figure 8. Vizier Star A, RA: 14 08 11.895 Dec: 36 44 56.23 and Star B, RA: 14 08 11.882 Dec:36 44 55.92

Figure 9. Vizier Star C (left) RA: 14 08 12.613 Dec: 36 44 59.36, Vizier Star D (right) RA: 14 08 12.408 Dec: 36 45 13.26

Conclusion

The measured separation between the primary and secondary components of WDS 13550-4235 is 13.573″ +/- 0.103″, and the position angle is 6.9° +/- 0.4.. The measured separation between the primary and secondary components of WDS 14082+3645 is 9.7″ +/- 0.3″, and the position angle is 70.95° +/- 1.04°. These measurements were compared to Stelle Doppie and are consistent with past measurements.

The measured separation of the tertiary component of the triple star system WDS 14082+3645 is 1.588″, and the position angle is 209.35°; the position angle is consistent with Stelle Doppie; however, the separation is not. More data is needed to understand the nature of this star.

Acknowledgments

We would like to thank Dr. Rachel Matson for providing the US Naval Observatory historical data on our two star systems.

This research has made use of the VizieR catalog access tool, CDS, Strasbourg, France (DOI 10.26093/cds/vizier). The original description of the VizieR service was published in 2000, A&AS 143, 23.

This work has made use of data from the European Space Agency (ESA) mission Gaia (https://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement.

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