Updating the Separation and Position Angle of WDS 08223-3408

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Abstract: The nature of most double stars is unknown due to a lack of observations and temporal coverage. One such double-star system is WDS 08223-3408, which has not had new measurements published in nearly six years. Previous measurements, dating back to its discovery in 1911, indicated that this system's angular separation, ρ, has changed by 0.340″ and its position angle, θ, has shifted 6.6°. The most recent published measurements from 2015 found ρ = 6.225″ and θ = 252.062°. This paper presents new measurements of ρ and θ from archived Las Cumbres Observatory images and from new images acquired in March 2021. The March 2021 observations were taken using SBIG STL-6303 CCD cameras mounted on 0.4-meter telescopes in the Las Cumbres Observatory Global Telescope Network. Two of the oldest reported values of ρ and θ, found in historical data on the system, are inconsistent with the rest of the reported measurements. The newest values, ρ = 6.190″ and θ = 252.238°, are similar to previous reported values, suggesting little change in the system over the past century.

Introduction

The double-star system WDS 08223-3408, also known as HD 70727 A & B, is located in the southern constellation Puppis. The exact nature of this system has not been firmly established. The visual magnitudes of stars A and B are V = 9.882 and V = 10.32, respectively (Høg, et al., 2000). The stars in this system were classified as A-type main sequence stars by the Michigan Catalogue of Two-dimensional Spectral Types for the HD Stars (Houk, N 1982). According to Gaia DR2 data (Gaia Collaboration, Prusti, T., et al. 2016, Gaia Collaboration, Brown, A. G. A., et al. 2018), the effective temperatures of the two stars are each ~8100 K, consistent with mid-A spectral types.

Prior to this project, only 10 observations of WDS 08223-3408 had been reported in the WDS catalog. The first measurement was made in 1911 by W. H. van den Bos while he was working at the Union Observatory in Johannesburg, South Africa. The most recent published observation was taken in 2015. Between 1911 and 2015, reported measurements implied a change in position angle of 6.6° and a change in angular separation of 0.340″ for this system. This apparent rate of change was one reason this system was chosen for new observations.

The main objective of this project was to obtain a current measurement of the angular separation and position angle for WDS 08223-3408. The measurements were made on CCD images obtained with 0.4-meter telescopes that are part of the Las Cumbres Observatory Global Telescope Network (LCOGT). Measurements were also made on images available in the LCOGT archive which happened to include WDS 08223-3408 in their field. The goal was to be able to better characterize this system.

Procedures

The Washington Double Star catalog was searched for systems meeting the following criteria: (1) right ascension between 4 and 17 hours, (2) declination between -80° and +80°, (3) angular separation between 5 and 10 arcseconds, (4) a primary star magnitude between 8 and 11, (5) maximum delta magnitude of 3 between primary and secondary, (6) fewer than 50 total observations, and (7) no published observations since 2015. These parameters were chosen to ensure the stars could be observed by telescopes in the LCOGT, the system could be clearly resolved with a 0.4-m telescope, and that sufficient time had elapsed that the new observation might provide a meaningful update to the observational record of the system. Several

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hundred stars met these requirements, from which WDS 08223-3408 was finally chosen.

Remote observations were acquired with 0.4-meter telescopes in the LCOGT network, each equipped with a SBIG-STL 6303 CCD camera. Each author submitted an observing proposal for 10 images, providing a total of 40 images of the WDS 08223-3408 system. Each image was a 2-second exposure through a clear filter and was reduced using LCOGT's BANZAI pipeline. Each set of 10 images were taken within 8 days of each other (two sets on 3/8/2021, one each on 3/13/2021 and 3/16/2021). Since the system is not expected to change on such a small timescale, the images were treated as one set of 40 consecutive images. Utilizing the centroiding algorithm in the software package AstroImageJ, the position angle and separation of the two stars were measured in each image (see Figure 1). The average position angle and separation values were calculated, along with the standard deviations and standard errors. These values are reported in Table 1 and Table 2.

The LCOGT also had 6 archived images centered on other objects but with the WDS 08223-3408 system in the field. Two of these observations were made with the 0.4-meter telescope in La Serena, Chile and 4 were made with 1-meter telescopes in La Serena or Sutherland, South Africa. Measurements of position angle and separation were also made on these images in AstroImageJ. Since these were single images on different dates, no statistics were calculated for these measurements. These measurements are also shown in Table 1.

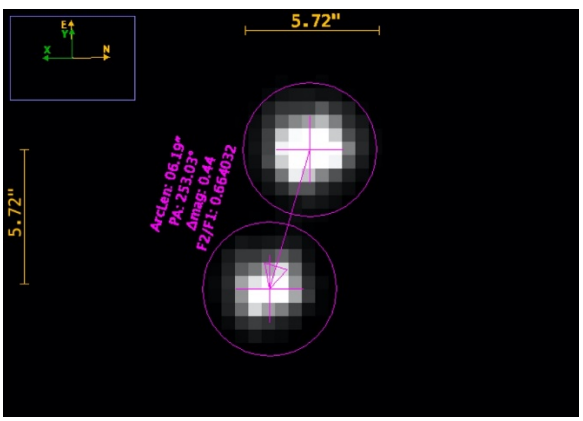

Figure 1. WDS 08223-3408 in AstroImageJ showing an example measurement of the separation and position angle using the centroid algorithm.

A data request was also submitted to Dr. Brian Mason from the United States Naval Observatory (USNO) for all historical observational data on WDS 08223-3408. These measurements are listed in Table 1. The historical measurements, the measurements from the archived LCOGT images, and the March 2021 measurements were input in the Plot Tool developed by Richard Harshaw (2020). One thing this tool does is convert the position angle and separation into Cartesian coordinates so they may be viewed in an xy-plane. The XY plot for this system is shown in Figure 2.

Results & Discussion

In Table 1, measurements made on the archived LCOGT images, the historical data from USNO, and the new measurements from the March 2021 observations are listed. The new reported values are an average of the measurements made on the 40 individual images. In Table 1, the row of values in italics (date 2017.2019) come from the average of measurements made on two images, both taken on March 14, 2017. The measurements from 1929.3 are from an unpublished source included in the UNSO historical data. This point is an obvious outlier (see Figure 2) and was given less weight in the analysis. Table 2 gives the standard deviations and standard errors for the March 2021 measurements of angular separation and position angle.

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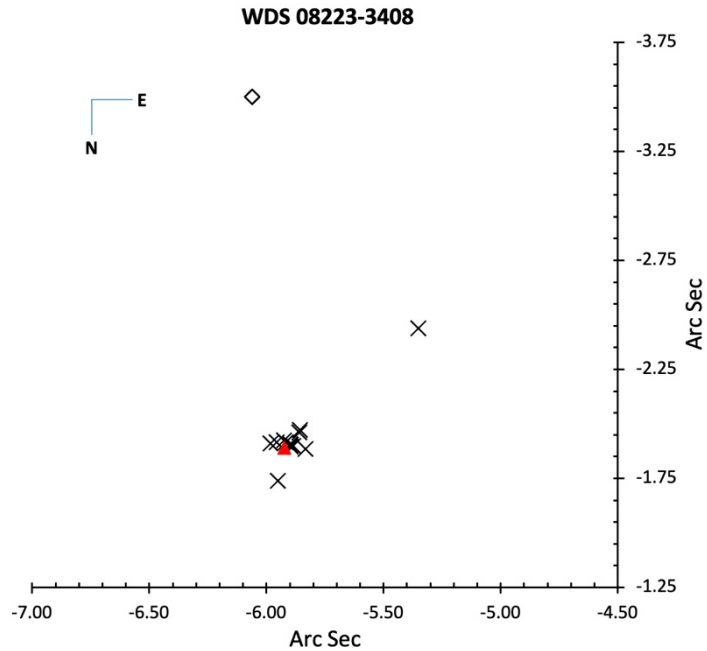

Figure 2. XY plot created using Plot Tool (Harshaw, 2020). The black crosses include historical data from the USNO and measurements from archived LCOGT images. The black diamond is an unpublished measurement included in the USNO data. The red triangle is the March 2021 measurement.

Source	Date	ρ (″)	θ (°)
USNO	1911.24	5.885	245.5
	1914.2	6.208	253.7
	1929.3	7	240
	1932.23	6.18	251.4
	1966.72	6.13	252.1
	1991.72	6.18	251.5
	1999.097	6.228	252.1
	1999.23	6.23	252
	2010.5	6.28	252.3
	2015.0	6.225	252.062
LCOGT Archive	2017.0459	6.1964	252.1079
	2017.2019	*6.2166*	*252.0618*
	2019.1567	6.1994	252.0868
	2019.3073	6.1928	252.1750
	2020.1013	6.2565	252.1634
March 2021	2021.1944	6.1905	252.2379

Table 1. This table contains measurements made from the archived LCOGT images, the historical data received from USNO, and the measurements from the March 2021 images. The italicized values (date 2017.2019) represent an average of measurements from two images taken on the same day.

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	ρ (″)	θ (°)
Average	6.1905	252.2379
Std. Dev.	0.0622	0.3878
Std. Error	0.0098	0.0613

Table 2. This table lists the standard deviation and standard errors computed from the 40 individual measurements from the March 2021 images.

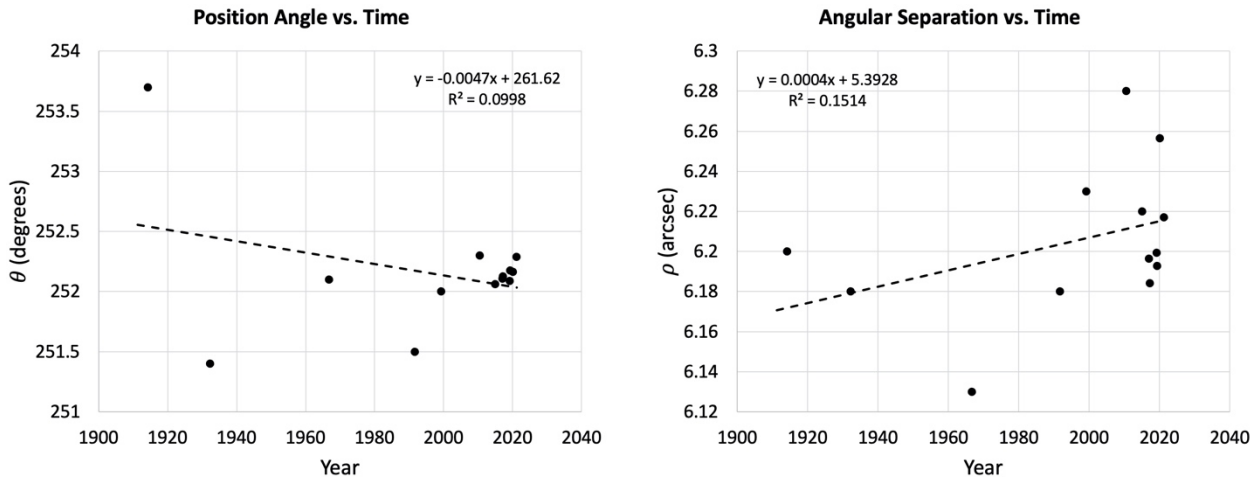

Figure 3. This plot shows the measurements of position angle and angular separation of the WDS 08223-3408 system over time. The outlying data points from 1911 and 1929, see Discussion, are not included.

The measurements of ρ and θ from the archived LCOGT images and the March 2021 images are consistent, all around ρ = 6.2″ and θ = 252.2°. In fact, these values are similar to the measurements going all the way back to 1932. In Figure 2, there are two points that appear to be outliers. The measurement from 1929, indicated by the diamond, is the most obvious. The other is the point around (-5.6″, -2.5″), representing the "discovery" measurement from 1911. Neglecting these two points, the measurements form a fairly tight cluster with no clear trend. Figure 3 shows how the angular separation and position angle of this system have evolved over time. While linear trend lines are shown for illustration, given the scatter in the data, neither trend is convincing. The evidence indicates that the system has not changed much over the last 110 years.

One complicating factor in the analysis is the distance to this system. Gaia EDR3 parallax measurements (Gaia Collaboration, et al. 2016, Gaia Collaboration, et al. 2020) yield a distance to star A of 538.01±4.66 pc and a distance to star B of 535.42±3.93 pc. This gives a physical separation between the stars of 2.59±8.59 pc. If the two stars were gravitationally bound, one would expect them to be approximately equidistant from Earth. While the Gaia distances are consistent with these stars being equidistant from Earth, the uncertainties mean this it is not conclusive. If the stars are in a binary system at a distance ≅537 pc, a distance this large means that any orbital motion that can be resolved will correspond to large orbital changes that would be expected to occur on long timescales. In other words, discerning any orbital motion will require a series of observations spanning a very long time.

The proper motion measurements from Gaia EDR3 yield total proper motion for star A of 6.066±0.033 mas/yr and for star B of 6.294±0.028 mas/yr. The percent difference of

these values is (3.7±9.2)%. Thus, it is possible that the two are physically related as a common proper motion pair, if not a bound system, but it is not conclusive. Again, the large distance to the system is likely contributing to the small magnitudes in the proper motion.

Conclusion

Whether the two stars in the WDS 08223-3408 double-star system are physically related or are merely an optical double is not known. Measurements of separation and position angle were taken on LCOGT archived images from 2017. Measurements were also obtained from new images of the system acquired in March 2021. These measurements were combined with historical measurements obtained from the USNO. Except for two outlying measurements from 1911 and 1929, the position angle and separation of these stars have changed little over the past 110 years.

Parallax and proper motion data from Gaia EDR3 for this system were also examined. The stars may be equidistant from Earth and with a physical separation that could allow a gravitationally bound system. However, given the error range on the physical separation, this is not conclusive. Similarly, the proper motion of the two stars in this system indicate that they appear to be moving together in space, allowing the possibility of a gravitationally bound system or common proper motion pair. However, the errors on the proper motion values also mean this is inconclusive.

Overall, the conclusion must be that more temporal coverage of this system is needed, likely over decades or centuries. More accurate parallax and proper motion measurements may be able to rule in or out a physical relation. However, given the distance to this system, it seems likely that its exact nature may not be known for quite some time.

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