CCD Astrometric Measurements of WDS 0023-7238 HJ 5439

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Abstract: We obtained astrometric measurements of the double star system 0023-7238 (HJ 5439) using the iTelescope network and MaximDL v6 software. We measured a mean position angle of 79.2º ± 0.2º and an average separation distance of 9.53″ ± 0.04″; these measurements show a decrease of 0.4 º and 0.23” from the last measurement in epoch 1998.50. Historical and current data show no obvious signs of orbital motion, which suggests that HJ 5439 is a visual double.

Introduction

Double stars are star systems which appear near to each other in the night sky, they can be either aligned by chance, (an optical double star), or in other cases, are gravitationally associated and orbiting each other (a binary star). If a double star is found to be a binary system via multiple observations, an orbit can be plotted and from there the two stars can be “weighed” and thus the mass determined. The mass of a star is its single most important characteristic, allowing astronomers to approximate the life, luminosity, and the amount of material available for fusion.

Double star research offers a favorable entry for beginner researchers to do original work due to the relative simplicity in gathering the relevant data: separation and position angle.

A star system was selected that was visible during fall semester (August-December) to gain experience in planning astronomical observations. The Washington Double Star Catalog (WDS) was searched for candidates with a right ascension between 00 and 07 hours, a declination between -80º and 80º, a separation distance between 7" and 15", and a magnitude differential no more than 6. WDS 0023-7238 HJ 5439 (hereafter, referred to as HJ 5439) fit these parameters and had only 9 total previous observations. This was favorable because our data would be more valuable in providing new information about the star, such as determining whether HJ 5439, Figure 1, is a physical or visual double star. Filters were used when obtaining images to minimize atmospheric dispersion.

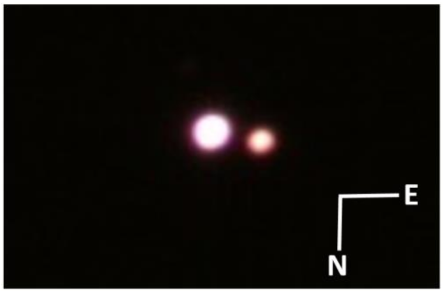

Figure 1. False color image of HJ 5439 by combining the frames from red, green, and blue filters. North is down, East is right and the size of the image is ~180″ by 120″.

Historical records state that HJ 5439 was first discovered in 1835 by Sir John Frederick William Herschel, the son of famed astronomer William Herschel (discoverer of Uranus). After being discovered, HJ 5439 was observed again in 1892 by an astronomer from Yale University, P.K. Lu, and since has been observed roughly every twenty years until 1998, when the 2MASS catalog recorded its position for the most recent measurement prior to this paper (2MASS Catalog). Notably, it appears that there are no papers specifically written about HJ 5439 specifically by any of its observers. Table 1 lists all known historical measurements for HJ 5439, recorded by the Washington Double Star database:

Date Observed	Position Angle (º)	Separation Distance (")	Primary Magnitude	Secondary Magnitude	Technique Code
1835.17	86.7	4.5	9.5	13	Mb
1892.79	83.7	9.496	-	-	Pa
1917.91	80.1	9.67	9.3	11.5	Ma
1926.90	79.7	9.254	-	-	Pa
1955.80	78.1	10.118	-	-	Pa
1977.888	79.1	9.62	-	2.5	Mb
1984.657	79.0	10.3	-	-	Pa
1998.500	79.6	9.757	10.09	12.01	Eu
1998.60	79.5	9.80	9.147	10.847	E2

Table 1. Historical measurements for HJ 5439. The Technique Codes for Table 1 can be seen below. Some measurements for the primary and secondary magnitudes were unavailable in the WDS database; and thus, are not reported here.

Table 1 Technique Codes

Pa = photographic, with astrograph
Ma = micrometer with refractor
Mb = micrometer with reflector
Eu = UCAC3 or UCAC4
E2 = 2MASS (Two Micron All-Sky Survey)

Equipment, Observations, and Data Analysis Procedures

Charged Coupled Device (CCD) images were taken using the T27 telescope, one of the many telescopes in the iTelescope network, located in New South Wales, Australia. T27, Figure 2, is also the largest telescope in the iTelescope network. Its primary mirror measures 27.5' (.7 meters) in length. The T27 telescope has a focal length of 4,531 mm and consists of a f/6.6 reflector along with CCD imaging for optimal imaging resolution. The CCD camera is 3056 by 3056 array (9 megapixels) imaging with a resolution of 0.53 ″/pixel (iTelescope - T27).

Figure 2. The T27 telescope from the iTelescope network used for the astrometric measurements of HJ 5439.

A total of 29 images were acquired on epoch 2016.82424 with the T27 telescope when the target was 40º above the horizon. Two images were taken with a red filter and two more images were taken with a blue filter. All four of these images had an exposure time of 60 seconds. A hydrogen-alpha filter was used to take another two more images with an exposure time of 150 seconds. We also used no filter ("luminance") to take an additional two images with an exposure time of 45 seconds. Lastly, 21 green images (19 unintentional images) were taken with an exposure time of 60 seconds. These specific exposure times were selected to ensure the prevention of oversaturation from the incoming rays of light, thus providing us with well-defined and highly resolved images.

All 29 of these images were preprocessed by the iTelescope data reduction pipeline to smooth out the distortions and adjust the resolutions. The images were then imported into MaximDL v6 software to attach the World Coordinate System (WCS) positions into the Flexible Image Transport System (FITS) headers by comparing the star field of our selected stars with respect to the Fourth U.S. Naval Observatory CCD Astrograph Catalogue (UCAC4). Throughout this process, MaximDL used 164 stars present around our star field to compute the precise coordinates of our binary stars within 0.14".

Mira Pro x64 was used to perform astrometric measurements to find the position angles (Theta) and separation (Rho) of HJ 5439 in each image; this process required Mira Pro to determine the A and B component stars, accurately mark the coordinates of these stars, and measure the centroids of A and B stars using Mirametrics' proprietary algorithm. The data was measured under the assumption that the centroid is the geometric center of the star, Figure 3.

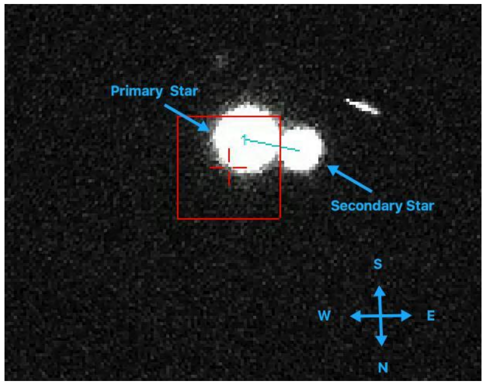

Figure 3. Mira Pro locating the centroids of the primary and secondary stars, dictated by the teal line, to perform astrometric measurements. The cross hairs centered on the red box are the coordinates of HJ 5439.

Mira Pro Results

The calculated values of the mean position angle and the mean separation distance of HJ 5439 for each filter used are outlined in Table 2. This table also includes the uncertainties associated with θ and ρ for individual filters and all 29 images combined. The listed uncertainties for θ and ρ are the standard error of the mean. These were determined by calculating the standard deviations of θ and ρ and dividing by the square root of the sample size, respectively. The mean position angle of all 29 images is 79.2º ± 0.2º while the calculated mean separation distance is 9.53" ± 0.04". These results indicate a discrepancy with the last measurement with reported uncertainties on 1998.50 (USNO), showing HJ 5439 as having a lower position angle with a shift of 0.3º. HJ 5439 shows a lower separation distance of 0.27" compared to epoch 1998.50.

HJ 5434 of 2016.82424				
Type of Filter: (specific #'s of filters used)	**Mean Position Angle θ (º)**	**Standard Error of Mean θ**	**Mean Separation Distance ρ (")**	**Standard Error of Mean ρ**
H-Alpha: (2)	79.8	-	9.40	-
Luminance: (2)	80.0	-	9.63	-
Red: (2)	78.1	-	9.46	-
Blue: (2)	79.3	-	9.47	-
Green: (19)	79.2	-	9.55	-
All Images: (29)	79.2	0.2	9.53	0.04
1998.50 measurement (Last analysis prior to this paper)	79.6	0.1	9.76	0.02

Table 2. Position Angle and Separation Distance measurements and uncertainties for HJ 5439. We also include the measurements from 1998.50, which was the latest analysis prior to this paper of HJ 5439.

Verifying Mira Pro

To test the validity of our results, we use an alternative astronomical imaging application, SAO DS9, to measure the position angle and the separation distance using the same methodology for two of our images. The separation distance differed by less than 0.5" and the position angle differed by about 2°, which is consistent with the uncertainties associated with the individual measurements. This analysis supports the idea that our measured results are robust and are expected to be consistent if verified independently.

Discussion:

The position angle, Figure 4, displays a counter-clockwise trend from 1835 to 1955. Assuming all historical measurements are accurate, between 1835 and 1920 theta has shifted 7° relative to the primary star. Between 1920 and 2016 theta has remained static; this discrepancy in the change of theta between the two respective time frames defies Newton's 1^{st} Law of Motion, suggesting that the 1835 measurement might be an error. The separation distance in Figure 5 has stayed constant around 10" except for the first measurement in 1835. Figure 6 shows that the secondary star demonstrates no obvious linear or arc-like motion with respect to the primary. For these reasons, we believe that our data, compared with the historical data, supports the idea that HJ 5439 is a non-physically associated double star system.

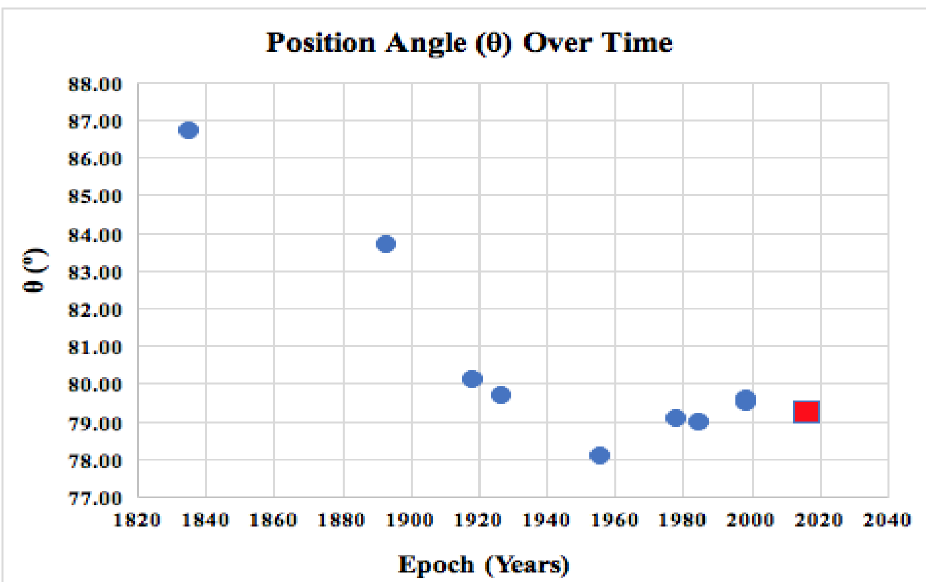

Figure 4. WDS 5439 position angle versus epoch. XY plot of the historical observations of HJ 5439's A & B component stars' relative positions. The blue dots indicate the position angles for each respective year. Our result (from Table 1) is marked as a red square. The error bars are too small to represent on this graph and the succeeding graphs, so they are omitted.

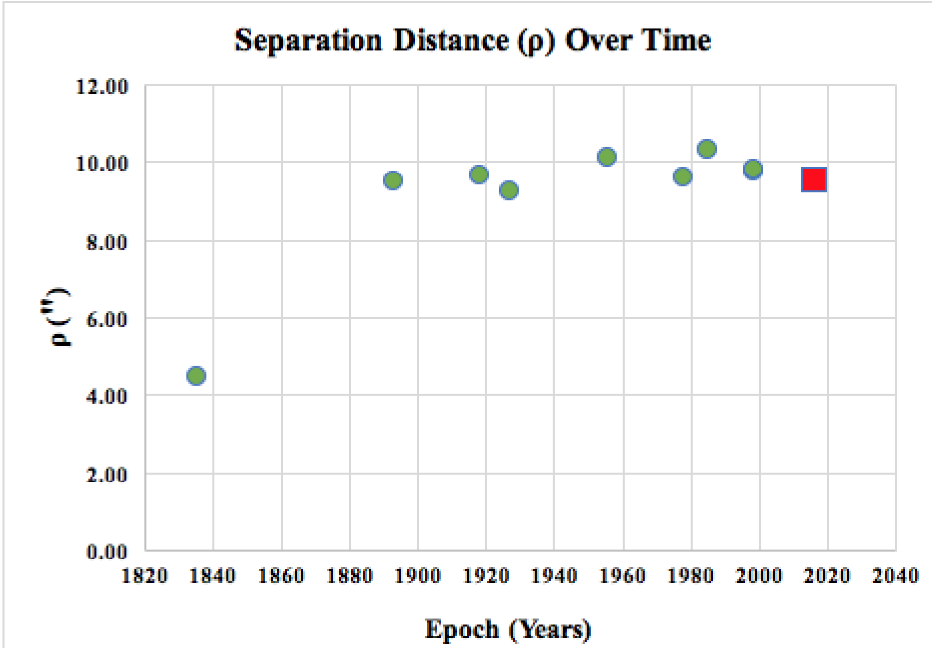

Figure 5. Separation distance versus epoch. XY plot of the historical observations of HJ 5439's A & B component stars' separation distances. The green dots indicate the separation distances for each respective year. Our result (from Table 1) is marked as a red square.

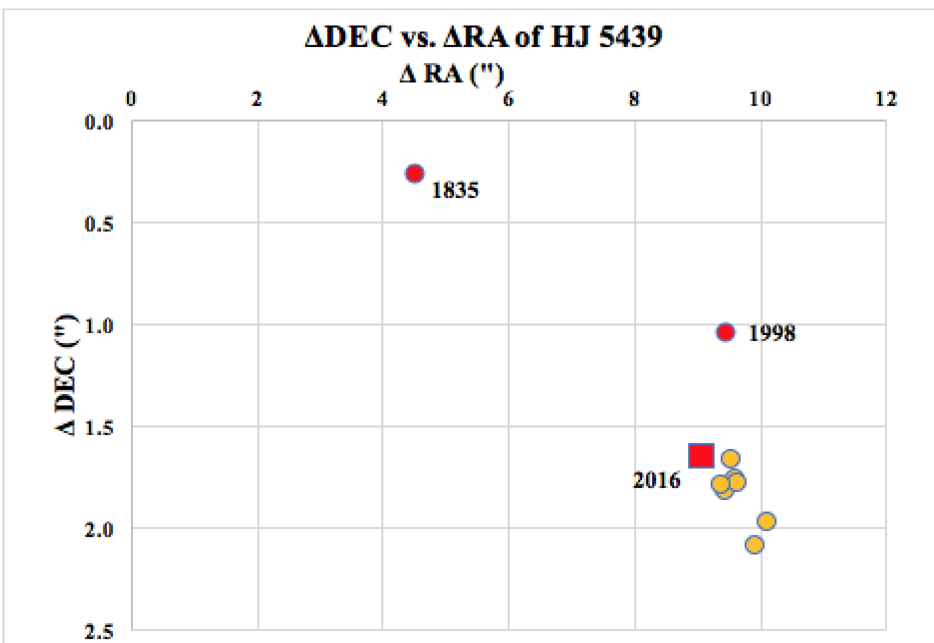

Figure 6. Relative declination versus relative declination plot of the historical observations of HJ 5439. This models an orbit with the primary component artificially fixed at the origin. The red points indicate the first and last historical measurements while our measurement is marked with a red square. The data presents no obvious indications of an arc or linear motion, suggesting that HJ 5439 is most likely a visual pair.

Conclusion

T27 from the iTelescope network was used to obtain 29 total images of 5 different filters of the double star system WDS 0023-7238 HJ 5439. We used astronomical imaging software to measure the position angle and the separation distance. Our measurements in epoch 2016.82424 were different from the most recent observation, measured in epoch 1998.50 yet consistent with many of the historical measurements. Our results, combined with the historical measurements, show no obvious orbital motion, suggesting that HJ 5439 may be a visual double star system.

Acknowledgments

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About the Authors:

Our research team consists of four students (Kelvin Nguyen, Sibi Radhakrishnan, Ariane Nazemi, and Max Schoenbrunner) who seek to gain valuable research experience while in the process of publishing our astrometric findings. Our goal is to help develop the scientific community's understanding of how this binary star system behaves throughout time and the various software that can be utilized to perform these measurements. We also hope that BRIEF continues to fund research in astronomy and produce many future publications.