Astrometric Observations of WDS 19246+4447 Using the Great Basin Observatory

Allyson DeCremer[1] and Jerry Hilburn[2]
[1] University of Nevada, Reno, Reno, Nevada; decremer5@gmail.com
[2] Great Basin Observatory, White Pine County, NV

Abstract

WDS 19246+4447 is a two-component system with ten historical measurements. For this paper, 10 images of the system were acquired and analyzed to determine the separation and position angles of the stars. The separation of this system has changed by approximately 0.05″ over the last ~27 years. The measurements were plotted in comparison to those previously taken and were best modeled with a polynomial fit, which revealed little correlation in the data. However, similar proper motions and parallax angles (3.6403 mas for the primary star and 3.6290 mas for the secondary star) may indicate that the stars exert a gravitational influence on each other and thus could be true binaries. After an analysis of the space velocity vectors and physical separation, we conclude that DEA 304 is likely an optical double.

1. Introduction

The system WDS 19246+4447 DEA 304 was selected for observation. It was chosen because it was of the appropriate magnitude and declination to be observable by the Great Basin Observatory (GBO). A total of ten reliable observations of the system were made, including nine historical points taken from 1998 through 2015, and the most recent observation from 2025. The observations were compared to the historical measurements to examine the motion of the system's components. Parallax and proper motion data from Gaia DR3 (Gaia Collaboration et al. 2016b, 2023j) were also used to assess the motions of the stars and to determine if this system is physical.

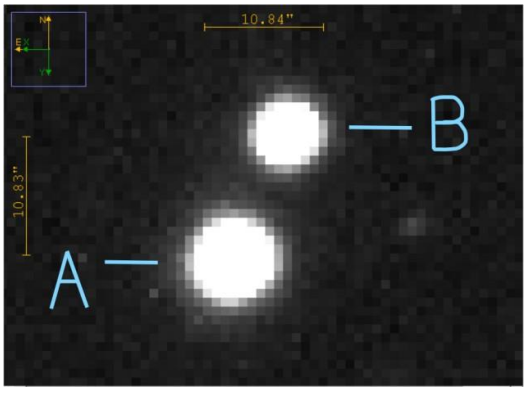

Figure 1. Finder chart for the components of WDS 19246+4447.

2. Equipment and Methods

The GBO, which was used for this project, consists of a Planewave CDK 700 telescope with an aperture of 27 in. It is located in Great Basin National Park and is managed as a partnership with Southern Utah University, University of Nevada-Reno, Great Basin National Park, and the Great Basin National Park Foundation (Anselmo, 2018). As the stars in the system have visual magnitudes of 10.84 and 11.96, an exposure time of 30 seconds was used, and a total of 10 frames were taken. The images were acquired through SG filter with a 2 x 2 binning on October 10, 2025 (2025.775, JD 2460959.309028) using a 0.7meter PlaneWave CDK700 telescope with a focal length of 4531 mm, a 700 mm aperture, and a focal ratio of 6.47. Additionally, we used a ZWO ASI6200MM Pro camera with a resolution of 0.34" x 0.34" per pixel, a pixel size of 3.76 x 3.76 µm, and a field of view of 0.46° x 0.3°. A finder chart for DEA 304 can be observed in Figure 1, while the observatory itself is displayed in Figure 2.

Figure 2. The Great Basin Observatory (Courtesy Paul Gardner)

The celestial coordinates for the images were acquired at GBO during the time of observation. Astrometric Stacking Program ASTAP (HNSKY, 2025) was later used to perform image calibration, including the application of bias, dark, and flat frames to the 10 images. AstroImageJ (Collins et al. 2017) was then used to measure separation and position angles. This measurement is illustrated in Figure 3. Seeing profiles for the stars in the system were also examined to ensure that they were not overexposed. Once the measurements were completed, the mean and standard deviation for each component was calculated. Comparison plots between the observed data and the historical measurements were produced using Plot Tool 3.19 (Harshaw, 2020).

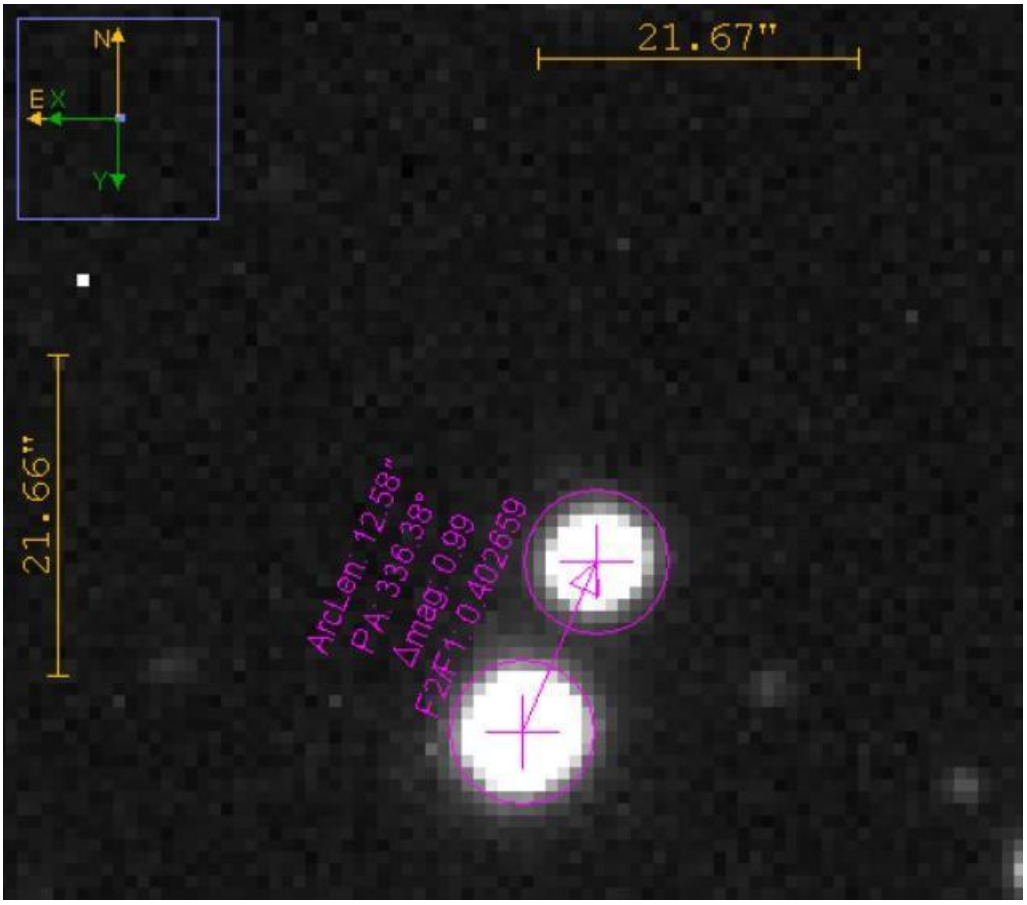

Figure 3. Measuring position angle (in degrees) and arc length (in arcseconds) with AstroImageJ.

3. Results

The results of the analysis, attributable to the ten collected images, are highlighted in Table 1. The mean values of ρ and θ, in tandem with the standard deviations and standard errors for both components are recorded here.

Table 1. Measurements of the separation (ρ) and position angle (θ) of WDS 19246+4447.

DEA 304	Position Angle (θ)	Separation (ρ)
Mean Value	336.411°	12.586"
Standard Deviation	±0.042°	±0.019"
Std. Error of the Mean (n=10)	0.013°	0.006"

4. Discussion

To compare the measurements with past observations, historical data was requested from the Naval Observatory (Matson, 2024). There are ten previously recorded measurements for this system listed in the Washington Double Star Catalog; however, the measurement obtained in 1893 was removed as an outlier due to precession. This historical data, along with recent measurements, are presented in *Table 2.* It is evident that minimal apparent motion (approximately 0.05") has been observed over the last century.

Table 2. Historical data for the AB components of WDS 19246+4447.

Year	Position Angle (θ)	Separation (ρ)
1893.81	338.4°	12.243"
1998	336.2°	12.6"
2003	336.5°	12.59"
2010	336.4°	12.56"
2012	336.48°	12.58"
2013	336.408°	12.56"
2013	336.45°	12.59"
2014	336.41°	12.58"
2015	336.15°	12.63"
2015	336.43°	12.59"
2025	336.411°	12.586"

To further understand the nature of the components of this system, parallax and proper motion data were retrieved from the Gaia DR3 database; this data can be observed in Table 3.Table 3. Gaia DR3 data for WDS 19246+4447. The reduced unit weight error (RUWE, Luri et al. 2018) is frequently used to evaluate the quality of Gaia data, and an RUWE value near one is indicative of reliable data. As the Gaia data for the primary and secondary stars can be approximated to this value, it is reasonable to assume the Gaia measurements are of good quality. WDS 19246+4447 is relatively nearby, at only about 275 pc away, which increases confidence regarding measurement of the parallax and proper motion.

Component	Gaia Source ID	Parallax (mas)	Distance-Range Calculation (pc)	RA Proper Motion (mas/year)	Dec Proper Motion (mas/year)	RUWE
A	2126256686975160000	3.6403 ± 0.0107	273.898 - 275.512	1.519 ± 0.014	-5.639 ± 0.013	0.932
B	2126256682672580000	3.6290 ± 0.0094	274.846 - 276.274	0.549 ± 0.012	-5.786 ± 0.011	0.859

Table 3. Gaia DR3 data for WDS 19246+4447.

The radial velocities of the components from Gaia DR3 are: RV_{PRI} = -40.52 ± 0.38 km/s and RV_{SEC} = 41.37 ± 0.63 km/s. The space velocity (V_{Space}) combines the radial velocity (with respect to the Sun) and the tangential velocity (i.e., proper motions). This value can be calculated using the following formula:

$$V_{Space} = \sqrt{RV^2 + \left(4.74\frac{\mu''}{\pi''}\right)^2} \qquad [Eq.\ 1]$$

In Eq. [1], RV is the radial velocity in km/s, μ is the total proper motion combining RA and DEC in "/yr, and π is the parallax of the component in ". Considering the errors of the proper motions and radial velocities of the components, the space velocities are nearly identical: PRI V_{Space} = 41.2 ± 0.4 km/s and SEC V_{Space} = 42.1 ± 0.6 km/s. Similar space velocities suggest that DEA 304 is a co-moving pair.

Using the newly measured separation angle along with the Gaia DR3 distances, the physical separation between the components was calculated using the law of cosines. The separation is 176,467 AU and this value uses the Gaia mean parallaxes and not the errors. Taking into account the errors in the parallaxes, the physical separation between the components ranged from 29,533 AU to 489,865 AU with an overlap in distance of approximately 137,372 AU.

To further assess the co-moving status of this system, we calculated the angle between each of the components' space velocity vectors in 3D space using the following equation:

$$\nu = \cos^{-1}\left(\frac{PRI \cdot SEC}{|PRI| \cdot |SEC|}\right) \qquad [Eq.\ 2]$$

This process is outlined in Nugent (2025), in which PRI·SEC represents the dot product between the primary and secondary component's space velocity vectors and |PRI|·|SEC| refers to the magnitude of such vectors. Nugent reasoned that values less than 15° indicate common space motion (CSM) pairs, values greater than 15° but less than 30° indicate similar space motion (SSM) pairs, and values greater than 30° indicate difference space motion (DSM) pairs. Following this procedure, a value of 1.75° was derived, thus suggesting that DEA 304 is a CSM pair.

To aid in determining if DEA 304 is gravitationally bound, the orbital period must be calculated using Newton's version of Kepler's 3rd law. This calculation is as follows:

$$P^2 = \left[\frac{4\pi^2 a^3}{G(Mass_{PRI} + Mass_{SEC})}\right] \qquad [Eq.\ 3]$$

In Eq. [3], P is the period, π is a mathematical constant, G is the gravitational constant, $Mass_{PRI}$ and $Mass_{SEC}$ are the masses of the primary and secondary components, and a is the semi-major axis of the orbit.

Following the procedure utilized by Nugent (2025), the masses of the components were calculated using the mass-luminosity relation (Lang 1992). This relation relies on the absolute bolometric magnitude of the components. The bolometric corrections were found using the effective temperatures (as listed in Gaia DR3) and the tables in Pecaut and Mamajek (2013). The spectral type for these components was not listed in the WDS catalog; however, their effective temperatures are consistent with spectral types of F9V for the primary and G6V for the secondary using these tables. Here, with an effective temperature of 6091 K, a bolometric correction of -0.08 was used for the primary. Similarly, the secondary had an effective temperature of 5588 K, thus the bolometric correction was estimated to be -0.15 for this component. Such values resulted in the following masses: $Mass_{PRI} \approx 1.28\ M_\odot$ and $Mass_{SEC} \approx 0.99\ M_\odot$.

With these estimated masses and the minimum separation (assuming both components are equidistant from the Sun) the period is estimated to be 1.2 million years (Eq. 3). This value reaches 17 million years when the mean physical separation is used with these component masses. Following the reasoning by Nugent (2025)-2, it is unlikely that the components are at a minimum physical separation of 29,533 AU considering the wide 137,372 AU overlap; however, there is still a possibility. This long orbital period based on this separation would explain the minimal change of observed position angles over the 27-year measurement period.

Boyce Astro has provided a probability calculator based on a note from Bob Buchheim, "Parallax Differences in Double Stars". Using this resource, the probability of the components being within one light year of each other in the radial direction is approximately 16.5%. This relatively low probability increases the likelihood that DEA 304 is an optical double, as opposed to a gravitationally bound system.

Conclusion

With a minor change in separation and a low R^2 value, it is difficult to determine whether this pair is physical from the historical measurements alone. While the proper motions appear to be identical on the celestial sphere, a space velocity vector analysis is required to confirm this suspicion. Here, DEA 304 maintains a low angle of separation (1.75°) and similar space velocities (with less than 1 km/s difference). However, based upon the large physical separation, DEA 304 is likely an optical double.

Acknowledgements

This project was made possible thanks to partnership with the Great Basin Observatory (GBO). We would like to thank those that operate the GBO. This research made use of AstroImageJ, Stella Doppie, and the Washington Double Star Catalog maintained by the U.S Naval Observatory. 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

Anselmo, Dallas, et al., 2018, Journal of Double Star Observations, 14(3), 492-495. http://www.jdso.org/volume14/number3/Anselmo_492_495.pdf

Collins, K. A., Kielkopf, J. F., Stassun, K. G., & Hessman, F. V., 2017, The Astronomical Journal, 153(2), 77. https://arxiv.org/pdf/1701.04817

Gaia Collaboration, T. Prusti, J.H.J. de Bruijne, et al., 2016b. The Gaia mission. Astronomy & Astrophysics, 595, A1. https://www.aanda.org/articles/aa/full_html/2016/11/aa29272-16/aa29272-16.html

Gaia Collaboration, Vallenari, A., Brown, A. G. A., et al., 2023j. Gaia Data Release 3: Summary of the content and survey properties. Astronomy & Astrophysics, 674, A1. https://www.aanda.org/articles/aa/full_html/2023/06/aa43940-22/aa43940-22.html

HNSKY, Han Kleijn. ASTAP, Astrometric Stacking Program. Available at https://www.hnsky.org/astap.htm.

Harshaw, R., 2020. Using Plot Tool 3.19 to Generate Graphical Representations of the Historical Measurement Data. Journal of Double Star Observations, 16(1), 386 - 400. http://www.jdso.org/volume16/number4/Harshaw_386_400.pdf

Lang, K., (1992), "*Astrophysical Data: Stars and Planets*", Springer-Verlag, New York. ISBN 0-387-97104-2, p. 116. Retrieved from: https://link.springer.com/book/10.1007/978-1-4684-0640-5

Luri, X, et al. 2018, Gaia Data Release 2: using Gaia parallaxes, Astronomy & Astrophysics, 616(A9), 19. https://arxiv.org/abs/1804.09376

Matson, Rachel, 2024, The Washington Double Star Catalog, Astronomy Department, U.S. Naval Observatory.

Nugent, R., (2025), "*An Analysis of the Double Star Systems WDS 02109+1341 STF 224 and WDS 10013-2246 HDO 124AB in 3 Dimensions*", Journal of Double Star Observations, Vol. 21, No. 4, pp. 370-382. Retrieved from: https://doublestarsjournal.org/index.php/jdso/article/view/137/41

Nugent, R., (2025)-2, "*Analysis of the Double Star WDS 08375-3345 HJ 4115*", Journal of Double Star Observations, Vol. 21, No. 2, pp. 129-135. Retrieved from: https://doublestarsjournal.org/index.php/jdso/article/view/67/15

Pecaut, M., Mamajek, E., (2013), "*Intrinsic Colors, Temperatures and Bolometric Corrections of PreMain Sequence Stars*", Astrophysical Journal Supplement Series, 208:9. Retrieved from: https://iopscience.iop.org/article/10.1088/0067-0049/208/1/9/pdf