Astrometric Measurements of WDS 21371-1622

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Abstract: We report new measurements of separation and position angle for WDS 21371-1622 (HJ 5282) taken on 2021 May 25 with the 0.4 m telescopes of the Las Cumbres Observatory. The separation and position angle for HJ 5282 AB were measured to be 20.52″ and 94.98°, respectively. These results, combined with historical data and Gaia measurements, suggest that the stars in the AB pair may not be physically related. We report a separation and position angle of 29.66″ and 9.93°, respectively, for HJ 5282 BC and confirm that the pair is not physically related.

1 Introduction

In this paper, we present new astrometric measurements of separation and position angle for WDS 21371-1622 (HJ 5282). A discussion of our target selection process and observations is given in Section 2 and our results are presented in Section 3. We provide a discussion of these results in Section 4.

2 Target Selection and Observations

We searched the Washington Double Star Catalog (WDS) (Mason et al., 2009) for sources appropriate for observation with the Las Cumbres Observatory global telescope network (LCOGT). The Gaia Double Star Selection Tool (GDS) (Rowe, 2020) was used to narrow results to those that fit the criteria shown in Table 1. Potential target sources were limited to those visible from the LCOGT and with magnitudes small enough to be easily seen with a 0.4 m telescope. We required double stars with a difference in magnitude less than 3 to ensure that the secondary component was not shielded by light from the primary. We also required that the stars be separated by more than 5″ to be clearly resolved by the LCOGT.

Table 1: Target Selection

RA range	11^h – 21^h
DEC range	-80°– +80°
Primary/Secondary Magnitude	6 – 12
Difference in magnitude	0 – 3
Angular separation	>5″

Stelle Doppie (Sordiglioni, 2020) was used to find additional information about candidate target sources that fit our search criteria. WDS 21371-1622 was chosen because of its significant change in position angle and separation since discovery. In addition, it had few previous observations and none since 2015. The information provided by Stelle Doppie for the AB and BC components of this source is shown in Table 2.

Table 2: Stelle Doppie Data for WDS 21371-1622

	AB	BC
RA	21^h 37^m 8.34^s	21^h 37^m 9.73^s
DEC	-16° 23′ 7.3″	-16° 23′ 8.5″
Date of Discovery	1836	1879
Initial position angle	80.0°	26.0°
Last recorded position angle	94.0°	11.0°
Initial separation	18.0″	29.0″
Last recorded separation	20.4″	29.6″
Change in sep since discovery	2.4″	0.6″
Pri, sec magnitude	10.38, 10.71	10.71, 11.52

WDS 21371-1622, also called HJ 5282, is a trinary system discovered by John Herschel. The brighter AB pair was discovered in 1836 and the BC pair was discovered 43 years later in 1879. An Aladin (Bonnarel, 2000) image of the three components is shown in Figure 1 with the ABC components forming an ‘L’ shape in the center of the image. Stelle Doppie indicates that the nature of HJ 5282 AB is uncertain and BC are not physically related. The addition of new astrometric observations to historical data could reveal the nature of the AB component and confirm that BC are not physically re-

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Figure 1: Aladin image of WDS 21371-1622. The trinary system can be seen in the center of the image forming an 'L' shape. The primary component A is to the lower right, the secondary B is on the bottom left, and C is to the upper left.

We utilized the Las Cumbres Observatory global telescope (LCOGT) (Brown, 2013) for the observation of our source. The 0.4 m telescope and SBIG STL6303 CCD camera at the Teide Observatory on Tenerife was used on 2021 May 25 to collect 15 images, each with an exposure time of 1.5 seconds.

3 Analysis and Results

Prior to analysis, the data was passed through the OSS pipeline (Fitzgerald, 2018) to calibrate the images and perform an initial assessment of the quality of the data. Measurements of the position angle (θ) and separation (ρ) between the primary and secondary stars were taken using AstroImageJ (Collins et al., 2017). The Howell centroid method (Howell, 2006) was used to find the center of each star. A sample measurement of θ and ρ for both the AB and BC components is shown in Figure 2.

Measurements of position angle and separation were made independently for each of the 15 images for both the AB and BC components. The average value of θ and ρ were calculated, as well as the standard deviation and standard error of the mean. Astrometric measurements for the AB and BC pairs in each image, and well as the standard deviation and standard error, can be found in Table 3. We find that for the AB pair, the average position angle and separation are 94.97°and 20.52″, respectively. For BC, the average position angle is 9.93°and the average separation is 29.66″.

Table 3: Measurements of θ and ρ for HJ 5282

	AB		BC	
Image no.	θ (°)	ρ (″)	θ (°)	ρ (″)
1	94.89	20.53	9.89	29.59
2	94.91	20.58	9.84	29.68
3	94.96	20.57	9.98	29.61
4	94.81	20.56	9.82	29.56
5	94.93	20.57	9.82	29.61
6	94.96	20.59	9.87	29.59
7	94.81	20.56	9.93	29.57
8	94.83	20.56	10.03	29.61
9	94.83	20.54	9.96	29.62
10	94.92	20.59	9.95	29.60
11	95.03	20.54	9.94	29.70
12	94.86	20.58	9.98	29.60
13	94.84	20.54	9.90	29.61
14	94.86	20.55	10.04	29.57
15	95.03	20.51	10.10	29.71
Average	94.97	20.52	9.93	29.66
Standard Dev.	0.074	0.025	0.084	0.046
Standard Error	0.019	0.006	0.022	0.012

4 Discussion

Historical data for HJ 5282 was requested from Dr. Brian Mason at the US Naval Observatory. This data was combined with our new measurements of position angle and separation to probe the nature of the target source and determine if an orbital solution could be found. The change of position angle and separation as a function of time were plotted for the AB and BC components to search for trends in the data. In addition, the Plot Tool 3.19 (Harshaw, 2020) was used to view the motion of the secondary component relative to the primary component and to calculate source distances, separations, and proper motions based upon Gaia DR2 (Gaia Collaboration, 2018) and EDR3 (Gaia Collaboration, 2021) measurements. A discussion of these results for the AB and BC components can be found in Sections 4.1 and 4.2, respectively.

4.1 HJ 5282 AB

A plot of the position angle and separation of the stars in the AB pair as a function of time can be found in Figure 3. Both

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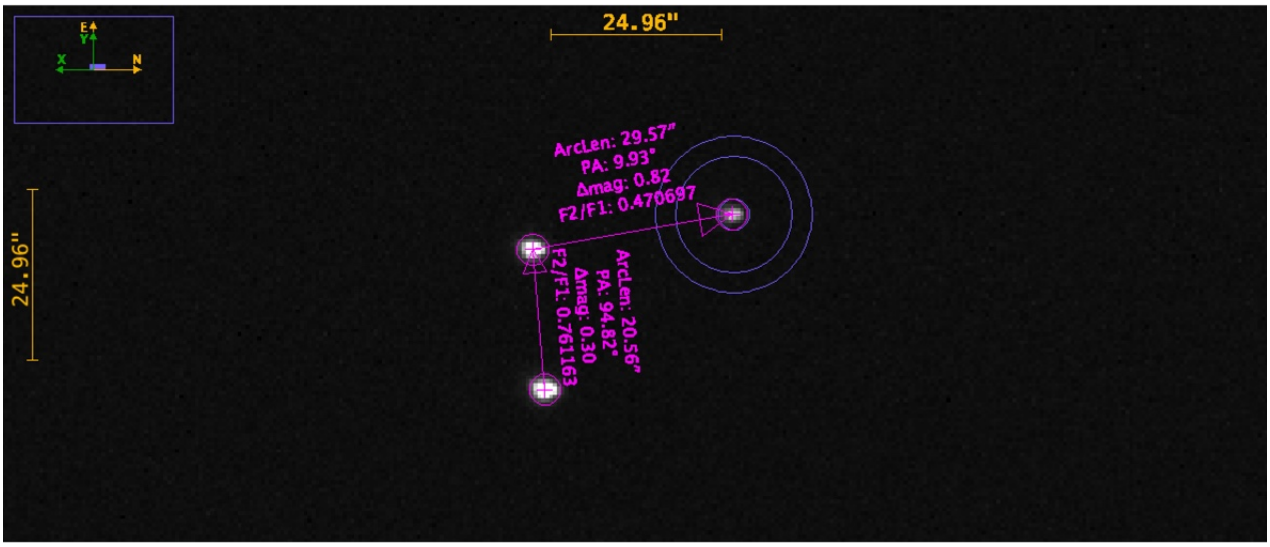

Figure 2: Sample measurement of separation (Arclen) and position angle (PA) using the Aperture Photometry Tool in AstroImageJ. Component A is at the bottom left, B at the top left, and C at top right.

the position angle and separation appear to be increasing with time. However, it should be noted that the separation reported for the discovery observation in 1836 does not fit the trend displayed by the more recent data. Similarly, the measurement of position angle from 1905 is much larger than expected given the trend of the other measurements. We have therefore decided to exclude the 1836 and 1905 measurements from the rest of our discussion for HJ 5282 AB.

The Plot Tool 3.19 was used to create a Cartesian plot (Figure 4) of the position of the secondary star (B) with respect to the primary (A) to glimpse how the stars are moving relative to each other over time. In the plot, star A is at the origin and the position of star B is shown by the diamonds. The historical data is shown in green and the results of this study are shown in red. The date of each observation is shown to the right of the respective data point. Careful inspection of the plot shows that most data points follow a smooth progression with time from the bottom left to the top right of the plot as star B moves from northeast of the primary toward the southeast. This motion is in agreement with the increase in position angle and separation seen in Figure 3. The two observations from 1913 yield significantly different results, although they were taken just a few days apart. In addition, these points are not in good agreement with the trend displayed by the rest of the data. We have therefore chosen to exclude them from our analysis of the AB pair.

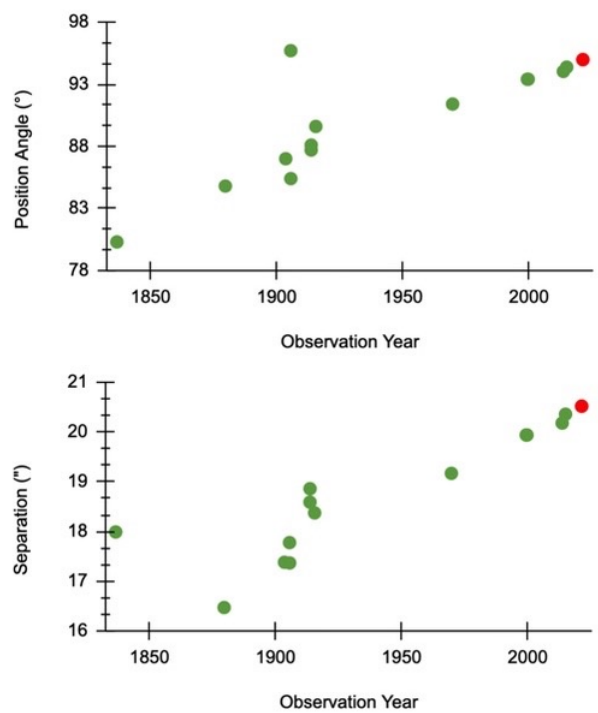

Figure 3: Position angle (top) and separation (bottom) as a function of time, omitting outlier data points. The results of the current study are shown in red.

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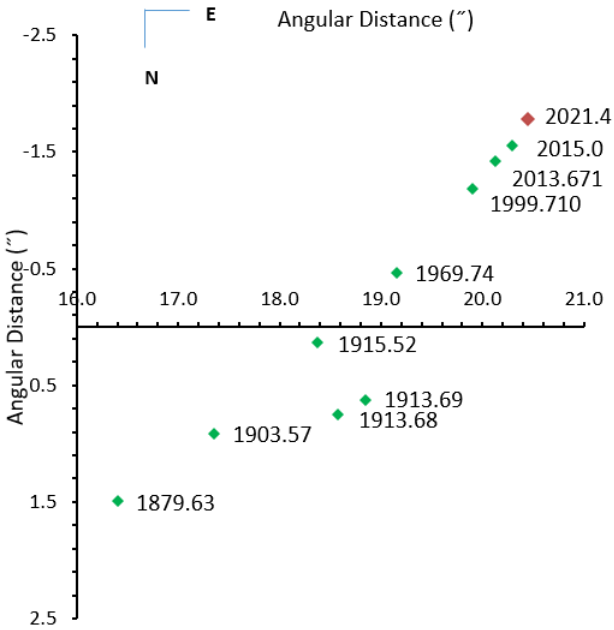

Figure 4: Motion of component B (green/red diamonds) relative to component A (at the origin). Historical data for B is shown in green and the results of the current study in red.

To determine more precisely the motion of component B with respect to component A, multiple fits of the data in Figure 4 (excluding the 1913 data) were performed. A linear regression fits the data well, yielding an R^2 value of 0.99. Visually, the trend appears to be curving slightly toward the southeast with the addition of the most recent data. The Desmos Orbital Solution Plotter (Hensley, 2018) was used to fit possible orbits for HJ 5282 AB. Given the seven-dimensional nature of finding the best fit orbit and our computational limitations, it should be noted that not all possible orbital solutions were tested. Instead, the Orbital Solution Plotter was used to visually minimize the residuals between the observations and the modeled positions to achieve the best fit as characterized by the largest R^2. Therefore, possible solutions are best guesses as to what the true orbital parameters may be. More accurate solutions may be achieved through the use of an algorithm to search all possible solutions. We found the best fit orbit to have an R^2 value of 0.97, suggesting that data are better fit by a linear trend. In addition, this best-fit solution required an orbital period that is much too short for stars with the expected masses and separation of the AB pair. We therefore conclude that the data are best fit by a linear trend, suggesting that the two stars are not a gravitationally bound binary system.

The Plot Tool (Harshaw, 2020) and data from Gaia DR2 and EDR3 provide additional information that can help characterize the nature of the system. EDR3 reports parallaxes for the A and B components to be 3.63 mas and 5.74 mas, respectively, implying distances of 275 pc and 174 pc for the two components. When these distances are combined with our measured angular separation, we find the minimum distance between the two stars is on order of 4400 AU. The Plot Tool reports that stars in the Sixth Catalog of Orbits of Visual Binary Stars (Hartkopf et al., 2021) with known orbits have an average separation on the order of 800 AU, with none larger than 5000 AU. Given the large difference in parallactic distance to the stars and the much larger-than-average separation for binary systems, it is unlikely that the pair is gravitationally bound.

Gaia EDR3 reports proper motions in right ascension and declination of 20.4 mas yr^{-1} and 0.83 mas yr^{-1}, respectively, for the A component. For B, the reported proper motions in RA, DEC are 46.0 mas yr^{-1}, -24.0 mas yr^{-1}. These proper motions lead to an expected relative motion of 5.06″ in separation and 134.14° in position angle when accumulated over the nearly 142 years since the first observation. We observe the stars to have a relative motion of 5.20″ along a position angle of 129.02°, in close agreement with the expected values. The agreement between the expected and observed relative motions based upon proper motion data suggests that the two stars are not in gravitationally bound orbits. This is further supported by the linear nature of the relative motion shown in Figure 4 and the larger-than-average separation of the stars in the pair.

4.2 HJ 5282 BC

A plot of the position angle and separation for the BC pair as a function of time is shown in Figure 5. Inspection of these graphs reveals a decreasing trend in θ with time, and an increase in ρ.

The Plot Tool 3.19 was used to create a Cartesian plot of the of the C component relative to B (Figure 6). The C component is moving clockwise with time on the plot, with the earliest observation from 1879 to the upper right and the results of this study shown in red to the lower left. As the component is generally moving from east toward the north, the position angle is decreasing, in agreement with the representation of the data in Figure 5. The relative positions of the BC pair are linear in nature, suggesting that HJ 5282 BC is an optical double rather than a physical binary.

Further study of the BC pair was done using the Plot Tool combined with Gaia DR2 and EDR3. Gaia EDR3 reports parallax measurements of 5.73″ and 0.63″ for the B and C components, respectively. These parallaxes lead to distances of 175 pc and 1597 pc for stars B and C. The difference in these

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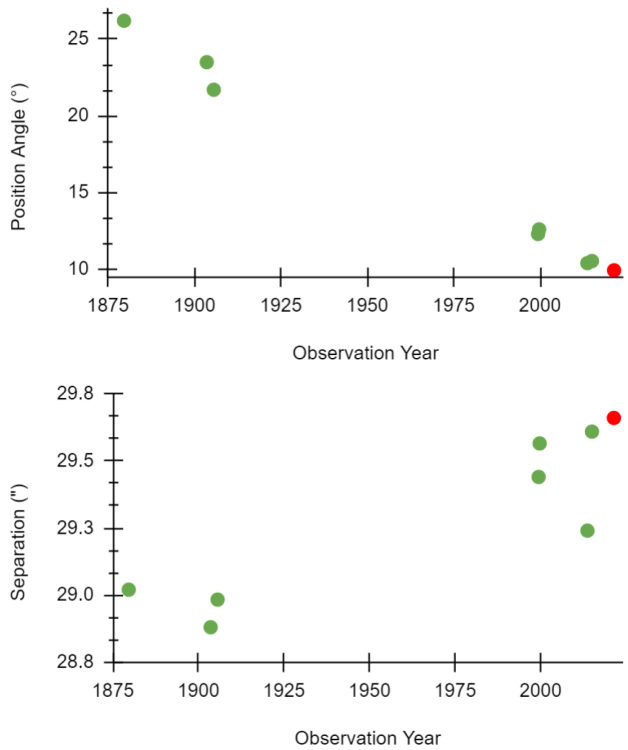

Figure 5: Position Angle (top) and Separation (bottom) as a function of time for the BC component, with the data for 1915 omitted. Historical data are shown as green circles and the results of the present work are in red.

distances suggest that the stars are not physically related.

In addition, an analysis of the proper motion of the components leads to further insight on the nature of the pair. Gaia DR2 reports proper motions in right ascension and declination of 46 mas yr^{-1} and -24 mas yr^{-1}, respectively, for the B component. For C, the reported proper motions in RA, DEC are -8 mas yr^{-1}, -2 mas yr^{-1}. These proper motions, accumulated over the 141.8 years since the first observation, lead to an expected relative motion of 8.27″ along a position angle of 292.17°. The observed relative motion, using both historical data and the new observations, was 8.33″ along a position angle of 292.43°, in close agreement with the expectation. This agreement further supports the non-binary nature of the system.

The linear nature of the Cartesian plot of the relative positions of the BC pair, combined with Gaia parallax information and the proper motion data, leads us to conclude that HJ 5282 BC is not a gravitationally bound binary. This is in agreement with the nature of the source reported by Stelle Doppie.

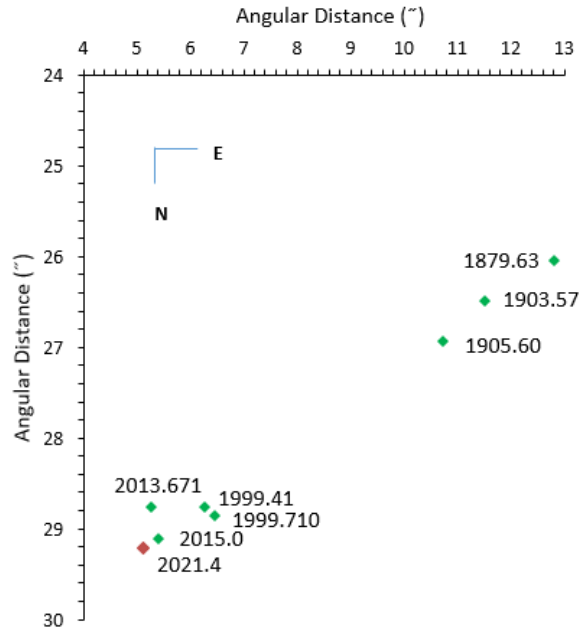

Figure 6: The position of component B (green/red diamonds) relative to component B (at origin). Historical data for C is shown in green and the results of the current study in red.

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This research has made use of the Washington Double Star Catalog from the US Naval Observatory.

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