Astrometric Measurement and Analysis of Celestial Motion for Double Star WDS 02176+5920

Marielle Cooper[1], Theophilus Human[1], Grady Boyce[2], Pat Boyce[2], Jae Calanog[1]

1. San Diego Miramar College
2. Boyce Research Initiatives and Education Foundation (BRIEF)

Abstract: Our team observed and analyzed the double star system WDS 02176+5920 (STI 1828) using the Las Cumbres Telescope network. The data was analyzed in AstroImageJ to measure position angle and separation. A mean position angle of 140.0° ± 0.2° (theta) and separation of 11.76" ± 0.05" (rho) was measured on Julian date 2458426.85100 The historical trend shows relatively no change in position angle and separation. However, the Harshaw calculation of the pair is low at 0.0017 (Harshaw 2014) and measurements on the proper motion of the right ascension and declination suggest the stars are moving in the same direction. These combined data points suggest a high probability that STI 1828 is common proper motion pair.

Introduction

The purpose of our research was to observe and analyze the position angle and separation of a double star system. The data was then analyzed to determine the nature of the selected double star to see if it could be classified as a physical or optical pair. A subcategory of physical double stars are common proper motion pairs which share similar proper motions but have very little relative change in separation over time (Greaves 2004). Classification of a physical binary can allow the total mass of the system to be determined, if an orbital solution is obtained and the distance to the system is known. As the nature of the STI 1828 system (shown in Figure 1) is unknown, the term double star shall be used throughout this paper.

To study double star pairs and determine their nature, the position angle (θ) and distance (ρ) between the stars is measured and compared to historical values. Graphing these values over time, it can be determined whether the stars may be gravitationally bound. Our research focused on WDS 02176+5920 (STI 1828). STI 1828 is in Cassiopeia and was selected as it met the requirements of falling between 00-08 RA hours, (02h 17m RA), having a separation greater than 5" (arcseconds), and a magnitude difference less than 3. Right Ascension was restricted between 00-08 RA as this is the portion of sky visible at night during October -November. The constraints of separations of greater than 5" and magnitude difference less than 3 were applied to ensure stars could be visibly separated in the telescope images. Additional selection criteria included a desire for magnitude visible through binoculars and a position in the Northern Hemisphere.

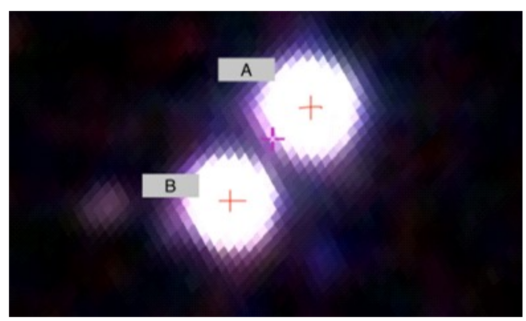

Figure 1. WDS 02176+5920 A is the primary star and B is the secondary

The first observation of this double star was recorded in 1908 by Johan Stein at the Vatican observatory with (θ) of 139.4° and (ρ) of 12.499". Since 1908 elev-

(Text continues on page 99)

Epoch	Position Angle	Separation
1908.05	139.4	12.499
1909.5	140.0	12.0
1910.97	140.2	11.408
1919.94	139.6	11.5
1921.85	138.9	11.66
1999.71	139.5	11.70
2003.68	139.8	11.742
2007.175	139.17	11.76
2010.5	140.0	11.76
2012.585	140.07	11.866
2013.066	140.13	11.776
2015.000	139.863	11.745
2018.843	140.0	11.76

Table 1: Historical Values of Position Angle and Separation Distance for STI 1828 02176+5920. Position angle is in degrees and Separation Distance in arc seconds. (Mason 2018)

en more observations have been recorded. The most recent measurement was in 2015 with (θ) of 139.8°, (ρ) of 11.745", and a difference in magnitude of 0.60.

Observations and Analysis

The Las Cumbres Observatory (LCO) was used for observation as its global network of telescopes allows for continuous visibility across the night sky. A 0.4-meter telescope was used mounted on a C-ring equatorial mount. The scientific camera used was an SBIG STX6303 mounted at the Cassegrain focus. Light was detected with the CCD capable of capturing 2048 x 3072 pixels with a resolution of 0.57 arcseconds per pixel. Default binning of 1 x 1 was used. The first data set was collected from the Haleakala site with telescope 2 (telescope id kb82) in Hawaii, USA. The second data set was collected from the McDonald Observatory using telescope 1 (telescope id kb92) in Texas, USA.

Two data sets were collected. The first one consisted of 18 images with the second having 15 images. The filters selected for the first data set were SDSS r', SDSS g', and clear. Filters were selected as the primary star had a spectral classification of G5V. For the second data set the same selection plus Bessel-B was used. Bessel-B was added to compare filter effects. Exposure times ranged from under a second for the clear to 12 seconds for the red filter. Due to telescope tracking issues for the images in the first data set, only the second data set was included for analysis. 15 images were analyzed from the second data set.

Data was returned after being processed through the Our Solar Sibling Pipeline (Fitzgerald 2018) which attached WCS coordinates, removed hot pixels, image artifacts, and flat fielded the images. The software AstroImageJ (AIJ) was used to analyze and measure the images.

The position angle and separation distance between the double stars was measured. 15 images were analyzed, four with SDSS red filters, four with SDSS green filters, three with Bessel blue filters, and four with no filter. The red filters at 12 seconds produced the clearest images while no filter and blue were lower quality images. AIJ then provided a measurement of position angle in degrees, separation distance in arcseconds, and delta magnitude between the stars. From the data the average standard deviation, and error were calculated for both position angle and separation. All data points were included as there were no obvious outliers and there was confidence in the measurement capabilities even at lower image qualities. For Epoch 2018.821 the average position angle was 140.0° ± 0.2° and 11.76" ± 0.05".

Discussion

The collected data was added and analyzed against historical data. Historical data suggested that no significant movement (movement greater than a standard deviation from the 2018 measurements) between the two stars had occurred in the past century. The data shown in Table 2 supports this conclusion. The movement recorded (Figures 2 and 3) through the century follows no obvious trend and it seems likely given the small differences that most or all movement falls within a standard deviation of each observation's measurement.

Epoch	Number of Images	Mean Position Angle (°)	Standard Deviation (°)	Mean Separation Distance (")	Standard Deviation (")
2018.843	15	140.0	0.2	11.76	0.05
2015.000	-	139.863	0	11.745	0

Table 2. Summary of the measurement of Position Angle and Separation Distance for STI 1828 02176+5920 from this paper compared to the last reported measurement in 2015. (Mason 2

Astrometric Measurement and Analysis of Celestial Motion for Double Star WDS 02176+5920

Of the 12 past observations, eight of the position angles recorded fall within the standard deviation of the 2018 position angle and seven within the standard deviation of the separation distance, Tables 1 and 2.

Graphs comparing position angle over time, separation over time, and the proper motion (Figures 2-4) demonstrate no clear relationship between the data points. Comparing the position angle data (Table 1 and Figure 2) from the early portion of the 20th century to the early 21st century, the range of the position angle remains within about one degree, with no obvious movement (Figure 2). While it is possible that there was a significant movement in both directions that then averaged out, it seems more probable that the accuracy of measurements improved over time, resulting in smaller standard deviations.

Graphing the separation distance against time , Figure 2, showed very little movement. Data from the late 20th/early 21st century is consistent, showing little change.

Figure 3 shows that separation distance in approximately the last 20 years has moved less than 0.2 arc seconds. While the early 20th century measurements show more variable separation distances, when combined with the modern measurements no clear pattern emerges.

The parametric graph also shows no clear movement in separation, Figure 4. Dates are marked on the

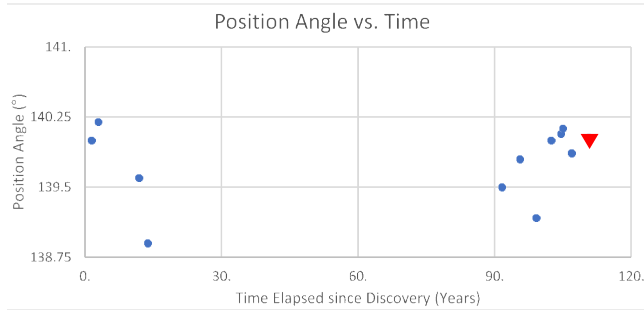

Figure 2. Graph of position angle (°) against the time passed since the first observation in 1908.05 including historical data and observations conducted. The red triangle marks the most recent data.

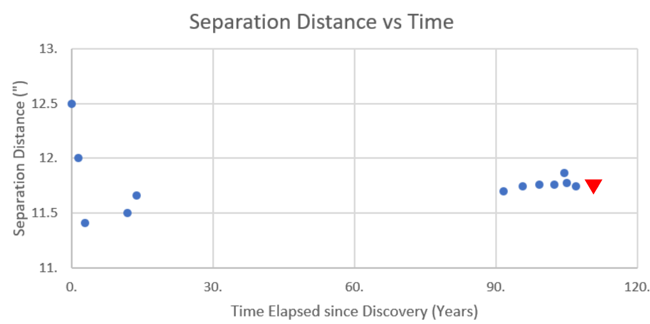

Figure 3. Graph of separation distance (") against the time passed since the first observation in 1908.05 including historical data and observations conducted. The red triangle marks the most recent data.

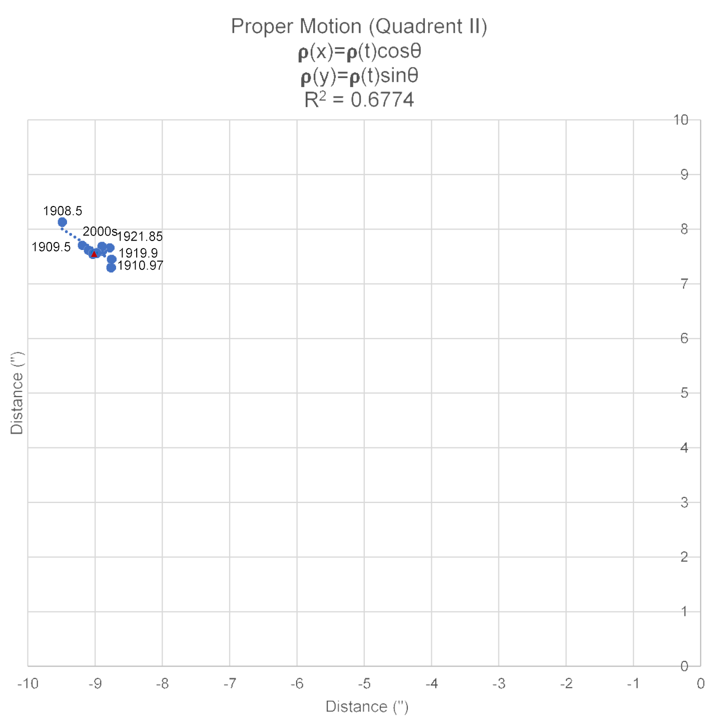

Figure 4: Graph of STI 1828 movement relative to the primary. The red triangle marks the most recent data. The R^2 for a linear fit is 0.6774 which does not fit a linear model.

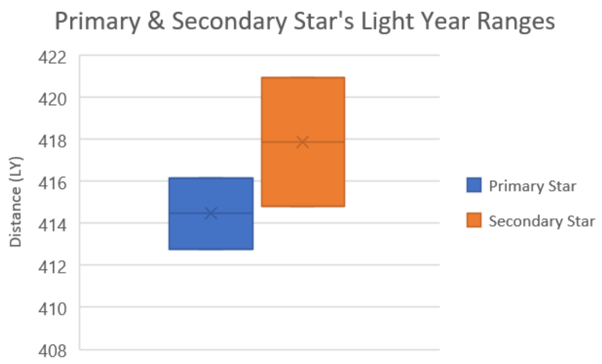

Figure 5. Graph showing potential distance overlap ranges between primary and secondary star.

graph to show the progression of time. The data is irregular, with 1998-2018 datapoints occurring clumped together while other epochs are spread apart. Analysis of the graph suggests a poor fit for either a linear or elliptic curve model, however it does fit a common proper motion pair model. As the movement is over a small range of values it is possible most movement is due to standard deviation in recording.

The proper motion of the star was also collected from Gaia release 2 data. It is summarized in Table 3.

Comparison shows that both the proper motion of the right ascension and declination of the primary and secondary are relatively close. This suggests that they are moving in the same direction.

There is evidence of stars having stellar companions (i.e. currently or previously gravitationally bound) with a distance of up to 8 parsecs between them (Shaya & Olling 2011). Gravitationally unbound stellar companions may be part of a stellar association, a very loose star cluster whose stars share a common origin but have become gravitationally unbound. Stellar companions with large distance between them are considered wide or very wide physical pairs (depending on distance). If the GAIA suggested 1.1 parsec separation between the primary and secondary star of STI 1828 is accurate it could comfortably fall into the wide binary range. Wide binaries often share similar proper motions making them common proper motion pairs or multiples (Shaya & Olling 2011). Common proper motion pairs are stars that have very similar proper motions but little to no relative motions between themselves over timescales of a century. The similarity of space motion however suggests they are related by origin. Additionally, it is common for their separation to be large enough to cause uncertainty of whether they orbit one another (Greaves 2004). STI 1828 seems to fit the categorization of common proper motion pair as it has a high degree of similarity between the star's proper motions.

The Harshaw Method (Harshaw 2014) was used to provide further analysis. There is a correlation between values close to zero being physical binaries and values close to 1 tending to be optical doubles. The result of the Harshaw calculation 0.0017 which suggests that STI 1828 is a physical double star though this method cannot predict the nature of the double's gravitational link.

There is a strong possibility that STI 1828 is a common proper motion pair as the proper motion suggests both stars are moving in the same direction. the Harshaw calculation predicts a physical pair, and the position angle and separation distance are relatively constant. The stars could also be gravitationally bound as the parallax suggests that the stars are close enough for a gravitational link to be possible. It is suggested that the position angle and separation distance be taken every five to ten years, to confirm consistency in the distance between the stars.

Conclusion

The data on STI 1828 suggests that stars are physically bound in a common proper motion pair. The new data acquired continued the trend of little movement in both position angle and separation distance over the last twenty years. The parallax data suggests the stars are close enough for gravitational linkage while the proper motion suggests the stars are heading in the same direction. The Harshaw analysis of this movement also suggests that that the primary and secondary star are physically bound.

Acknowledgements

This paper would not have been possible without the aide and support of the Boyce Research Initiatives and Education Foundation (BRIEF), Theophilius Human, Pat Boyce, Grady Boyce, and Jae Calanog. I thank them all for their time and feedback. The analysis and

Star	Proper Motion Right Ascension (mas/yr)	RA Proper Motion Uncertainty	Declination Proper Motion (mas/yr)	Dec Proper Motion Uncertainty
Primary	-43.411	0.06	-43.705	0.078
Secondary	-43.481	0.125	-43.903	0.127

Table 3: Summary of the Proper Motion of STI 1828. Data acquired from GAIA Release 2.

Astrometric Measurement and Analysis of Celestial Motion for Double Star WDS 02176+5920

work contained within also relied upon the LCOGT network and made use of the SIMBAD and Aladin databases operated by the CDS in Strasbourg, France.

This work has made use of data from the European Space Agency (ESA) mission Gaia (https://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the GAIA Multilateral Agreement.

References

Boyce, G. and Boyce, P. Boyce, Research Initiatives and Education Foundation (BRIEF), http://www.boyce-astro.org/home.html.

Fitzgerald, M.T., 2018, accepted, "The Our Solar Siblings Pipeline: Tackling the data issues of the scaling problem for robotic telescope based astronomy education projects.", Robotic Telescopes, Student Research and Education Proceedings.

Gaia Collaboration, 2016, "The Gaia mission", *A & A* **595**, A1.

Gaia Collaboration, 2018, "Gaia Data Release 2: Summary of the contents and survey properties". ArXiv e-prints.

Greaves, J., 2004, "New Northern hemisphere common proper-motion pairs", *Monthly Notices of the Royal Astronomical Society*, **355**, Issue 2, 585–590, https://doi.org/10.1111/j.1365-2966.2004.08341.x

Las Cumbres Observatory Network https://lco.global/observatory/sites/

Mason, B, 2018. Washington Double Star Catalog. Astronomy Department, United States Naval Observatory, http://ad.usno.navy.mil/proj/WDS/.

Sordiglioni, G. 2018. Stella Doppie Double Star Catalog, http://www.stelledoppie.it/index2.php?menu=29&iddoppia=48579.

Shaya, E.J & Olling, R.P., 2011, "Very Wide Binaries and Other Comoving Stellar Companions: A Bayesian Analysis of the Hipparcos Catalogue", *The Astrophysical Journal Supplement Series*, 192:2 (17 pp).

Harshaw, R., 2014, "Another Statistical Tool for Evaluating Binary Stars", *Journal of Double Star Observations*, **10**, 32.

Wenger et al., 2000. "The SIMBAD astronomical database", *A&AS*, 143:9.