Astrometric Measurements of WDS 13175-4625 DON 1104

Vanessa Harvey[1], Ann-Katrin Bock[1], Erin De Pree[2], Elan Lavie[3], Jennifer Krestow[1], Elizabeth Grimm[1], Nicholas Johnson[1], Michael Strane[1], Rachel Freed[4]

1. Glendale Community College, Glendale, California, USA, contact: *vharvey@glendale.edu*
2. Bates College, Lewiston, Maine, USA
3. El Cerrito High School, El Cerrito, California, USA
4. Institute for Student Astronomical Research, Sonoma, California, USA

Abstract

We present astrometric measurements of the double star system WDS 13175-4625 DON 1104 using the Las Cumbres Observatory Cerro Tololo and Siding Spring telescopes measured on March 14, 2023 and April 25, 2023, respectively. A position angle of 256.3° ± 0.48° and angular separation of 7.51" ± 0.069" were determined. Based on astrometric analysis as well as the parallax and proper motion values from Gaia DR3, we conclude that these stars are not gravitationally bound.

1. Introduction

In this paper we provide current astrometric measurements of WDS 13175-4625 DON 1104 with the objective of determining whether the double star system shows evidence of gravitational association. Only four measurements were made of this system in the past 114 years.

The Washington Double Star (WDS) Catalog through Stelle Doppie (Sordiglioni, 2023) was used to search for the candidate star using the following criteria: a component separation between 5 and 10 arcseconds, a primary star magnitude between 8 and 10, a delta magnitude (Δmag) of less than or equal to 3, an uncertain binary status, and a date of last observation less than or equal to the year 2015. The right ascension was chosen to be between 13 and 23 hours and the declination between −90° and +90°. WDS 13175-4625 DON 1104 met all our criteria except for Δmag. We chose a 5-magnitude separation between the primary and secondary stars for the system.

Since its discovery in 1909, there have been a total of four measurements for WDS 13175-4625 DON 1104. The primary star has a spectral type of M0/M1III indicating that it is a red giant star, and it has a magnitude of 8.48 in the visual. Its right ascension is 13h 17m 27.73s and its declination is –46° 24' 11.1" placing it in the constellation Centaurus. The secondary star has a magnitude of 13.50. The first angular separation measured in 1909 was 11.5" with a position angle of 259.7°. Its most recent measurement by Gaia in 2015 showed an angular separation of 8.1" and position angle of 256°.

2. Equipment and Procedures

The astrometric images of WDS 13175-4625 DON 1104 were captured by the Las Cumbres Observatory Global Telescope Network (LCOGT) 0.4-m telescope, using the SBIG 6303 charge-coupled device (CCD) camera at the Cerro Tololo Observatory in Chile on March 13, 2023 (2023.203) and Siding Spring Observatory in Australia on April 25, 2023 (2023.317). The images were calibrated, bias subtracted, and flat fielded by the LCOGT using the BANZAI pipeline.

Because of the five-magnitude difference between the component stars, care was taken to determine the exposure time such that the counts of the two stars fit within the dynamic range of the CCD camera. Initial test exposures of six frames at five and ten seconds each in the Bessell-V filter were made to determine the signal-to-noise of the secondary star and take initial astrometric measurements. Of these 12 measurements ten showed low signal-to-noise (< 100) for the secondary star, particularly the five second exposures. These were followed by test images at five and ten seconds in the infrared using the Pan-STARRS-z filter (central wavelength 8700-nm, bandwidth 1040-nm) to determine if the secondary star's signal-to-noise would be stronger at longer wavelengths. In these images in the infrared the secondary star barely appeared above the background for measurement. Images were also taken at five and ten seconds using the Bessell-B filter to determine if the signal of the secondary star would improve with observations at a shorter wavelength. The signal-to-noise of the secondary star did not improve with the blue filter as the secondary star also barely appeared above background for measurement.

Additional exposure times were taken at 20-, 25-, and 30-seconds. However, at these exposure times the peak measurements for the primary star were approaching the saturation level of the camera. It was then determined from observing the peak values of the primary star and signal-to-noise of the secondary star from all of the measurements that an exposure time of 10 seconds in the Bessell-V filter would yield a signal-to-noise of at least 100 for the secondary star while keeping the peak measurement of the primary star below the saturation level of ~64000 ADU (for the raw images) or 102400 e- (for the processed images). Thus, an additional 14 images were taken using these criteria at the Siding Spring Observatory. These measurements were added to the initial Cerro Tololo Observatory 10-sec exposures where the signal-to-noise was at least 100 for a total of 16 images for this study.

Images were analyzed using the AstroImageJ (AIJ) software suite (Collins et al., 2017). Angular separation and position angle of the stars were measured using the Howell centroid method (Howell, 1989). The object aperture was set to 6.0 pixels and the inner and outer radii of the background annulus were set to 30 and 40 pixels, respectively.

The AIJ astrometric measurements of position angle and angular separation were recorded, and the mean, sample standard deviation, and standard error of the mean were calculated. In addition, parallax and proper motion data was searched for in the Gaia Data Release 3 (DR3) catalog (Gaia Collaboration, 2015) and historical data for WDS 13175-4625 DON 1104 was requested from Dr. Rachel Matson at the U. S. Naval Observatory.

3. Data

Data was collected from the LCOGT 0.4-m telescopes using the SBIG 6303 CCD camera with the Bessell-V filter. The FITS files were reduced by LCOGT using the BANZAI pipeline and these processed images were analyzed using AstroImageJ (AIJ). A typical image, with measurements, is shown in Fig. 1.

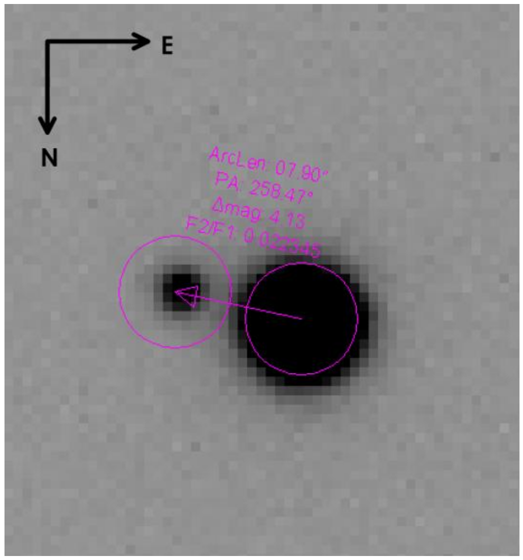

Figure 1: Example of an image of WDS 13175-4625 DON 1104 with measurements from AstroImageJ

Table 1 shows the mean, standard deviation, and standard error of the mean for the 16 images.

Table 1. Current results for WDS 13175-4625 DON 1104. The position angle is 256.3° ± 0.48° and the separation is 7.51" ± 0.069".

	Observatory	Dates	Images		PA (°)	SEP (″)
WDS13175-4625 DON1104	Cerro Tololo	2023.203	2	Mean (of all 16 images)	256.3	7.51
	Sliding Spring	2023.317	14	Sample Standard Deviation	1.9	0.30
				Standard Error of the Mean	0.48	0.069

4. Discussion

The historical data, shown in Table 2, for WDS 13175-4625 DON 1104 was requested from the U.S. Naval Observatory (Matson, 2023). The historical data consists of 4 data points starting in the year 1909 and ending in the year 2015. Table 2 shows the values for their position angle (PA) in degrees, separation (SEP) in arcseconds, as well as the measurement method used for the star system.

The historical data values for position angle and separation, shown in Fig. 2 along with our current measurement, were resolved to x-y coordinates (in arcseconds) using the following equations:

$$x(RA) = \rho\cos\theta \quad (1)$$

$$y(DEC) = \rho\sin\theta \quad (2)$$

where x is right ascension (RA), y is declination (DEC), ρ is the angular separation (SEP) and θ is the position angle (PA). The date for each measurement is shown. No orbital trend is observed.

Table 2. Historical and current measurements of WDS 13175-4625 DON 1104.

Date	PA (θ, deg)	Sep (ρ, arcsec)	x (RA, arcsec)	y (DEC, arcsec)	Measurement Method
1909.32	259.7	11.536	-2.06266	-11.3501	Pa: photographic, with astrograph
1929.24	258.4	10.42	-2.09523	-10.2072	Ma: micrometer with refractor
2000.22	261.2	7.8	-1.19329	-7.70818	E2: 2MASS (Two Micron All-Sky Survey)
2015	255.513	8.149	-2.03856	-7.8899	Hg: Gaia
2023.32	256.3	7.51	-1.93	-7.28	P: photographic technique

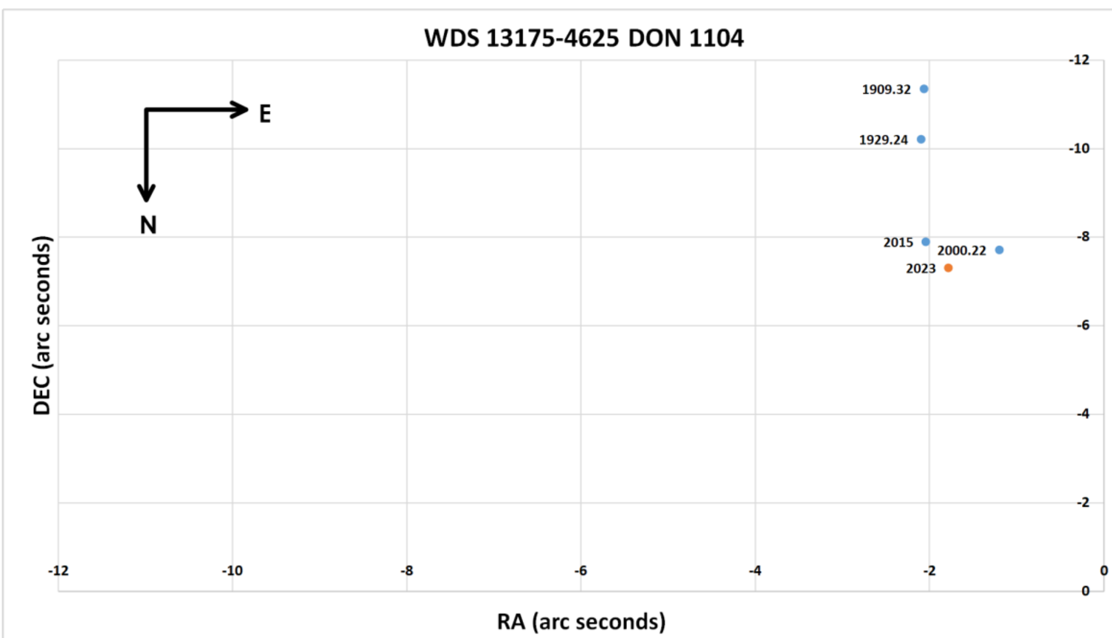

Figure 2: x (right ascension, RA) and y (declination, DEC) of the historical data (blue) and current data (orange)

To further investigate the movement of the secondary star, position angle versus time in Fig. 3 and separation versus time Fig. 4 were plotted. The position angle shows no clear relationship or trend with epoch progression. The separation, however, shows a decreasing linear trend with epoch progression. A linear fit to the data (Fig. 4) gives an R-squared of 0.96 showing a strong linear correlation indicating that the stars may be approaching each other.

Figure 3: Position angle versus time

Figure 4: Separation versus time

Using the VizieR astronomical catalog (Ochsenbein, 2000), the Gaia DR3 data (Gaia Collaboration, 2022) for the proper motion and parallax values were found and are provided in Table 3. Using the parallax equation,

$$\frac{1}{\text{parallax (in arcseconds)}} = \text{distance (in parsecs)} \tag{3}$$

the distance to each star was calculated and also included in Table 3. (Please note that accurately converting from parallax to distance is more complex than this equation (Luri, 2018), but it does give us a general estimate to work with.) The primary star is 683.4 parsecs (141 million AU or 2229 light-years) away while the secondary star is only 221.8 parsecs (45.7 million AU or 723.4 light-years) distant. There is a minimum separation of over 95 million AU, or 1500 light-years. Harshaw (2018) has noted that very few known binaries exceed separations of 3000 AU and stated that most of them are closer than 1000 AU.

Given the lack of orbital motion seen in the movement of the secondary and given the parallax and proper motion values for both stars provided by Gaia in Table 3, we conclude that these stars are not binary, nor do they show any other gravitational association.

Table 3. Parallax and proper motion from Gaia Data Release 3 (Gaia Collaboration, 2022) and the calculated distance.

Star	Parallax (mas)	Distance (pc)	Proper motion in right ascension (mas/year)	Proper motion in declination (mas/year)
Primary	1.4633	683.4 pc (2229 ly)	–17.383	–4.428
Secondary	4.5091	221.8 pc (723 ly)	13.428	–6.730

5. Conclusions

In this study, we have added additional measurements of position angle and separation for WDS 13175-4625 DON 1104. As a result of including this measurement and comparing the relative motion of the secondary star with respect to the primary star over the last 114 years as well as comparing the Gaia DR3 measurements of their parallax and proper motion relative to one another, we conclude that these stars are not gravitationally bound.

Acknowledgments

The authors would like to thank Nikolaus Volgenau of the Las Cumbres Observatory Global Telescope Network for his assistance, as well as the Las Cumbres Observatory Global Telescope for use of their observatories.

We would also like to thank the Glendale Community College Foundation for funding this research opportunity for the Glendale Community College students.

In addition, we thank Dr. Rachel Matson at the US Naval Observatory for supplying historical data for this study.

This research has made use of the Washington Double Star catalog maintained by the U.S. Naval Observatory, as well as data provided by Stelle Doppie. 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.

References

Collins, K. A., Kielkopf, J. F., Stassun, K. G., & Hessman, F. V. (2017). AstroImageJ: Image processing and photometric extraction for ultra-precise astronomical light curves. The Astronomical Journal, 153(2). Retrieved from https://iopscience.iop.org/article/10.3847/1538-3881/153/2/77.

Gaia Collaboration. (2016). The Gaia mission. Astronomy and Astrophysics, 595. DOI:10.1051/0004-6361/201629272.

Gaia Collaboration. (2022). Gaia Data Release 3: Summary of the Content and Survey Properties. *Astronomy & Astrophysics*. Retrieved from https://www.aanda.org/component/article?access=doi&doi=10.1051/0004-6361/202243940.

Harshaw, R. (2018). Gaia DR2 and the Washington Double Star Catalog: A Tale of Two Databases. *Journal of Double Star Observations.* Vol 14. No 4.

Howell, S. B. (1989). Two-dimensional aperture photometry: signal-to-noise ratio of point-source observations and optimal data-extraction techniques. Publications of the Astronomical Society of the Pacific, 101(640), 616. Retrieved from https://iopscience.iop.org/article/10.1086/132477.

Las Cumbres Observatory Network. (2023). Las Cumbres Observatory Observation Portal, https://lco.global/observatory/instruments/.

Luri, X., A. G. A. Brown, L. M. Sarro, F. Arenou, C. Bailer-Jones, A. Castro-Ginard, J. de Bruijne, T. Prusti, C. Babusiaux, and H. E. Delgado. (2018). Gaia Data Release 2: Using Gaia Parallaxes. *Astronomy & Astrophysics*, 616:A9. DOI: 10.1051/0004-6361/201832964.

Matson, R. (2023). Personal Communication. The Washington Double Star Catalog, Astronomy Department, US Naval Observatory.

Ochsenbein, F., Bauer, P., and Marcout, J. (2000). The VizieR database of astronomical catalogues. *Astronomy and Astrophysics Supplement Series*, 143(1):23–32. Retrieved from https://aas.aanda.org/articles/aas/abs/2000/07/ds1826/ds1826.html.

Sordiglioni, G. (2023). WDS 13175-4625 DON 1104. Retrieved March 6, 2023 from https://www.stelledoppie.it/index2.php?iddoppia=56461.

The Washington Double Star Catalog. (2023). Washington Double Star Catalog. https://crf.usno.navy.mil/wds.