Near Infrared Robotic Observation of Double Star System WDS 13513-3928

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Abstract: A near infrared robotic observation of the double star system WDS 13513-3928 was performed at the Siding Spring Observatory in New South Wales, Australia—part of the Las Cumbres Observatory Network. The mean position angle (θ) and separation (ρ) were measured to be 51.79° ± 0.01° and 28.32" ± 0.006", respectively, and were calculated from a series of twenty images. The mean values obtained, along with historical measurements from the United States Naval Observatory (USNO) and astrometric data collected by the European Space Agency's (ESA) Gaia satellite, substantiate the claim that the system is likely an optical double system.

Introduction

In observational astronomy, a double star system is a system of two or more stars which visually appear near each other in the sky (Genet 2015). As Genet explains in the Small Telescope Astronomical Research (STAR) Handbook (2015), these can be classified further as either optical doubles—stars which "appear close to each other in the sky because of their chance alignment along the line-of-sight from Earth"—or physical doubles—stars which are "traveling together as 'common proper motion pairs' or…gravitationally-bound binaries that rotate around a common center of gravity".

This research focused on making astrometric measurements of the double star system WDS 13513-3928 (hereafter HJ 4618), Figure 1. HJ 4618 was chosen for this project because it was listed in the Washington Double Star (WDS) Catalog as a non-physical binary, but showed some signs of possible orbital motion. HJ 4618 also had a body of historical data dating back to John Herschel's initial measurement in 1834, Table 1, and has been observed a total of 10 times—with the last time being in 2010.

The initial criteria laid out for choosing a star system for this project was specified as a right ascension (RA) between 12 and 18 hours, a delta magnitude of no greater than 6, and a separation of no less than 7". HJ 4618 fit our requirements with a RA of 13h 51m 17.77s, a delta magnitude of 2.78, and a separation of 27.4".

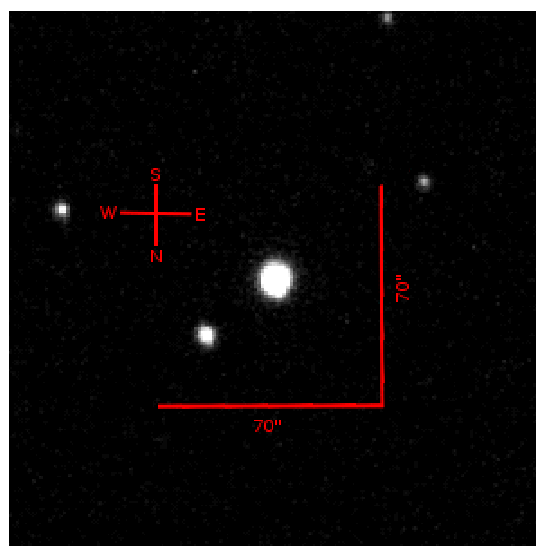

Figure 1. Near infrared CCD image of HJ 4618. ~38 second exposure using a PanSTARRS zs filter.

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Table 1: Historical measurements for the double star system HJ 4618 acquired from the United States Naval Observatory.

Epoch	θ	ρ
1834.48	339.6°	12.0"
1907.49	18.5°	16.1"
1913.63	22.5°	17.7"
1920.17	22.5°	17.6"
1929.43	28.9°	18.3"
1959.46	38.5°	21.3"
1998.52	48.1°	25.9"
1999.29	48.4°	26.1"
2004.36	49.0°	26.7"
2010.50	50.1°	27.4"

Equipment and Observations

The observations were made remotely at the Siding Springs Observatory in New South Wales, Australia, on epoch 2018.261. The equipment utilized was a robotically controlled 0.4 meter Meade telescope, Figure 2, mounted with a SBIG STX6303 Charged Coupled Device (CCD). The telescopes were accessed via the Los Cumbres Observatory network online observing portal.

A total of 20 images were ordered using the Pan-STARRS zs (near infrared) filter. The exposure times, Table 2, ranged between 38.277 and 40.297 seconds.

Processing and Analysis

Prior to receiving the images, they were processed in Michael Fitzgerald's Our Solar Siblings (OSS) pipeline. This process consisted of the following:

1. Any compression of the fits file is removed.
2. Files are renamed to something more human-readable. It contains the object name, the filter, the exposure time, the UTC time and date, the air mass, the MJD and the camera (and hence observatory location) the image was taken from.
3. The known bad parts of the image for that camera are marked bad. A database of the bad pixels for each camera in the pipeline access is stored.
4. For a smaller format camera, 20 edge pixels are removed from the image, because many CCD images misbehave around the edges.
5. A lower threshold count value for the image is estimated and pixels below this value are marked bad. Due to the known count distribution for any particular given image, it can be very clearly ascertained what the smallest physically reasonable value in the image should be. Any values below this are marked bad.
6. Cosmic rays are removed as much as possible.

Figure 2: Robotically controlled 0.4m Meade telescope at Siding Springs Observatory, NSW, Australia, with SBIG STX6303 CCD camera.

The parameters are set quite conservatively such that targets of actual interest are not affected, but even still, about 99% of the cosmic rays do get removed at this step.
7. The bad pixels are interpolated. The bad pixels are interpolated currently using a Gaussian Kernel.
8. Preview TIFs and JPGs are made. This makes it easy for project personnel as well as users to flip through the images quickly to see if any images need to be resubmitted.
9. A new World Coordinate System (WCS) is calculated and implemented. Any existing WCS is removed from the image, as the shape of the image has changed.
10. Adjustments to the fits header are made. A number of different software packages have different quirks that require fits header items to be set a particular way. These changes are made at this point to facilitate easy usage.
11. Images are distributed to users' Google drive accounts. Based on the USERID in the fits header, the final processed images are distributed straight into the user's Google drive account.

(for more on the OSS pipeline, see Fitzgerald 2018)

After the images were processed in the OSS pipeline, Mira Pro x64 was used to make the astrometric measurements. Mira utilizes an auto-centroiding feature that calculates the centroid based on a user provided sample pixel radius. The distance and angle tool is uti-

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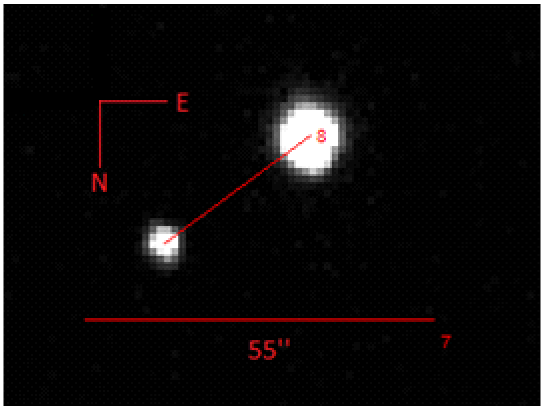

Figure 3. Position angle and separation measurements made with Mira Pro x64.

lized to draw a measurement line between the primary and secondary centroids of each image, Figure 3, and a table of all 20 measurements was exported into an Excel spreadsheet, Table 2.

Results

The mean, standard deviation (σ), and standard deviation of the mean (σ/√n) were calculated utilizing the measured θ and ρ values, Table 3. A mean measurement of 51.79° ± 0.01° and 28.32" ± 0.006" was calculated for θ and ρ, respectively.

Discussion

The new measurements, along with the historical data acquired from the USNO, were plotted on a Cartesian xy-plane showing the change in location of the secondary with respect to the primary star, Figure 4. This was done so that any trends or patterns could be observed in the data.

The parallax data collected by the European Space Agency's Gaia satellite (Gaia Collaboration et al., 2016) was also utilized in order to determine the rough distances to each star from Earth, and therefore allowed us to calculate the approximate distance between the primary and secondary stars.

It was found that the primary star had a parallax of 11.72 milli-arcseconds, and the secondary star had a parallax of 2.2559 milli-arcseconds (Gaia Collaboration et al., 2018). By utilizing the small angle approximation, the rough distance to each star from earth in parsecs (pc) can be calculated by

$$\text{Distance (pc)} \approx \frac{R}{\tan\theta} \approx \frac{R}{\theta} \qquad [1]$$

where R is the radius of the earth's orbit around the sun (1 astronomical unit) and θ is the parallax of the star in arcseconds. Using the Gaia parallax data for HJ 4618 with Equation 1, the approximate distances to the primary and secondary stars were calculated to be 85.3 pc and 443.3 pc, or 278.3 ly and 1445.8 ly, respectively.

Table 2: Table depicting the exposure times, position angle, and separation measurements of HJ 4618.

New Measurements of HJ 4618		
Exposure Time (sec)	θ (degrees)	ρ (arcseconds)
38.277	51.78	28.36
38.281	51.78	28.35
38.282	51.79	28.32
38.282	51.82	28.30
38.284	51.78	28.32
38.284	51.86	28.33
38.285	51.85	28.28
38.287	51.81	28.29
38.288	51.79	28.34
38.289	51.70	28.37
40.280	51.80	28.31
40.279	51.81	28.32
40.279	51.76	28.29
40.281	51.73	28.34
40.283	51.84	28.29
40.283	51.79	28.33
40.285	51.86	28.30
40.286	51.85	28.35
40.291	51.77	28.35
40.297	51.73	28.35

Table 3: The calculated mean, standard deviation (σ), and standard deviation of the mean (σ/√n) of HJ 4618 using the 20 measurements in Table 2

Statistical Analysis of Measurements		
	θ (degrees)	ρ (arcseconds)
Mean	51.79	28.32
σ	0.05	0.03
σ/√n	0.01	0.006

We were then able to take the distances calculated above, along with the right ascension and declination, and translate them from an earth-centered spherical coordinate system into a more familiar Cartesian coordinate plane, Figure 5, in R^3.

By translating into a Cartesian coordinate system,

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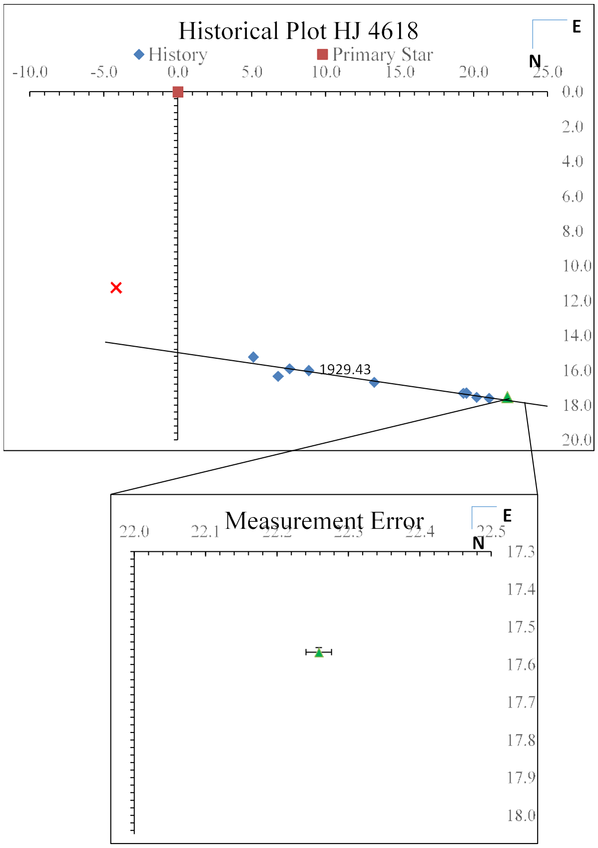

Figure 4: Historical plot showing all of the known measurements to date (upper). This plot shows the relative change in position of the secondary star in relation to the primary star. Please note the Herschel measurement (denoted with a red x) on 1834.48 was regarded as an outlier with respect to the trend line shown here.The exploded plot (lower) shows the error bars on the newest measurement, because the marker hides them in the original plot.

we were then able to utilize the distance formula in order to find the approximate separation between the primary and secondary stars in R^3, Equation 2.

$$\text{Separation (ly)} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2} \quad [2]$$

The approximate separation between the primary and secondary stars was calculated to be 1167.5 light years.

Based on the available data, the authors have concluded that HJ 4618 is likely a visual binary system. This conclusion has been reached utilizing all of the available historical data along with the newest data point we recorded, and the astrometric data provided by the ESA Gaia satellite.

When the Herschel measurement in Figure 4 is regarded as an outlier, the plot shows a continuing linear motion trend between the primary and secondary stars.

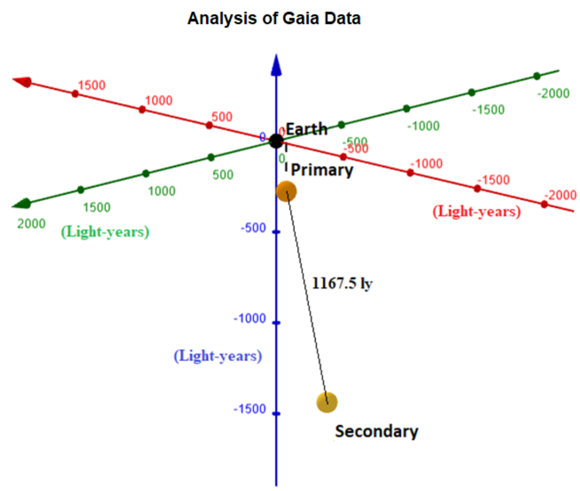

Figure 5: Plot showing the approximate distances between earth and the components of HJ 4618.

Given the successive measurements that lie on or near the linear trend line, the secondary star appears to be moving away from the primary star with no gravitational effects. The data point that we recorded fit this linear trend line very well with minimal deviation.

Given the estimated 1167.5 light year separation of the primary and secondary stars, Figure 5, the authors have determined it is highly unlikely that they are exerting any noticeable gravitational effects on each other. Future research would likely include an examination of the proper motion of these stars in order to determine their velocity toward or away from each other.

Conclusion

On epoch 2018.261, near-infrared images of possible binary star system HJ 4618 were taken at the Siding Springs Observatory in New South Wales, Australia. The calculated θ and ρ values were 51.79° ± 0.01° and 28.32" ± 0.006", respectively.

The authors have concluded, based on the available data, that HJ 4618 is likely a visual binary system, and are not gravitationally influencing each other

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About the Authors: Stephen, James, and Carson are all undergraduate Physics and Astronomy students at the New Mexico Institute of Mining and Technology in Socorro, New Mexico.