Determining the Separation and Position Angle of WDS 04078-6903

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Abstract: Astrometric measurements of the double star system, WDS 04078-6903 were performed to find the current separation and position angle. Images of the stars were obtained through the Las Cumbres Observatory Global Telescope Network using a 0.4-meter telescope. The mean separation of the binary system is 6.88 arcsec and the mean position angle is 232.30 degrees. Based on a comparison with historical data, there has been no change in either the position angle or separation in the past six years.

Introduction

The purpose of this research was to determine the current position angle and separation of the double star WDS 04078-6903 (HJ3631). The Washington Double Star Catalog (WDS) identifies this system as a double located in the southern hemisphere constellation, Hydrus. The double star was originally observed by John Herschel in 1834 at his observatory at the Cape of Good Hope, South Africa. Both stars are main sequence stars with a spectral class of F7. The primary star has a magnitude of 9.93 and the secondary star 10.44.

According to records at the U.S. Naval Observatory, there have been nineteen observations of this double star since its discovery, fifteen of which involved measurements of position angle and separation. The last recorded measurements were taken in 2015 showing a separation of 6.88 arc seconds and a position angle of 232.30 degrees. The current measurement of the two stars was determined using images obtained with the Las Cumbres Observatory Global Telescope Network (LCOGTN). The comparison of the new measurements to historical data lead to an evaluation of the accuracy of some of the historical data.

Figure 1. The 0.4-m telescope at Cerro Tololo, Chile (Courtesy of LCOGTN)

Equipment

The FITS images used in this study were obtained using 0.4m robotic telescopes operated by the LCOGTN at their facilities at the Cerro Tololo Inter-American Observatory in Chile, and Siding Spring near Coonabarabran, New South Wales, Australia. The telescopes are identical Meade 16-inch (40cm) RCS optical tube assemblies, mounted in LCO equatorial C-

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ring mountings. The cameras used were SBIG STL6303 CCD cameras with 29.2x19.5 arcminute fields of view, and pixel size of 0.571 arcseconds, using clear filters.

Procedures

Over the course of four nights, between March 8 and March 24, 2021 (2021.18 - 2021.23), a total of 101 images were obtained through the LCOGTN. Eighty-five images were of sufficient resolution to be analyzed. A sample image is shown in Figure 2. Historical data of the pair was obtained from Dr. Brian Mason of the U.S. Naval Observatory. The software, AstroImageJ (Collins et al., 2017), was used to determine the current position angle and separation of our stars using the Howell (1989) centroid method which included a 4-pixel aperture radius and a background annulus from 20 to 25 pixels. The mean, standard deviation, and standard error of the mean for the separation and position angle were calculated.

Results

An analysis of the 85 images yielded a mean separation of 6.88 arcseconds and a mean position angle of 232.30 degrees. The standard deviation and mean were also calculated and are shown in Table 1.

Using the Plot Tool 3.19, created by Richard Harshaw (2020), the current position of the secondary star was plotted along with the historical position data obtained from Dr. Brian Mason of the U.S. Naval Observatory. The Plot Tool converted the astrometric measurements from polar coordinates to cartesian coordinates with the primary star at the origin (Figure 3). The data point indicated in red indicates the position of the secondary star in 2015 and 2021. The location of the secondary star reported by Herschel in 1834 is indicated in purple.

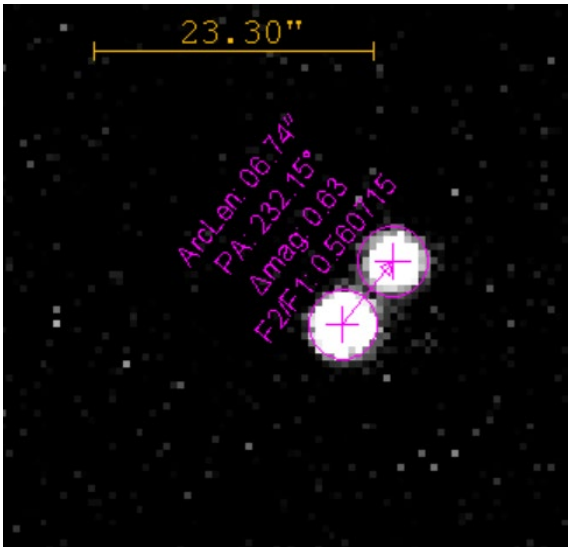

Figure 2. Image of WDS 04078-6903 in AstroImageJ. The circles indicated the centroid fit positions for the two stars.

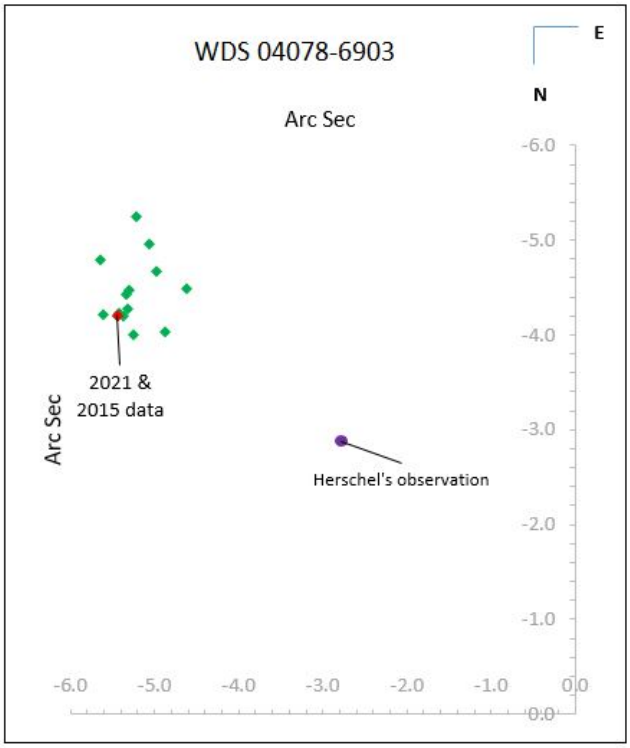

Figure 3. Plot of WDS 04078-6903 historical positions (green diamonds), Herschel's original measurement (purple circle) and current measurement (red diamond).

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85 images	**Separation**	**Pos. Angle**
Mean	6.88	232.30
St. Dev.	0.08	0.59
Error	0.01	0.06

Table 1. Summary of data obtained from analysis of 85 images with AstroImageJ.

Parallax and proper motion data for the primary and secondary star were obtained from the latest Gaia release, DR3 (Table 2). This data was collected by the Gaia telescope between July 25, 2014 and May 28, 2017 (J2016.0).

Star	**A**	**B**
Gaia Source ID (EDR3)	4666561166301850000	4666561170597180000
parallax (mas)	5.3167	5.4254
parallax err (mas)	0.1113	0.0811
PM RA (mas/yr)	11.794	12.425
PM RA err (mas/yr)	0.121	0.085
PM DEC (mas/yr)	-21.011	-21.037
PM DEC err (mas/yr)	0.149	0.097

Table 2. Parallaxes and proper motions for WDS 04078-6903 A and B from Gaia EDR 3.

Discussion

According to historical data obtained from the U.S. Naval Observatory, the last measurement of this star occurred in 2015 with a position angle of 232.30 degrees and a separation of 6.88 arcsec. The astrometric data from the current observations indicates no change in the star system's position angle and separation in the past six years, within measurement error. Figure 4 shows the position angle and separation of the secondary star as a function of time since 1851. While there is an overall upward trend in the position angle, there is a level of randomness in the measured separation with data appearing more consistent in the past few decades. This may be due to uncertainty levels in the measurements, especially in the earliest data, because of the nature of equipment used.

According to the data provided by GAIA EDR3 (Table 2), the parallax of the two stars is the same, within the measurement uncertainties,

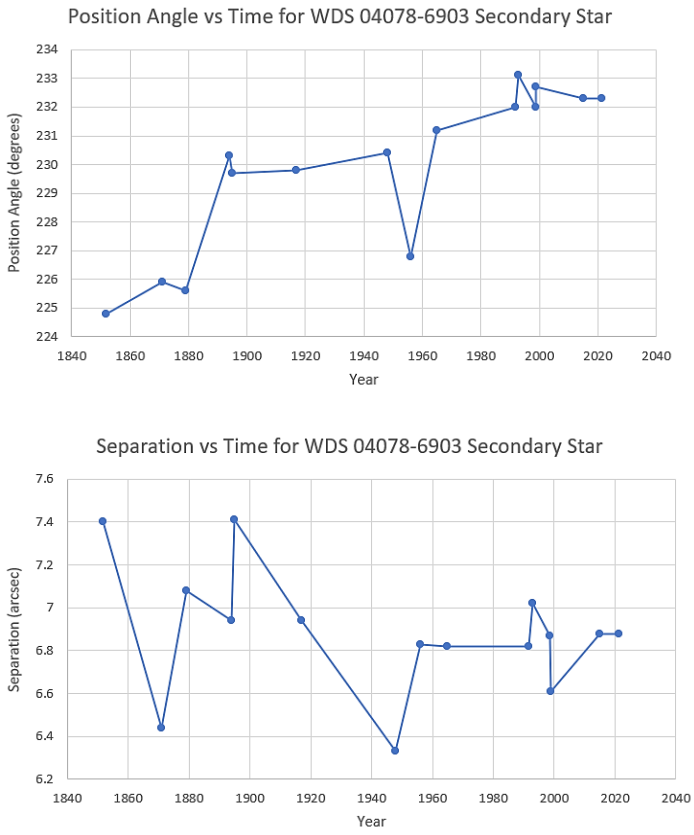

Figure 4. Position angle and separation of the secondary star since 1851.

indicating they are at the same distance. The proper motions in declination are -21.011 and –21.037 for stars A and B respectively, which can be considered the same values within measurement error. The values in RA are 11.794 and 12.425 are not the same within measurement error but are similar. Both the declination and RA measurements are close enough to support the idea these stars are a bound pair.

Information accompanying Harshaw's Plot Tool 3.19 indicates "analysis of 6,000 or so entries in the Sixth Orbital Catalog show that the average separation between stars is on the order of 800 AU, with nothing farther than 5,000". The weighted distance computation from the Plot Tool shows WDS 04078-6903 separated by 1,191 AU, which gives further support to these stars being a physical pair.

When analyzing the historical position data for this double (Figure 3), Herschel's 1834 measure appears to be an outlier, suggesting it may not be reliable. According to Herschel, his observations of this double were made with his 18-inch reflector. Herschel stated his primary mission when observing with this instrument was to discover nebulae and star clusters; double star measurements were a "subordinate interest" (Herschel, p. 164). He admits that his double star measures with the 18-inch were often hurried and not as accurate as his measures with his equatorially mounted 5-inch refractor. Of the separations of double stars measured with the 18-inch, Herschel says: "I consider them generally somewhat too small in the closer stars; they are also affected by the apparent size, neatness of definition, &c., of the stars [due to the visual image effects of large aperture], and are, of course, in a very high degree vague and precarious, serving for little more than general classification." (Herschel, p. 169). Herschel did not make a follow-up observation of this star with his 5-inch refractor, so we only have his unreliable measures with the 18-inch. As a result, the Herschel measurement should not be considered when determining the physical nature of this double.

Conclusion

Data obtained from the latest GAIA release shows the two stars have the same parallax and similar proper motions in declination and right ascension, supporting the nature of the system as a physical pair. According to the current analysis of images in this study, the position angle and separation of the star system have not changed in the past six years. There is a notable difference between the position angle and separation recorded by John Herschel and subsequent observation data, suggesting Herschel's data may be erroneous. According to observations of WDS 04078-6903 from 1965 to the present, the secondary star has shown little movement relative to the primary star in the past 56 years.

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