Measurements and Gaia Data Suggest that WDS 21183+4140AC are not Physically Associated

Jael Clark[1], Adelyn Fisher[1], Cameron Pace[2], Kimberly McCollum[1]
1. SUCCESS Academy, SUU
2. Southern Utah University

Abstract

WDS 21183+4140 is a triple star system, with few historical measurements. Despite a lack of measurements, the observations that do exist paint a somewhat complicated picture. In an effort to sort out the confusion regarding the motion of this system, we made additional observations, and compared them to the historical measurements. We found that the 2010 measurement appears to be somewhat inconsistent with those of other years. In an effort to clarify the situation, parallax and proper motion data were extracted for the A and C components from the Gaia database. These data suggest that the A and C components are not physical, as the A component is at a distance of ~1250 pc while the C component is at a distance of ~820 pc.

Introduction

The star system we observed was WDS 21183+4140. WDS 21183+4140 is a triple star system. We chose to measure the A and C components because the A and B components were too close together for us to resolve. We also selected this system because it is neglected.

WDS 21183+4140AC only has 3 measurements, the most recent of which was taken in 2010 by R. Gili & J.-L. Prieur in 2010. The first observation of the AC system was recorded in the 2MASS catalog in 1998. However, 3 measurements are not sufficient to determine the orbital nature of the system. The situation is further complicated by the fact that these previous measurements do not appear to be consistent with either linear or orbital motion. Through this work, we set out to clarify the motion of this system.

In order to do this, we took images of this system with the GBO and measured them to compare with the historical data. We also extracted parallax and proper motion data for WDS 21183+4140AC from the Gaia database (Gaia Collaboration et al. 2018). The Gaia mission is uniquely suited to produce accurate astrometry for systems such as WDS 21183+4140AC.

Methods

For our research, we used the Great Basin Observatory (GBO) located in Great Basin National Park in Nevada. The Observatory is cared for and managed by the Great Basin National Park, the Great Basin National Park Foundation, as well as Southern Utah University, Concordia University, University of Nevada-Reno, and Western Nevada College. The GBO telescope is a PlaneWave 0.7m CDK 700, with an SBIG STX-16803 CCD camera, which gives a plate scale of 0.4 arcsec per pixel. The GBO's focal ratio is f/6.5 and, combined with the camera, provides a field view of 27 X 27 arcminutes. The telescope is equipped with 16 filters: LRGB, Ha, OIII,

Received June 17, 2021

SII, BVRI, g'r'i'z', and a diffraction grating (Anselmo et al. 2018).

We took 20 images in total of WDS 21183+4140AC, taken on November 5, 2020. A finding chart for this system is found in Figure 1. These images had an exposure time of 60 seconds. The V filter was used, and the binning was set to 1 X 1. The images were bias, dark and flat corrected via AstroImageJ (Collins et al. 2017). As part of the dark correction, the exposure time was scaled to 0.5 since the master dark from that day had an exposure time of 120 seconds. The astrometry was performed through http://nova.astrometry.net/ (Lang 2010). Finally, the separation (ρ) and angle (θ) were measured with AstroImageJ (Collins et al. 2017). The measurements from the 20 images were averaged, and the standard deviation was determined.

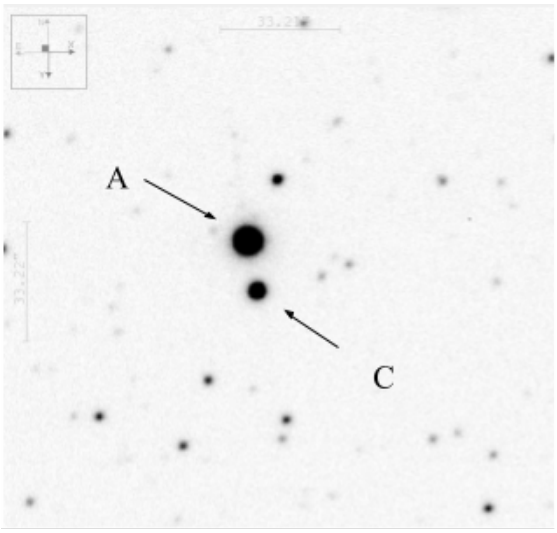

Figure 1: Image of the A and C components of WDS 21183+4140AC. The image has a plate scale of 0.4 arcsec/pixel.

Results

Table 1 shows the results of our measurements. This table includes the separation and position angle, and includes the mean, the standard deviation, and the standard error for both rho and theta.

WDS no.	Date	Images		Angle	Rho
21183+4140AC	11-05-2020	20	Mean	187.40	14.11
			Std. Dev	0.02	0.01
			Std Error	0.005	0.001

Table 1: 2020 observations on the double star system.

Discussion

We requested the historical data from the Naval Observatory (Matson, 2021). There are three previously recorded observations of WDS 21183+4140AC in the WDS: these measurements, together with our observation are shown in Table 2. These data, with the exception of the 2010 observation, appear to show linear motion. To better visualize this, the measurements of all epochs are plotted in Figure 2. In this plot, it can be seen that the observation taken in 2010 appears to be discrepant. In reviewing the authors' paper (Gili & Priuer 2012), however, we could not discern a reason for it to be such a notable outlier. While a proper investigation into the methods of said researchers was undertaken, it was inconclusive in regards to a cause for the peculiarity.

For illustration purposes, Figure 3 shows the positions with the measurement from 2010 omitted. Although the data here

suggests that the C component is moving linearly, with the limited data available, it is difficult to see if this is really the case. Furthermore, orbital motion can mimic linear motion under certain viewing angles. Since there are only three data points, it would be beneficial to take more measurements in the future to more fully understand the motion of these components.

In an effort to further understand the motion of this pair, we retrieved the parallax and proper motion for this system from the Gaia database (Gaia Collaboration et al. 2018a). Table 3 displays this information. It can be seen that the A and B components appear to be physical, as their parallax and proper motion are quite similar. In contrast, the C component appears to be unrelated to the A and B components, as its parallax suggests that it is ~500 pc away from the A component. The proper motion of the C component is also quite different from that of the A and B components. Figure 4 plots the proper motions of the A and C components. It can be seen that they appear to be moving in different directions, suggesting that they are not physical.

Although the measured parallaxes for these stars are quite small, they are well within the range of what can be measured by Gaia. Measurements for which the formal error is less than 20% are considered 'precise' by many authors (e.g. Gaia Collaboration et al. 2018b, Brown 2021). The parallax measurements of these stars are quite precise, as none of them have an error that is more than 2% of the measured value. However, the formal errors themselves don't tell the whole story. In the case of bright (V<11) sources, the formal errors could be underestimated by as much as 30% (Luri et al. 2018). For this system, the A component has a G magnitude of 10.23 while the C component has a magnitude of 12.47. Additionally, some parallax observations may have 'good' formal errors, but they may not be consistent with the Gaia five-parameter model. This is especially true for bright sources or those in crowded regions. One data quality indicator for how well a measurement fits the five-parameter model is the re-normalized unit weight error (RUWE; Lindegren 2018). For well-behaved fits, the RUWE is expected to be around 1.0. For this system, the A component has RUWE= 0.806 and the C component has RUWE=1.007. This suggests that the data for these stars are consistent with the five-parameter model, lending confidence to their measured parallaxes. Taken together with the historical astrometry and our new measurement, it seems likely that the A and C components are not physical.

Date	Rho	Angle
1998	14.12	188.5
2002	14.054	187.8
2010	12.944	188.2
2020	14.11	187.40

Table 2: Historical data for 21183+4140AC.

Measurements and Gaia Data Suggest that WDS 21183+4140AC are not Physically Associated

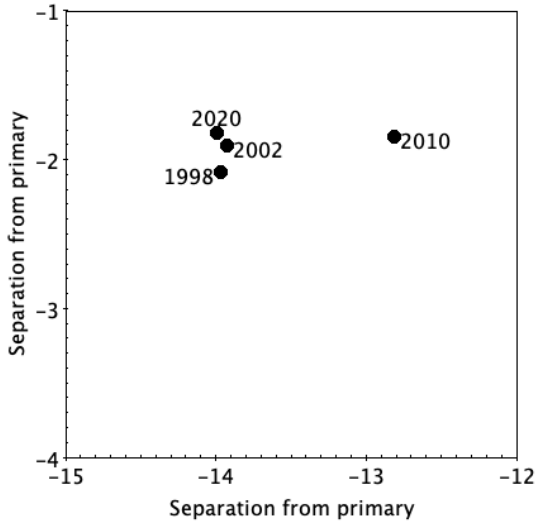

Figure 2: Position plot, in arcseconds, of our measurements as well as the historical measurements. It appears that the 2010 measurement could be an outlier, therefore no linear line can be drawn in the points.

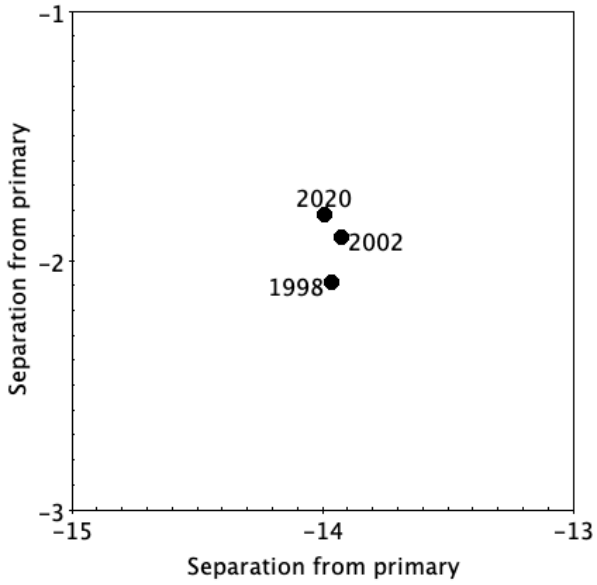

Figure 3: Illustrates our measurements and the historical measurements closer without the 2010 outlier (arcseconds).

Component	Parallax (mas)	pmra	Pmra error	pmdec	Pmdec error	Distance (pc)
A	0.786±0.013	-2.772±0.013		-3.975±0.014		1250-1300
B	0.930±0.027	-2.706±0.028		-4.017±0.043		1050-1100
C	1.21±0.011	5.272±0.010		-6.904±0.011		820-830

Table 3: Data we received from Gaia

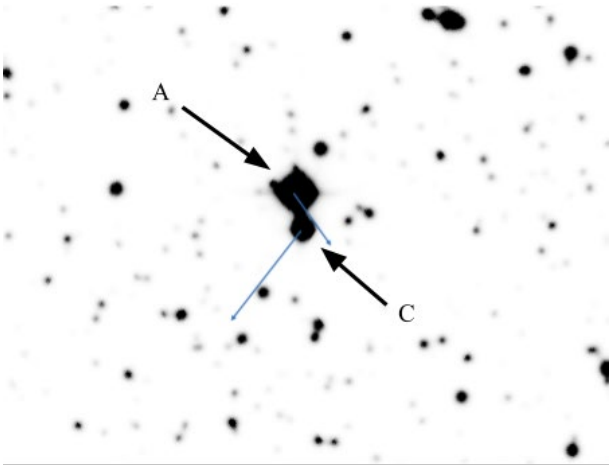

Figure 4: The proper motion of the A and C components based on the information obtained from Gaia.

Acknowledgements

This project was made possible by the collaboration with Southern Utah University and the Great Basin Observatory (GBO). We would like to thank those who operate the GBO. This research made use of AstroImageJ, Astrometry.net, and the Washington Double Star Catalog maintained by 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

Anselmo, Dallas, et al., 2018, Journal of Double Star Observations, 14 (3).

Brown, Anthony, 2021, *Annual Review of Astronomy and Astrophysics,* **59**.

Collins, K. A., Kielkopf, J. F., Stassun, K. G., & Hess man, F. V., 2017, The Astronomical Journal, 153(2), 77.

Gaia Collaboration, Brown, A. G. A. Vallenari, A. Prusti, T. de Bruijne, J. H. J. et al., 2018a, Astronomy & Astrophysics, 616, A1.

Gaia Collaboration, Katz D, Antoja T, Romero-G´omez M, Drimmel R, et al. 2018b. A&A 616:A11

Gili, R., & Prieur, J. -L., 2012, Astronomische Nachrichten,.333, 8.

Lang, Dustin, et al., 2010, The Astronomical Journal, 139, 5, 1782.

Luri, X., Brown, A. G. A., Sarro, L. M., Arenou, F., Bailer-Jones, C. A. L., Castro-Ginard, A., de Bruijne, J., Prusti, T., Babusiaux, C., Delga do, H. E., 2018, Astronomy & Astrophysics, 616, id.A9, 19.

Matson, Rachel, 2021, The Washington Double Star Catalog, Astronomy Department, U.S. Naval Observatory.

Received June 17, 2021