Observing Binary Star System (WDS) 20136+5307

James Henderson[1], Keaton Ludwig[2], Ali Smith[2], Wren Allen[2], Bradley W. Peterson[2]

[1]Berea College, Berea, KY
[2] Hastings College, Hastings, NE

Abstract: Astrometric measurements on the binary star system WDS 20136+5307 were performed to find their current separation and position angle. Images of the stars were obtained from the Las Cumbres Observatory (LCO) using a 0.4-meter class telescope. The mean separation of the binary system is 5.21 arcseconds with a mean position angle of 105.63 degrees. Based on evidence from the parallax, proper motions, and orbital solution, these stars are physically interacting.

1) Introduction

The objective of this research is to find the position angle and separation of the components of star system WDS 20136+5307, originally discovered by the Baltic German astronomer and geodesist, Friedrich Georg Wilhelm von Struve. Observations were recorded at and obtained from the Las Cumbres Observatory (LCO), while additional data related to our double star system was obtained from the United States Naval Observatory. Current analysis shows a final recorded observation in 2015, separation of 5.40 arcseconds, position angle of 106 degrees, and delta magnitude (□M) of 2.19. With images gathered from LCO, we determined the current position angle and separation between the two stars. Finally, after analyzing the new components, our team charted a new position for the system's secondary star.

2) Equipment

The Las Cumbres Observatory has 23 robotic telescopes in seven different locations around the world. Our observations came from Teide Observatory in Tenerife, Spain. The 16-inch telescope is equipped with a SBIG 6303 CCD camera. This is a 0.4-meter class telescope with a class-standard pixel scale of 0.571 arcseconds/pixel (bin 1×1) and FOV of 29.2 arcseconds × 19.5 arcseconds.

3) Procedures

Immediately following the scheduling of the observations with the robotic telescopes of the Las Cumbres Observatory, Brian Mason of the Naval Observatory was contacted via email. Upon request, he sent back historical data of the pair, where observations dated back to 1828. The Las Cumbres Observatory was used to collect images of WDS 20136+5307.

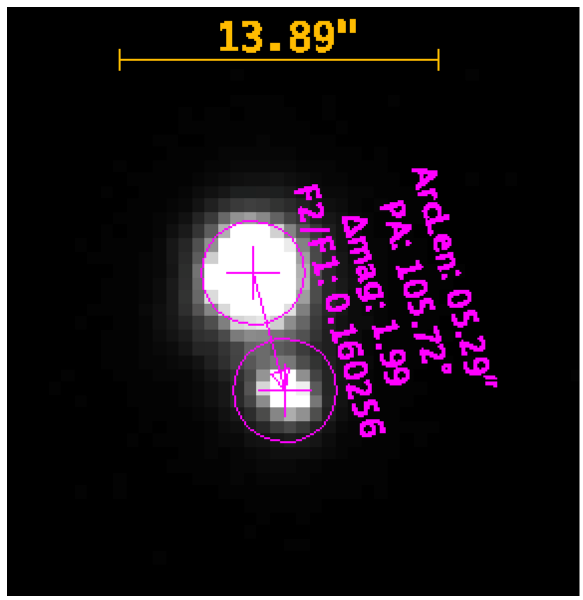

Figure 1. Image of WDS 201356+5307 in AstroImageJ. The circles indicate the centroid fit positions for the two stars. North is to the left and East is down.

Ten 2.3-second images were collected on October 1, 2020 (2020.75). Of these, 6 were suitable for measurement. One of the rejected images was poorly focused; in the other three, one of the stars had an extended appearance, probably due to atmospheric turbulence. A sample image is shown in Figure 1. The separation and position angle were measured using AstroImageJ (Collins et al., 2017) with a 4-pixel aperture radius and background annulus from 15 - 20 pixels.

Received November 22, 2020

Observing Binary Star System (WDS) 20136+5307

4) Results and Discussion

From the six images, measurements yield a mean separation of 5.21 arcseconds and a mean position angle of 105.63 degrees. Using a standard deviation drawn from the data sample, a calculated standard error of the mean for separation and position angle yielded 0.05 arcseconds and 0.15 degrees, respectively. The data and analysis of six images at a range of ±1σ is shown in Table 1. At a standard deviation of ±3σ, a standard error of the mean yields a separation and position angle of 0.14 arcseconds and 0.44 degrees respectively, at a confidence interval of 99.7%.

Previous measurements from 2015 show a position angle of 106 degrees and a separation of 5.40 arcseconds. Current observations of WDS 20136+5307 found that there is a mean position angle of 105.63 degrees and a mean separation of 5.21 arcseconds. The astrometric data from the current observations suggests that the distance between the stars in this binary system is decreasing.

An orbit solution based on historical measurements may indicate that a star system is physical and not optical. In Figure 2, we show a plot of the orbit solution computed by Izmailov (2019) as found in the Sixth Orbit Catalog of Visual Binary Stars. Green crosses represent the earliest measurements made by micrometers. The accuracy of these instruments are subject to human error and serious seeing problems and are overall a difficult way to make measurements. The spread of measurements in this portion of the plot is indicative of this difficulty. Moving clockwise, more recent measurements based on CCD imaging are shown as pink triangles. These appear with less error, with the exception of what appears to be an outlier. A black arrow points directly to the team's measurement.

Using Plot Tool 3.19, created by Richard Harshaw (2020), a segment of the secondary star's orbit, holding the primary star stationary, was created with the historical data received from Brian Mason and augmented with our measurement of position angle and separation. A plot of this orbital segment is shown in Figure 3, where our measurement is represented by a red dot. While the historical data provides reliable snapshots of this pair through time, a few steps were needed to maximize what the data can tell us. To do this, our team first used a ±3σ clip of the historical data, which excludes any data in which falls outside of three standard deviations of the data set mean, ensuring that the data was free of obvious outliers. Next, the data needed to be assigned weights, as each data point may not be equally representative. For example, measurements made by CCD imaging are more reliable than measurements by micrometer, however, less so than measurements through satellite methods, such as the Gaia Data Releases. Therefore, satellite methods are weighted higher than CCD, and CCD is weighted higher than micrometer. Other weighted criteria include the telescope Rayleigh limit in relation to the measured separation angle and the number of nights observed (Harshaw 2020). A quadratic fit to the data, corresponding to a bound system, is consistent with the data, but additional data points collected over an extended period of time will be required to rule out the possibility of a linear relationship.

Image #	Separation (arcseconds)	Pos. Angle (deg)
1	5.29	105.72
2	5.33	106.32
3	5.22	105.42
4	5.27	105.36
5	5.01	105.56
6	5.16	105.41
Mean	5.21	105.63
St. Dev.	0.11	0.36
Error	0.05	0.15

Table 1. Measurements of WDS 201356+5307

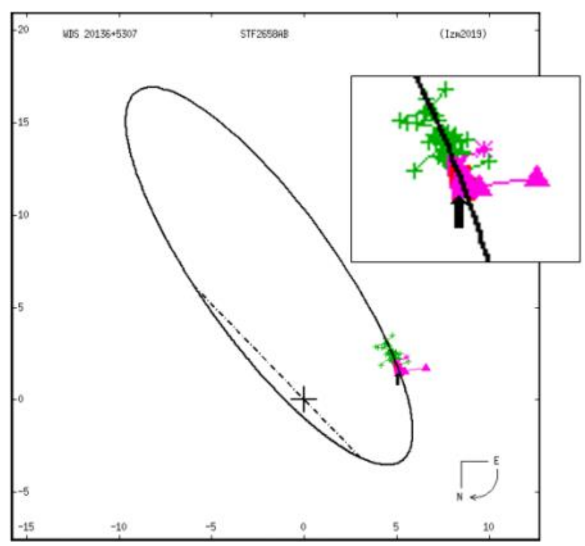

Figure 2. Orbital path of WDS 20136+5307 from Sixth Orbit Catalog of Visual Binary Stars. The fit was calculated by Izmailov (2019) and is based on historical data. The black arrow points directly to the team's measurement. Inset shows the image enlarged for clarity.

Observing Binary Star System (WDS) 20136+5307

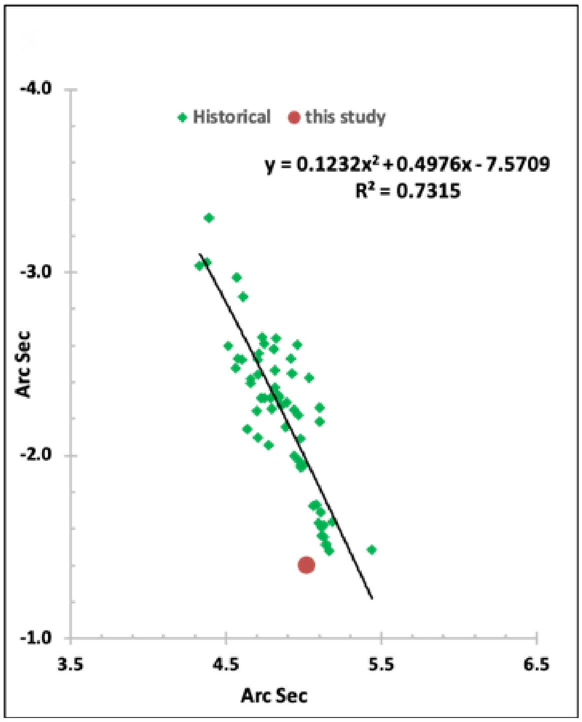

Figure 3. Plot of WDS 201356+5307 historical positions (green diamonds) with the position from the present study (red circle). Plot made using Plot Tool 3.19 (Harshaw, 2020). North is down and East to the right.

Star	A	B
Gaia Source ID	2184643400111530624	2184643400111529984
parallax (mas)	21.28	21.28
parallax err (mas)	0.03	0.03
PM RA (mas/yr)	46.22	43.19
PM RA err (mas/yr)	0.05	0.06
PM Dec (mas/yr)	178.10	169.33
PM Dec err (mas/yr)	0.05	0.08

Table 2. Parallaxes and proper motions for WDS 20136+5307 A and B from GAIA DR 2.

The binary nature of this system is further supported by astrometric data provided by GAIA DR 2 (Gaia Collaboration 2016, 2018). These data are shown in Table 2. The parallaxes are identical to within the measurement uncertainties, indicating that they are at the same distance. The quoted uncertainties for the individual stars depend on the magnitude of the stars and on the scanning law, which describes the pointing of the Gaia spacecraft as a function of time (Luri et al. 2018, Gaia Collaboration 2016.) There may be additional sources of systematic error that are not accounted for.

Finally, we can examine the proper motions of the stars. The values in RA are 46.22 and 43.19 mas/yr in stars A and B, respectively, while the values in declination are. 178.10 and 169.33 mas/yrs. These proper motions are close enough together to support the idea that these stars are a bound pair.

5) Conclusion

The objective of this research was to acquire more data on the separation and position angle of the double star, which is consistent with the historical data. The pair, based on parallax, proper motions, and the orbital solution, continue to suggest that this is not an optical pair and is physically interacting as a common proper motion pair.

6) Acknowledgements

Our team would like to thank the following who made our observations and research possible. Firstly, we would like to thank Rachel Freed for her guidance and expertise over the duration of the Astronomy Research Seminar, and referee Richard Harshaw for comments that greatly improved the manuscript. We would also like to thank David Rowe of PlaneWave Instruments for his detailed extraction of the WDS catalog from Gaia DR2 and for his handy Gaia Double Star Selection Tool. We are also grateful to the Las Cumbres Observatory for accepting our observation request and collecting images vital to our research, and Brian Mason of the United States Naval Observatory for historical data related to our binary star system.

This research has made use of the Washington Double Star Catalog maintained at the U. S. Naval Observatory.

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

Collins, K., Kielkopf, J., Stassun, K., and Hessman, F. (2017). “AstroImageJ: Image processing and photo metric extraction for ultra-precise astronomical light curves.” The Astronomical Journal, 153 (2).

Gaia Collaboration et al. (2016). “The Gaia mission.” Astronomy & Astrophysics, 591 (A1).

Gaia Collaboration et al. (2018). Gaia Data Release 2. Summary of the contents and survey properties.” Astronomy & Astrophysics, 616 (A1).

Genet, R., Buchheim R., Johnson, J., Harshaw, R., & Freed, R. (2018). STAR Small Telescope Astronom ical Research Handbook (1st ed.). Tucson, AZ: In stitute For Student Astronomical Research (InStaR).

Harshaw, R., (2020). “Using Plot Tool 3.19 to Generate Graphical Representations of the Historical Meas urement Data.” Journal of Double Star Observa tions, 16 (1), 386 - 400.

Izmailov, I. S., 2019. “The Orbits of 451 Wide Visual Double Stars.” Astronomy Letters, 45, 30 - 38.

Luri, X., Brown, A. G. A., Sarro, L. M., et al. (2018). “Gaia Data Release 2: Using Gaia parallaxes.” As tronomy & Astrophysics, 616 (A9).

Las Cumbres Observatory. (2020). Data retrieved from https://lco.global/observatory/sites

United States Naval Observatory. (2010, October 2). Data from the Washington Double Star Catalog (WDS). Washington D.C.