Astrometric Measurements of Binary Star System WDS 12069+0548

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Abstract: Astrometric measurements were obtained of the double star system WDS 12069+0548 HJ 1210 using the iTelescope network. A mean position angle of 116.68º ± 0.40º and a separation distance of 7.044″ ± 0.123″ were measured, and showed an increase of 1.23º and 0.052″ respectively from the last observation in epoch 2012.220. Historical data, in combination with our current measurements, were unable to show obvious signs of orbital motion. While the data was inconclusive in verifying the previous assumption of the system being a physical binary based on the relative proper motion, it was in line with the historical trend of a gradual increase in position angle and separation.

Introduction

The main objective of this research was to make astrometric measurements of the binary star system WDS 12069 +0548 HJ 1210 (hereinafter HJ 1210) to determine the position angle (θ) and separation (ρ), contribute data to the Washington Double Star Catalog (WDS) observations, and attempt to confirm the previous assertion that the system is gravitationally bound based on the relative proper motion. Making additional measurements of this system not only allowed us to contribute data to the scientific community, but it will also enable others to both learn from and build upon our contributions in the future.

Criteria for candidate star selection was a right ascension between 12 and 18 hours, a delta magnitude no more than 6.0, and a separation no less than 6.5" (arc seconds). The WDS was utilized to find a candidate. HJ 1210, Figure 1, fit the criteria with a right ascension of 12h:06m:56.52s, a delta magnitude of 2.41, and a separation of 6.992".

Historical reports, obtained from the United States Naval Observatory (USNO), show that HJ 1210 has a total of 28 observations between 1828 and 2012 and was originally discovered by John Herschel, son of famed astronomer William Herschel. Herschel conducted astrometric research through 1833, during which time he discovered many double star systems, including HJ 1210 in 1928 (O'Connor 1999). After the initial discovery, HJ 1210 was measured 8 more times between 1898 and 1925. There was a renewed interest in the system, beginning in 1975, which led to 18 more observations through 2012, including an observation by the European Space Agency (ESA) Hipparcos satellite in 1991. Table 1 shows a selection of the known historical measurements obtained from the USNO Historical Report.

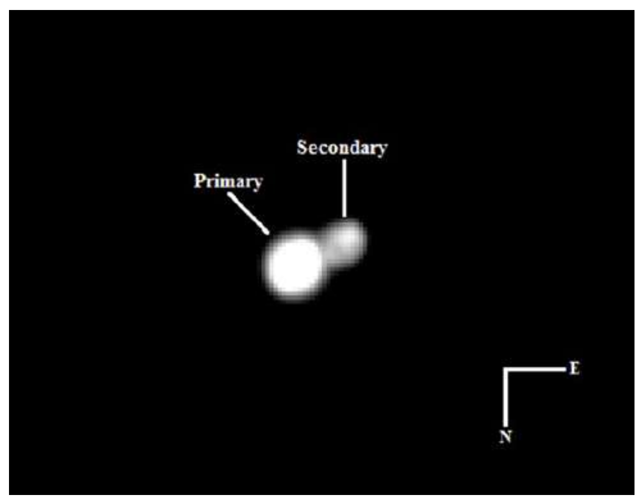

Figure 1. 30 second exposure luminance band filtered CCD image of HJ 1210

Equipment, Observations, and Analysis Methods

Images were obtained via the iTelescope network T27, Figure 2, at the Siding Spring Observatory in New

Table 1. *Selection of historical data for HJ 1210. Measurement taken in 1986 (theta of 25° and a rho of 9.23") shows significant departure from the trend outlined by other measurements and was excluded from any further consideration. Please note the somewhat random measurements in both position angle and separation reported between 1898 and 1925.*

Historical Data of HJ1210		
Epoch	Theta	Rho
1828.000	100.0°	6.500"
1898.310	110.5°	6.675"
1904.070	105.7°	6.540"
1909.270	107.1°	6.240"
1911.309	105°	6.830"
1922.040	107.2°	6.650"
1925.320	106.6°	7.500"
1975.220	114.38°	6.815"
1986.320	25°	9.230"
1991.25	114.5°	6.834"
2010.500	116.8°	7.190"
2012.220	115.45°	6.992"

South Wales, Australia, on epoch 2017.237 between 0130 and 0330 AEDT +1100 UTC. The equipment was a Planewave CDK 0.70-meter front lit reflector telescope with a FLI-PL 9000 Charged Coupled Device (CCD). T27 is the largest telescope in the iTelescope network, and is coupled with a CCD capable of taking images with a resolution of 0.53 arc-seconds per pixel (iTelescope).

Eight images in total were requested utilizing a luminance filter (15 and 30 second exposures), blue filter (15, 30, and 60 second exposures), and hydrogen alpha filter (60, 120, and 180 second exposures). Two of the images, the 15 and 60 second blue filter exposures, were too under- and over-exposed, respectively, to be able to obtain accurate measurements from and were discarded.

The images were imported into Maxim DL to apply the World Coordinate System (WCS) coordinates to the Flexible Image Transport System (FITS) headers of the images to affix the angle of the camera onto the images. Doing this allows accurate measurements of the system to be made. Maxim compared the stars in the image against the 4th U.S. Naval Observatory CCD Astrograph Catalog (UCAC4) to discern their right ascension and declination. By comparing 68 stars in our field of view with 166 stars in the UCAC4 catalog, Maxim was able to locate our system with an average residual of only 0.2".

The WCS calibrated images were imported into Mira Pro x64 to measure the position angle and separation distance between the primary and secondary stars in each image, Figure 3. The program's noise reduction tools were used to obtain better separation between the stars and allow more accurate measurements. Once measurements were obtained for each of the six images, the results were used to calculate the mean, standard deviation, and standard error of mean.

Figure 2. T27 - Planewave CDK 0.70 m Reflector Telescope. (http://www.itelescope.net/telescope-t27/)

Results

From the images obtained, a mean position angle of 116.68° was calculated with a separation distance of 7.044 arc-seconds, Table 2. These results show an in-

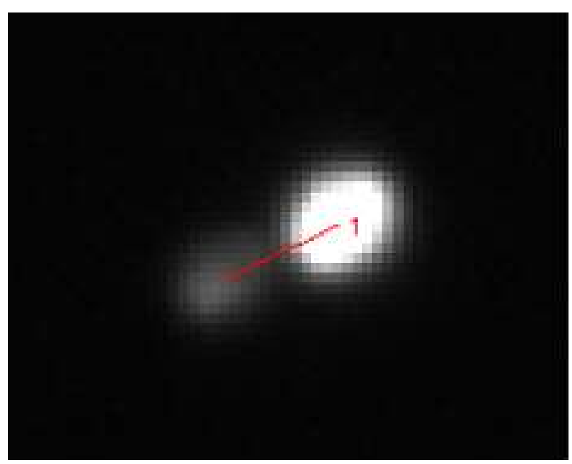

Figure 3. Depiction of how HJ 1210 was measured using Mira Pro x64. 120-second exposure with hydrogen alpha band filter.

Table 2. *Results of CCD Measurements*

Measurements of HJ 1210		
Filter - Exposure (s)	**Theta**	**Rho**
Luminance / 15s	116.147°	6.75305"
Luminance / 30s	118.238°	7.45136"
Blue / 30s	117.574°	7.39955"
Hydrogen Alpha / 60s	116.191°	6.9216"
Hydrogen Alpha / 120s	115.869°	6.86924"
Hydrogen Alpha / 180s	116.084°	6.87048"
Mean	116.684°	7.044"
Standard Deviation of the Mean	0.398°	0.123"

crease of 1.23° in mean position angle and an increase of 0.052" in mean separation distance when compared with the most recent observation in 2012. The increase in the mean separation distance is not significant given that our measurement resolution is 0.5" per pixel.

Discussion

Previous assumptions of the system being a physical binary were based on their relative proper motion. Combining our data with the previous measurements, we have generated three plots:

1) orbital plot for the system, Figure 4.
2) position angle as a function of time, Figure 5.
3) separation distance as a function of time, Fig. 6.

In each figure, the results are plotted together with the historic data and seem consistent with the trends outlined by the previous measurements. For example, in Figure 5, the result supports steady increase in position angle of the secondary component with respect to the primary. Given the 0.5” per pixel error in our measurements, the separation angle between the two components is constant since the first data was taken by Herschel in 1828.

In addition to this overall trend, if these two stars are physical binaries, all three figures point to likely errors in historic measurements. For example, both the position angle and separation distance measurements performed between 1898 until 1925 (early 1900s hereinafter) do not follow the linear trend. Position angle is seen varying by more than five degrees from the mean value outlined by our linear fit, Figure 5. The separation distance departs by one arc second from the linear fit, Figure 6. This is a substantial change and surpasses the overall change outlined by the full range of historic measurements. Even more convincingly, Figure 4 points to some random motion of the secondary star, with respect to the primary, in the early 1900s. The historical reports show that these early 1900s measurements were made using a micrometer on a reflector telescope, which is less precise and has a greater error than today’s methods, and are also not consistent with the laws of physics. We can therefore state that these measurements are likely observational errors.

All measurements made after 1950 show a tight distribution around the linear fit in Figures 4, 5, and 6.

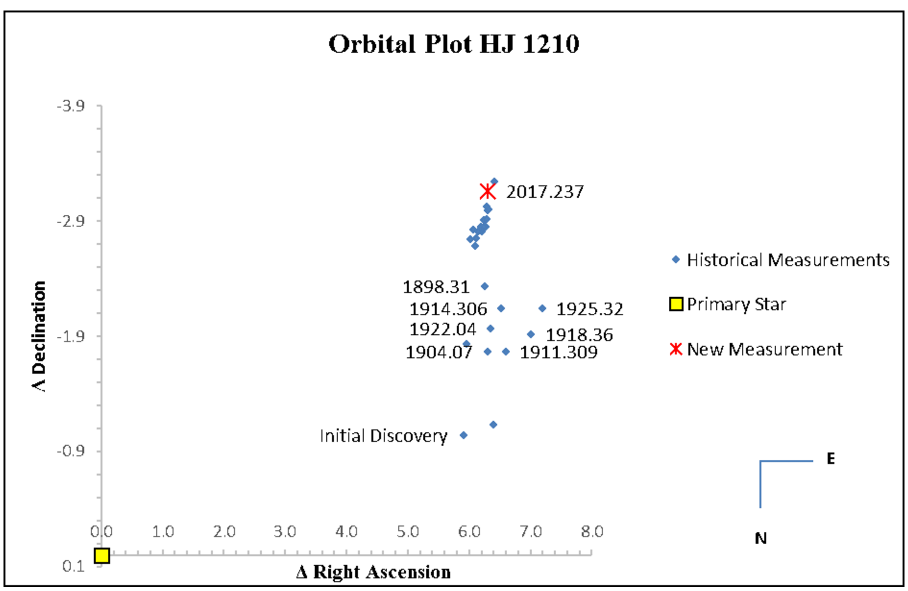

Figure 4. *Changes in declination and right ascension for HJ 1210. This plot models an orbit with the primary star artificially centered at the origin (yellow square). The blue diamonds represent historical measurements while the red asterisk represents our newest measurement. The early 1900s measurements are labeled and they show the random motion measurement errors of the secondary star with respect to the primary star.*

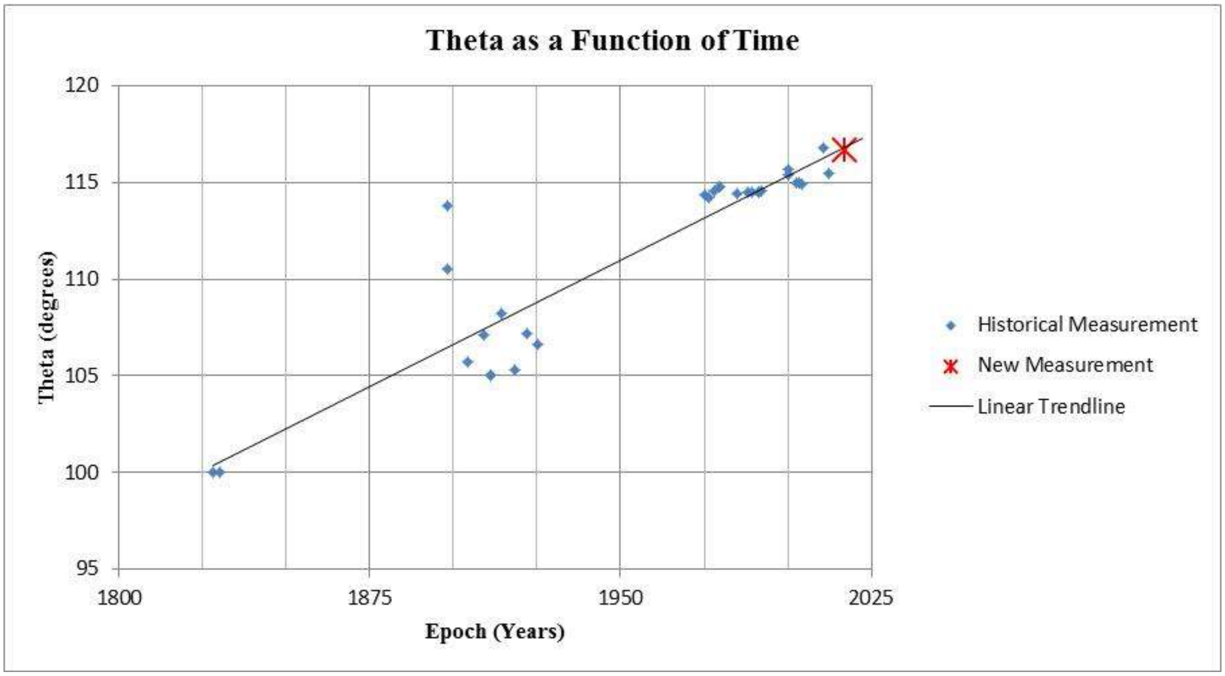

Figure 5. Change in position angle over time. The blue diamonds represent historical measurements while the red asterisk represents our new measurement.

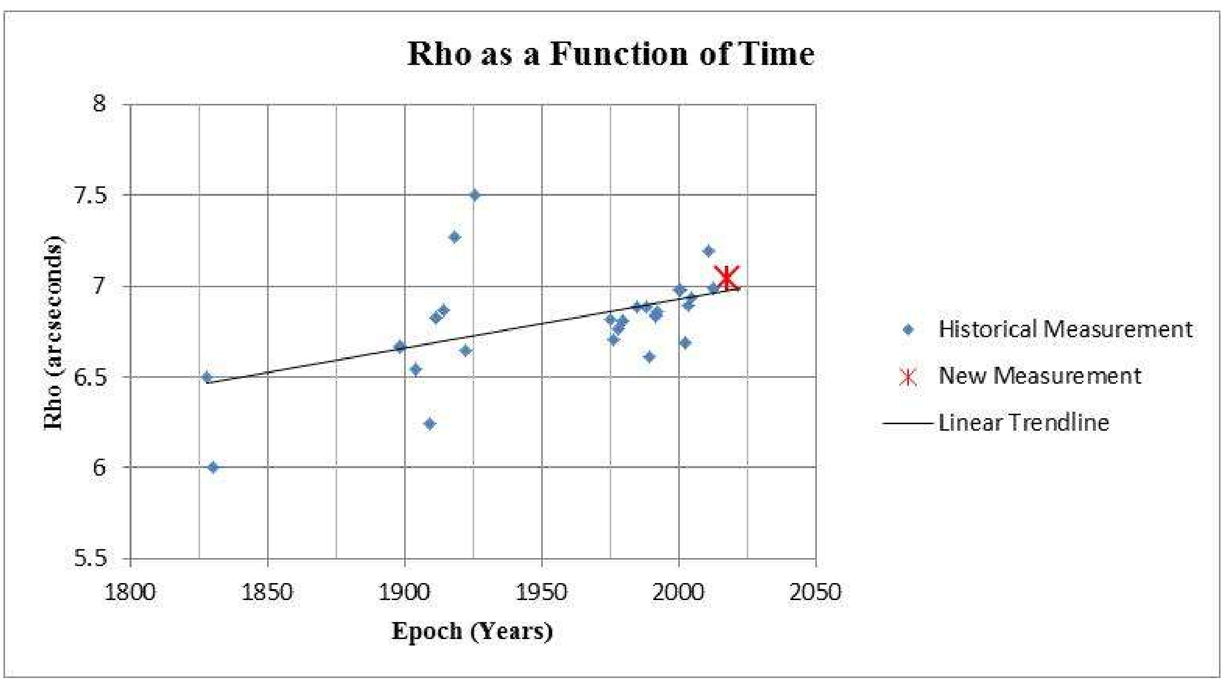

Figure 6. Change in separation distance over time. The blue diamonds represent historical measurements while the red asterisk represents our new measurement.

While the position angle is changing by several degrees (Figure 5) the separation distance remains constant (Figure 6). This is often the case when the secondary star is close to its aphelion and/or perihelion point. In the orbital plot, Figure 4, these data (taken after 1950) lie along a somewhat curved line.

If the measurements taken after 1950 are considered, together with the two initial Herschel measurements, they tend to lie along a straight line, inconsistent with the curved orbital path expected from a physically bound system. Since the distance to the HJ 1210 system is known, based on the separation angle between the primary and secondary component, we can estimate that our system, if binary, most likely has an orbital period of several thousand years. In binary systems with such a large orbital period, stars will spend several hundred years moving along straight lines, which poses a challenge in decidedly calling a system gravitationally bound based on the orbital plot alone. In addition, it has been shown in papers previously published by Boyce-Astro groups that some of Hershel's measurements had large errors. If this is the case in this system as well, maybe the real orbital motion would appear more curved than what currently is evident.

Conclusion

On epoch 2017.237, telescope T27 at the Siding Spring Observatory was used via the iTelescope network to obtain eight images, six of which were used, to make astrometric measurements of the position angle and separation distance of the binary star system HJ 1210. Astronomical image analysis software was utilized to make these measurements. Combined with the historic data dating back to 1828, our data did not show any obvious signs of orbital motion. However, a continuation of historic motion trends was confirmed. Some of the historic data indicates a somewhat random motion of the secondary star with respect to the primary, and is likely due to observational errors in the measurements in the early 1900s. The greatest challenge in interpreting this data was the questionable reliability of the historic data.

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***About the Authors**: This research team consisted of four students (Stephen White, Paige Benson, Sepehr Ardebilianfard, and Gezal Bahmani) from San Diego Mesa College. Our diverse educational foci—consisting of physics, astrophysics, electrical engineering, and bioengineering—meant that each of us brought a unique set of skills to the table, ultimately making the project both possible and enjoyable. This project was not only a way for us to experience firsthand the rigor of scientific research, but an opportunity to leave our first mark on the annals of science.*